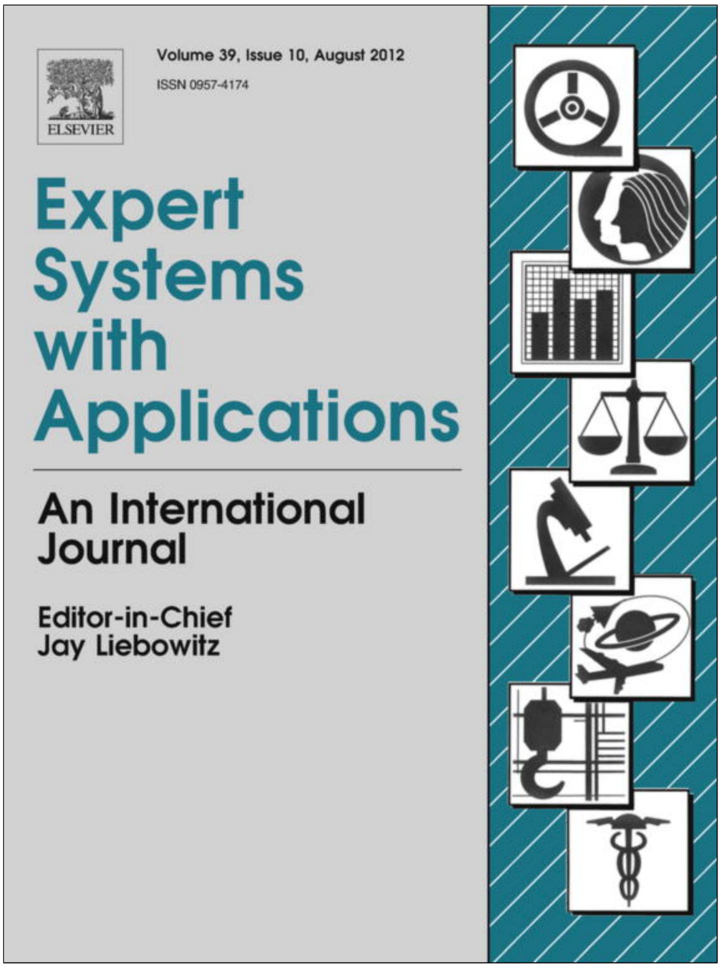
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# A framework for user-centric model for evaluating the performance of distributed software system architecture

Boluwaji A. Akinnuwesi [a], Faith-Michael E. Uzoka [b,*], Stephen O. Olabiyisi [c], Elijah O. Omidiora [c]

[a] Department of Information Technology, Bells University of Technology, Ota, Ogun State, Nigeria
[b] Department of Computer Science & Information Systems, Mount Royal University Calgary, Canada
[c] Department of Computer Science & Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria

A R T I C L E  I N F O

*Keywords:*
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A B S T R A C T

In this work we carried out a review of models for evaluating the performance of distributed software system architecture (DSSA) and Information System (IS) success evaluation models with a view to establishing the utilization of organizational variables in the evaluation of DSSA performance. The findings from the review show that the existing DSSA performance evaluation models are machine-centric and existing IS success measurement models do not map organizational variables with DSSA components. In view of these, we developed a user-centric model for DSSA performance evaluation using organizational variables. Our model utilizes neuro-fuzzy logic in matching organizational/user variables with DSSA evaluation factors.



## 1. Introduction

DSSA is composed of software components, the properties of the components, the relationships between the components, the relationship constraints, principles and guidelines governing the system design (Bass & Kazman, 2003; Garlan & Perry, 1995; Hassan & Daniel, 2000). It is the bedrock and organizational structure of distributed software system (DSS). A DSSA can be recursively decomposed into parts that interact through interfaces, relationships that connect the parts, and constraints for assembling the parts. Parts that interact through interfaces include classes, components and subsystems. Today, DSS is one of the complex artefacts that are used by organizations to deplore services simultaneously to many people online and in real time. It is increasingly used as enabling technology for modern enterprise applications; therefore in the face of globalization and ever increasing competition, Quality of Service (QoS) requirements like performance, security, reliability, robustness, and correctness are of crucial importance (Samuel, 2006). In view of this, organizations must ensure that the DSSA is well designed to provide all organizational services and also satisfy the performance expectations of the end users (customers). It is of paramount importance that the stakeholders in an enterprise get the maximum satisfaction from the software systems (Sari, Marjo, & Sanna, 2001).

Efficient and effective software architecture is a product of good collaborative efforts between the client organization and software developers. The success or failure of an enterprise software system depends on the kind of relationship between the end users and the software developers (Brian, Jerry, & Edward, 2006; Muthitacharoen & Saeed, 2009; Procaccino & Verner, 2009; Serkan & Kursat, 2005). If any of the parties is unable to make meaningful and useful contribution, the software performance may not be guaranteed. Therefore, while designing DSSA, the organizational factors that have to be established by the management staff and customers of the client organizations should be given significant attention by the software developers in order to develop acceptable and usable system.

Organizational factors are organization's functional and non functional requirements that the software developers incorporate into the DSSA. The impact of these factors on the developers' choice of software architectural style and design depends on the following key elements of an organization: people, structure, technology and the external environment in which the organization operates. People are individuals and groups that make up the internal and social system of an organization. They are dynamic and carry out different departmental functions in the organization, and thus have diverse requirements. They work towards achieving the objectives of the organization. Structure defines the formal relationships of the departmental functions vis-à-vis the people in the organization. Different people in the organization perform different tasks and they are related in some structural way in order to effectively coordinate their works. Technology involves machines and other technical infrastructure that aid people to perform their tasks effectively and efficiently in their various departments. External environment is the part of a larger system that contains some other elements such as government, family and other organizations, and

* Corresponding author.
*E-mail address:* uzokafm@yahoo.com (F.-M.E. Uzoka).

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these elements influence each other in a complex system. Organiations operate within the external environment. Specific requirements are attributed to each of the elements of the organization and these must be clearly described during the requirements definition phase of the Software Development Life Cycle (SDLC) and considered while designing the DSSA.

In this research work, emphasis is on the identification of significant factors that can be considered as major decision variables of an organization that influence the design of DSSA. Also the framework of a user-centric model to evaluate the performance of DSSA using the organizational variables as parameters for evaluation is presented.

The rest of the paper is organized as follows: Review of related literature is presented in Section 2. Presented in Section 3 are: conceptual diagram of the developed model, the model algorithm and methodology employed to develop the model. Discussion and Conclusion are presented in Section 4.

## 2. Review of related literature

The review of existing DSSA performance evaluation models was done with a view to identifying the evaluation parameters and the classification of the parameters. The models were classified based on the development approach adopted. The identified approaches are: queuing network, petri net, queuing petri net, pattern based approach and soft computing approach. The summary of the review is presented in Table 1.

We carried out a review of some related research works that focused on the identification of some contextual factors and how they impact on the success or failure of Information System (IS) projects vis-à-vis IS implementation and usage in organization. The objective here is to identify some contextual factors that can serve as organizational variables and also to establish if previous research works relate directly or indirectly the contextual factors with DSSA components. Table 2 presents a summary of the IS success measurement models vis-à-vis the success measurement variables.

### 2.1. Deductions

The following are the deductions from the literature review:

(i) Existing parameters for evaluating DSSA performance are machine centred and they are objective. The machine centric parameters entail variables peculiar to system hardware such as: processor speed, bus and network bandwidth size, RAM size, cache size, server response time, server execution time; and software process parameters such as: message size, event load, time to perform an action, request arrival time, request service time. Therefore the models are machine-centric.

(ii) Though in the DSSA performance evaluation models, the contributions of the client organization/end users during software development process were acknowledged, none of the models draws parameters for evaluation from the contextual organizational decision variables.

(iii) Performance metrics considered are mostly the following: throughput, response time, and resource utilization.

(iv) None of the IS success measurement models show a relationship mapping of the organizational variables and the components of software system architecture. Thus the IS success in organization is not measured at the system architectural design level but rather at the IS implementation and usage levels. Moreover the use of the organizational variables to determine the performance of the system architecture before implementation is not considered.

## 3. Conceptual framework of the neuro-fuzzy based user-centric DSSA performance evaluation model

The conceptual diagram of the proposed DSSA performance evaluation model is presented in Fig. 1. The major components of the model are as follows:

(a) Organizational variables and DSSA factors
(b) Neuro-fuzzy software performance evaluation engine consisting of the following:
(i) Fuzzy engine
(ii) Matching function and.
(ii) Neural Network (NN) engine.

The algorithm of the developed neuro-fuzzy performance evaluation model (NFPEM) based on the conceptual framework is presented in Section 3.1, while the detailed description of the model development (with results) is presented in Section 3.2.

***Where:*** $y_1$ = Business Entity, $y_2$ = Preparedness of the Client Organization, $y_3$ = Service Agent, $y_4$ = Process and Presentation Logic, $y_5$ = Users Interest and IT Expertise, $y_6$ = User Involvement, $y_7$ = User Interface, $y_8$ = Data Access and Security, $y_9$ = Business Workflow, $y_{10}$ = Service Layer; $x_1$ = Communication rules with external organizations (CRE1), $x_2$ = Data communication rules and semantics within the client organization (DCRO), $x_3$ = Willingness of users for IT training (WUIT), $x_4$ = IT infrastructure available in client organization (ITIF), $x_5$ = Budget of the client organization for software project (BSPJ), $x_6$ = Feasibility study done by the project team in client organization (FSTU), $x_7$ = Expected size of the organization database (SODB), $x_8$ = Policies for interoperability (PIN1), $x_9$ = Defined mapping of data with external business entity and services (DMEB), $x_{10}$ = Users definition for input data and the format for input (UDI1), $x_{11}$ = Data input validation strategy/procedure defined by client organization (DVSC), $x_{12}$ = Developers' understanding of the organization's goal and task (DUOG), $x_{13}$ = Internal services of the client organization and their relationships (ISO1), $x_{14}$ = Professional qualification of users (PQUS), $x_{15}$ = Academic qualification of users (AQUS), $x_{17}$ = Involvement of users in system design (USDE), $x_{18}$ = Involvement of users in system operation (USOP), $x_{19}$ = Population of users expected to use/operate the system (PUOS), $x_{21}$ = Information requirements of users and the format in which it expected (UIRF), $x_{22}$ = Organization goals and tasks (OGTS), $x_{23}$ = Organization policies/procedure for transaction flow (OPTF), $x_{24}$ = Organization defined functions required in the user interface (ODFI), $x_{25}$ = Organization defined access right for users of applications (DUAR), $x_{26}$ = Business rules associated with the data to be processed (BRDP), $x_{27}$ = Data security measures put in place by the organization (ODS1), $x_{22}$ = Organizations goals and tasks (OGTS), $x_{28}$ = Data flow procedure (DFP1), $x_{29}$ = Defined timeout for services/operations (DTSO), $x_{30}$ = External services requested by the client organization from external organizations (ESEO), $x_{31}$ = Message contract for communication between organizations (MCC1).

### 3.1. NFPEM algorithm

The algorithm developed for NFPEM is as follows:
**Algorithm Header**: ***User_Centric_PE ()***

**Step 1:**

(i) Input values for $x_{ij}$, $i = 1,2,3,\ldots,31$ and $j = 1,2,3,\ldots,n$ ($n$ = total number users sampled to collect data for $x_{bf\ ij}$). Values for $x_{ij}$ are gotten from users of DSS using the DSSA performance assessment form, presented in Appendix B.

**Table 1**
Summary of existing DSSA performance evaluation models.

| Class of model | Description of model | Evaluation parameters | Class of parameter |
|---|---|---|---|
| Queuing Network Based DSSA Performance Evaluation Models | Savino-Vazquez and Puigjaner (2001), | *System Hardware parameters:* Buffer size, processor speed of server. *System Process Parameters:* queue size, number of incoming request, request arrival time, request departure time. | Machine centric. |
| | Simonetta et al. (2004) | *System Hardware parameters:* Number of service centres, service rate of service centre, number of servers in service centres, physical resources available, system workloads, network topology. *System Process Parameters:* arrival rate of requests at service centre, routing procedure of requests, Number of request circulating in the system. | Machine centric. |
| | Vibhu et al. (2005) | *System Hardware parameters:*Range of number of clients accessing the system, average think time of each client, number of layers in the software system, relationship between the machines and software components, number of CPUs and disks on each of the machine and thread limitation (if any), uplink and downlink capacities of the connectors connecting machines running adjacent layers of the system, size of packets of the links, service time required to service one request by a software layer, forward transition probability, rating factors of the CPU and the disks of each machines in the system. | Machine centric. |
| | Simonetta and Moreno (2005) | Same as in Vibhu et al. (2005) | Machine centric. |
| | Israr et al. (2005) | Same as in Vibhu et al. (2005). | Machine centric. |
| Petri Net Based DSSA Performance Evaluation Models | Merseguer et al. (2000a) | *System Hardware parameters:* System load, system delays, system routing rate, latency of process, CPU time. | Machine centric |
| | Merseguer et al. (2001) | *System Hardware parameters:* Network time. | Machine centric |
| | Juan et al. (2004) | *System Hardware parameters:* Routing rate, action duration, system response time. | Machine centric |
| | Juan et al. (2008) | *System Hardware parameters:* Routing rate, action duration, system response time. | Machine centric |
| | Motameni et al. (2008) | *System Hardware parameters:*Routing rate, action duration, system response time. | Machine centric |
| Queuing Petri Net Based DSSA Performance Evaluation Models | Samuel and Alejandro (2003) | *System Hardware parameters:* buffer size, processor speed of server, routing rate. *System Process Parameters:* Service demand of queue, service rate of queue, token population of queue, queue size, | Machine centric |
| | Samuel (2006) | Same as in Samuel and Alejandro (2003). | Machine centric |
| Pattern Based DSSA Performance Evaluation Models | Merseguer et al. (2000b). This complements the approach given in Merseguer et al. (2000a). | *System Process Parameters:* Event load, time to perform an action, request arrival time, request service time, number of concurrent users. | Machine centric |
| | Merseguer et al. (2003) | Same as in Merseguer et al. (2000b). | Machine centric |
| | Happe et al. (2008) | *System Hardware parameters:* System configuration (hardware & network components), buffer/pool size *System Process Parameters:*message size (incoming & outgoing), delivery time for message, number of message sent, size of message sent, number of message delivered, size of message delivered, transaction/request size. | Machine centric |
| Soft Computing Based DSSA performance Evaluation Models | Idris and Abran (2001) | *System Process Parameters:* Seventeen parameters:- software size, project mode plus 15 cost drivers. | Machine centric |
| | Idris et al. (2004) | Same as in Idris and Abran (2001). | Machine centric |
| | Maddox (2005) | *System Hardware parameters:* CPU Queue length, memory (RAM) available, pages input per second, read time, write time, I/Os per second. | Machine centric |
| | Omitaomu and Adedeji (2007) | *System Process Parameters:* Three parameters representing three possible values of project costs, benefits, evaluation periods and discount rate. | Machine centric |

(ii) Input rating confidence of users $c_{ij}$. $c_{ij}$ is rating confidence of $i$th user for $j$th variable

**Step 2:** Compute normalized rating confidence of users, $\boldsymbol{\alpha}_{ij}$, using the following procedure

KAM Normalization Procedure

i. Ranks are allocated to all the respondents' rating confidence for variable $x_j$. Respondents with the same confidence rating are allocated the same rank. Therefore, the rank equals 1 for a respondent that has the highest rating confidence in our sample on a particular variable (that is, it has the highest score), the rank equals to 2 for a respondent that has the second highest, and so on.

ii. For each respondent for variable $x_j$, the total number of respondents with a higher rank is calculated $(\widehat{R}_{i,j})$

iii. Eq. (1) is used in order to normalize the rating confidence for every respondent on every variable according to their ranking and in relation to the total number of respondents in the sample ($N$) with available data:

$$\alpha_{i,j} = 1 - \frac{\widehat{R}_{i,j}}{N} \quad (1)$$

where: $\alpha_{i,j}$ = Normalized rating confidence

**Step 3:** Adjust rated values of users for each $j$th variable using:

$$\varphi_{i,j} = \alpha_{i,j}\{u_{t-1}, u_t, u_{t+1}\} \quad (2)$$

**Table 2**
Summary description of IS success measurement models.

| Literature | Research description | Organizational variables considered | Mapping organizational variables with DSSA design components |
|---|---|---|---|
| Ein-Dor and Segev (1978) | This work established organizational contextual variables and their associated impacts on the success and failure of MIS (Management Information System). The variables were categorized into uncontrollable, partially controllable and controlled. A conceptual scheme was designed and was useful both for evaluating any MIS project before implementation and for analyzing problems or feasibility of change in systems that are functioning. | *Uncontrollable variables:* Organizational size; Organizational structure; Organizational time frame; Extra-organizational situation.<br>*Partially controllable variables:* Organizational resources; Organizational maturity; Psychological climate in the organization<br>*Controlled variables:* Rank of responsible executives; Location of responsible executive; The steering committee. | Not considered in this study |
| Kaye (1990) | This work did a review of literature on the introduction of Information Systems (IS) in compounding industries vis-à-vis the factors that influence their successes. Based on the results of the review, a process model of change was developed and the model is applied to survey results to illuminate the factors which influence success and failure of IS within compounding industry. The findings in this work support the view that users attitudes prior to introduction of IS and their involvement in the system analysis and design phase will be vital to the success of the IS implementation. | Users attitude, User involvement in system analysis and design phase | Not considered in this study |
| DeLone and McLean (1992) | This paper proposed a model that has 6 interrelated factors to conceptualize and operationalize IS success. Each of the factors have measures to determine their effect on IS success. | System Quality; Information Quality; Use; User Satisfaction; Individual Impact; Organizational Impact | Not considered in this study |
| Saunders and Jones (1992). | The authors in this paper carried out a survey using questionnaire and interview method in order to identify the critical IS function performance dimensions vis-à-vis the organizational factors that may that may affect the relative ranking of the dimensions. A model was proposed for evaluating the performance of the IS functions based on the identified dimensions and the organizational factor. The study also established the extent to which IS executive agrees with Senior Management in their organization on the manner on which the IS is evaluated. | Mission of the organization; Size of organization; Industry category; Top management support; IS executive hierarchical placement; Competitive environment; Size of IS function. | Not considered in this study |
| Ballantine et al. (1996) | This work evaluated DeLone and McLean (1992) IS success model on a number of dimensions and therefore proposed a 3-D model which fundamentally extended DeLone and Mclean work. In 3-D, IS success was separated into 3 fundamental dimensions or levels: *technical development, deployment to users and delivery of business benefits*. The following filters were incorporated:*Environmental filter, Integration filter and Implementation filter*.The filters act between the levels of IS effectiveness and contain influences which inhibit or encourage the adoption of the system at the next level. | User experience; User involvement; User expectation; Complexity of system; Quality of project management; Quality of technology used; development methodology used; degree of user involvement; Professional skills and experience of the development staff; Quality of data; Technical system; User satisfaction; Support and maintenance services for the system; Quality of information generated; Skill of users and resources a deployed for implementation; Organization structure and culture; Status of the system owner; Support from top management staff; the way system output is used; Level of resources available; Alignment of individual and business objectives; Competitors movement; Political, Social and Economic factors; Learning procedure in place. | Not considered in this study |
| Jennex et al. (1998) | In this research, a model for evaluating the functionality of Organizational Memory Information System (OMIS) was defined. The OMIS success model was based on the IS Success Model proposed in DeLone and McLean (1992). | *System quality*:- (*Technical resource, Form of OMIS, Level of OMIS*); *Information quality; Amount of OMIS use; User satisfaction with OMIS; Individual impact; Organizational impact.* | Not considered in this study |
| Chieochan et al. (2000) | This research work made use of quantitative technique to investigate the internal and external factors affecting the use of Information Technology (IT) in Thai agricultural cooperative. The aim was to test and improve existing theories and methodologies in the adoption of information system in Thai agricultural cooperatives. | *Internal factors:* Characteristics of managers of Thai agricultural cooperatives (that is attitude towards adoption of IT, IT knowledge and innovation); Organizational characteristics (that is business size, organizational structure and organizational culture)<br>*External factors:* political, economical, social and infrastructural factors | Not considered in this study |

| | | | |
|---|---|---|---|
| Tallon et al. (2000) | In this paper, a process-oriented model was developed to measure the impact of IT on critical business activities within the value chain. Based on the survey that was carried out, the authors classified corporate goals for IT into one of four types: unfocused, operations focus, market focus and dual focus. The corporate goals are indicators of payoffs from IT. The executives in organization with more focused goals for IT perceived greater payoffs from IT across the value chain. It was established that management practices such as strategic alignment and IT investment evaluation contribute to higher perceived levels of IT business value. | Process planning and support; Supplier relations; Production and operations; Product and service enhancement; Sales and marketing; Customer relation; Strategic alignment. | Not considered in this study |
| Molla and Licker (2001) | This paper modified the DeLone and McLean (1992) IS success model by defining and adding a dependent variable called Customer Ecommerce Satisfaction (CES). CES was proposed as a dependent variable to e-Commerce success. Using CES provided an appropriate proxy for evaluating the success of e-commerce and extended the missing link to organizational performance. CES was seen within the context of the functionality provided by the e-Commerce system. | e-Commerce system quality; Content quality; Use; Customer e-Commerce satisfaction; Trust; Support and Service. | Not considered in this study |
| Jennex and Olfman (2002) | An expansion of OMIS success model proposed in Jennex et al. (1998) was done in this paper. It included some constructs for Information Quality factor. | *System quality*:- (*Technical resource, Form of OMIS, Level of OMIS*); *Information quality*:- (*Knowledge strategy/process, Links to experts that serve as source of knowledge, Richness of expert knowledge); Amount of OMIS use; User satisfaction with OMIS; Individual impact; Organizational impact* | Not considered in this study |
| DeLone and McLean (2003) | This work proposed an updated version of DeLone and McLean (1992) IS success model. The following dimensions were included in the enhanced model: Service quality for service provided by the IS group; Intention to use; Net benefit. A feedback loop from Net benefit dimension to Intention to use dimension and User satisfaction dimension was added. | Information quality; System quality; Service quality; Intention to use, Use; User satisfaction; Net benefit | Not considered in this study |
| Lee et al. (2003) | This paper examined the key organizational, external environmental, and IT-related factors that influence IT usage in organizations across management and non-management levels of IT usage in order to understand the differential impacts of the contextual factors affecting the usage of IT by the users at the two level of management. IT implementation and usage is examined from the perspectives of the functional executives of the organization. This is unlike prior research studies that used IT executive-perspective to understand IT implementation and usage. Contextual factors were captured and the IT usage as is perceived by the functional end-users. | *Organization (Internal factor):* Centralization, Formalization<br>*External Environmental Factor:* Competition, Pressure, External Connectivity<br>*IT-related Factor:* Organization IT attitude, Sourcing Mode for IT Capabilities | Not considered in this study |
| Sedera et al. (2003) | This paper discussed and analyzed impact of Enterprise Resource Planning (ERP) system on organizational performance using size of organization as discriminant variable. Information is gathered from 310 respondents from 27 public sector organizations. The results presented are: (a) that larger organizations have received more benefits compared to small organizations. (b) that small organizations demonstrated higher reliance on their ERP systems. (c) that employment cohorts demonstrate significant differences in perceived benefits in small and large organizations. | Size of organization | Not considered in this study |
| DeLone and McLean (2004). | This paper proposed an improved version of DeLone and McLean (1992) IS success model and used it to measure e-Commerce success. The primary improvements to DeLone and McLean (1992) IS success model are: (i) addition of service quality which reflects the importance of service and support in successful IS systems; (ii) collapsing of individual impacts and organizational impacts into a more parsimonious net benefits construct. | Information quality; System quality; Service quality; Intension to use; User satisfaction; Net benefit. | Not considered in this study |
| Elbeltagi et al. (2005) | This study identified the factors that influence the adoption and usage of IS in developing countries using Egypt as case study. It examined the usage of a Decision Support System (DSS) in local authorities of Egypt using an adapted Technology Acceptance Model (TAM). | Task Characteristics; Cultural Characteristics; Environmental Characteristics; DSS Characteristics; Internal Support; External Support; Top Management Support; Organizational Characteristics and Decision Maker Characteristics | Not considered in this study |
| Jennex and Olfmam (2006) | This work modified the OMIS success model developed in Jennex and Olfman (2002) and the IS success model proposed in DeLone and McLean (2003) in order to developed a Knowledge Management (KM) success model. | *System quality*:- (*Technological resources, KM level, KM form*); *Knowledge quality*:-(*KM strategy/process, Links to expert, Richness of expert's knowledge*); *Service quality*:- (*Management support, IS KM service quality, User KM service quality*); *Intent to use/Perceived benefit; User satisfaction; Net benefit.* | Not considered in this study |

(continued on next page)

**Table 2** (*continued*)

| Literature | Research description | Organizational variables considered | Mapping organizational variables with DSSA design components |
|---|---|---|---|
| Sertac et al. (2006) | This paper identified types of management control information and controller capabilities that significantly impact on the performance IT systems. A research model was presented to examine the relationship between the design and use of management control systems and their direct or indirect impact on IT performance. Using Partial Least Squares (PLS) analysis the study provided valuable insights that IT controller's skills and their role as coordinators are critical for achieving higher performance results of corporate IT functions. | Management control system of the organization, IT controller's skill, coordinating ability of the IT controller of the organization. | Not considered in this study |
| Hussein et al. (2007) | This study used surveyed questionnaire to empirically investigate the influence of organizational factors on IS success in Malaysian electronic government agencies. Six factors were identified to influence IS success. Also four IS success dimensions were identified: *systems quality, information quality, perceived usefulness, and user satisfaction*. Based on the results of the statistical tools adopted, the study established that the IS success variables are significantly and highly correlated. The results were found to corroborate with results in previous related works. | Decision-Making structure; Top management support; Goal alignment; Managerial IT knowledge; Management style; Resources allocation | Not considered in this study |
| Ke and Wei (2008) | A study of the relevance of the dimensions of organizational culture relevant to ERP implementation was carried out in this paper. The authors concluded that ERP implementation success is positively associated with the dimensions of organizational culture. Moreover, leadership strategy at the top management level is identified as one of the factors can the desired culture conducive to ERP implementation. | ***Organizational culture:*** This entails: Learning and development, participating decision making, power sharing, comprehensive and cross-functional communication, support and collaboration and tolerating risk and conflicts.<br><br>***Leadership strategy*** | Not considered in this study |
| Okunoye and Bertaux (2008) | In this paper, a context-based framework of Knowledge Management (KM) is presented to help organization address contextual issues in knowledge management and thus leads to better preparation, implementation and assessment of KM projects. | Task, culture, structure, information and decision processes, reward systems and people. | Not considered in this study |

$(u_{t-1})$ = Defined lower bound of the value of the linguistic rating directly below the actual rating of users
$(u_t)$ = Defined median point of the value of the actual linguistic rating of users

$(u_{t+1})$ = Defined upper bound of the value of the linguistic rating directly above (if exists) the actual rating of users.

This enables the computation of possible triplets $(\varphi_{i,j})$, whose membership function would be utilized in determining the crisp value.

**Step 4:** Compute the membership values of the adjusted rated values, $\varphi_{i,j}$, of users, using the functions defined in Table 7

**Step 5:** Compute the crisp value $\mu_X\{\varphi_{i,j}\}$ of using the defuzzification function:

$$\hat{z}_{i,j} = \frac{\sum \varphi_{i,j}(\mu_x(\varphi_{i,j}))}{\sum \mu_x(\varphi_{i,j})} \tag{3}$$

where $\hat{z}_{i,j}$=Crisp value obtained;$\mu_X(\varphi_{i,j})$ = Fuzzy membership values

**Step 6:** Compute the mean $x_i$ of $\hat{z}_{i,j}$, i = 1,2,3,...,31 and $j$ = 1, 2,3,...,$n$

$$x_i = \frac{\sum_{j=1}^{n} \hat{z}_{i,j}}{n}$$

**Step 7:** Compute values of $y_{j,\ j=1,2,3,\ldots,10}$ using the following equations (matching function):

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \end{pmatrix} = \begin{pmatrix} -4.48 + 0.56x_1 + 0.44x_2 \\ -5.84 + 0.37x_3 + 0.29x_4 + 0.22x_5 + 0.17x_6 + 0.167x_7 \\ -1.07 + 0.86x_8 + 0.14x_9 \\ -6.16 + 0.55x_{10} + 0.37x_{11} + 0.24x_{12} + 0.06x_{13} \\ -4.03 + 0.90x_{14} + 0.07x_{15} \\ -3.70 + 0.78x_{17} + 0.34x_{18} + 0.20x_{19} \\ -6.71 + 0.61x_{21} + 0.25x_{22} + 0.26x_{23} + 0.15x_{24} \\ -5.15 + 0.59x_{25} + 0.29x_{26} + 0.24x_{27} \\ -5.60 + 0.41x_{22} + 0.45x_{28} + 0.32x_{29} \\ -4.55 + 0.67x_{30} + 0.38x_{31} \end{pmatrix}$$

**Step 8:** NN process starts
Invoke the NN algorithm: ***NN*($y_j$)[$j$ = 1...10]**

**Step 9:** Algorithm terminates

**Algorithm of the NN engine of NFPEM**

The algorithm developed for the NN engine of the model is presented as follows:

**Algorithm Header**: ***NN*($d_j$) [$j$ = 1...10].**

**Step 1:** Assign constant values to: $\eta$ (NN learning rate), $0 < \eta \leqslant 1$; $Q$ (defined threshold Performance value), $0.0 \leqslant Q \leqslant 1.0$
Initialize $w_i$ (multiplicative weight), $0.0 \leqslant w_j \leqslant 1.0$, $j$ = 1,2, 3,...,10

**Step 2:** Input values of $y_j$ for $j$ = 1 to 10 ($y_j$ is the value computed using the matching function)

**Step 3:** Execute the summation function:

$$P = \sum w_j y_j; j = (1,2,\ldots 10) \tag{4}$$

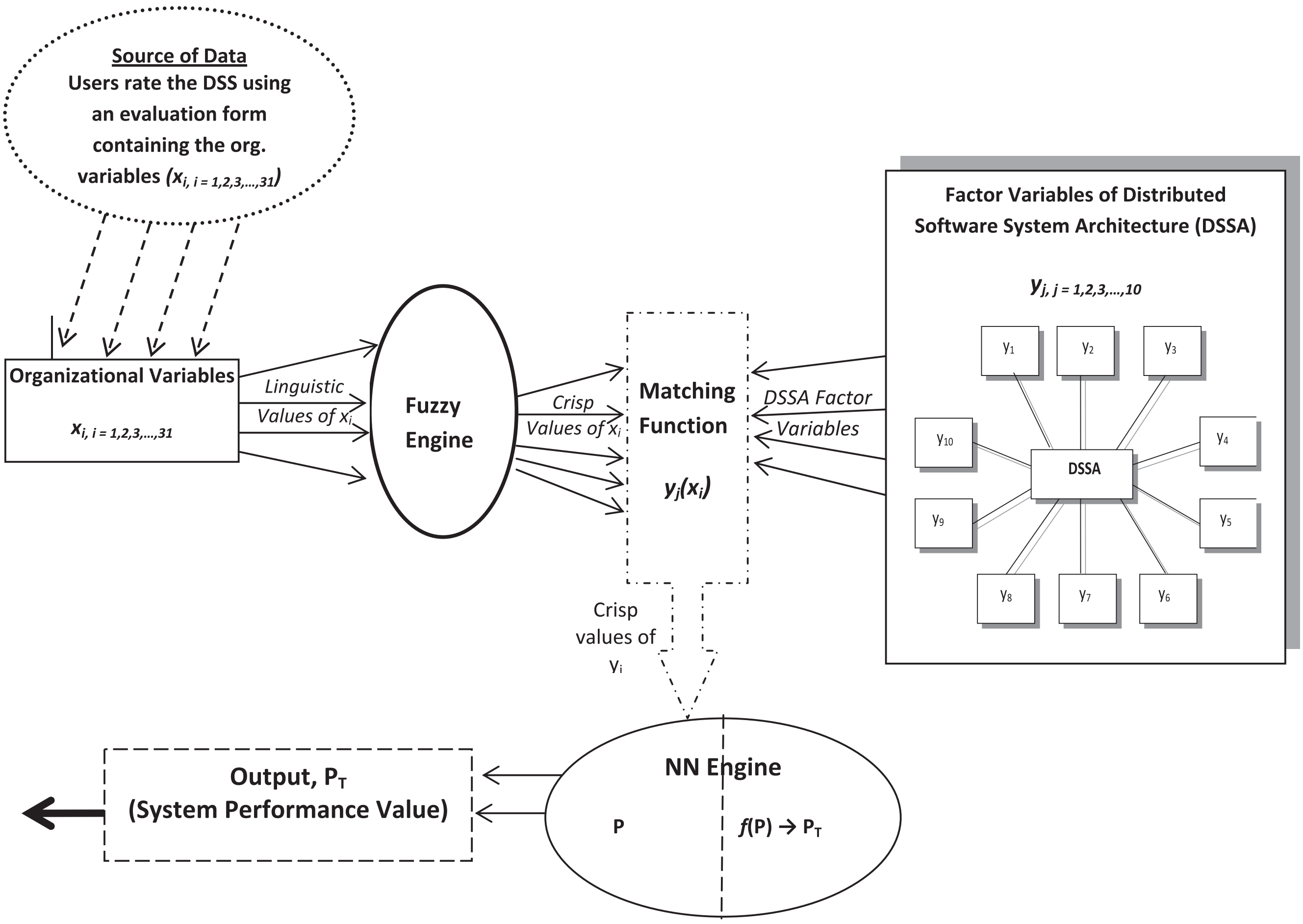


**Fig. 1.** Conceptual diagram of neuro-fuzzy based user-centric performance evaluation model (NFPEM).

**Step 4:** Execute the normalization function:

$$f(P) = P_T = \left\{ \begin{array}{ll} P & \text{if } (0.0 \leqslant P \leqslant 1.0) \quad \text{and} \quad (P \geqslant Q) \\ \frac{1}{1+e^{-P}} & \text{if } P < 0, P > 1.0 \end{array} \right\} \tag{5}$$

if $P_T = P$ then output $P$ and Goto **Step 6**; otherwise Goto **Step 5**

**Step 5:** Delta training rule starts

i. Compute delta, $\delta : \delta = Q - P$

ii. Adjust weights $w_j$ using delta weight adjustment function:

$$w_j^* = w_j + \eta \delta y_j, \ j = 1, 2, \dots, 10 \tag{6}$$

iii. Repeat steps **Step 3** through to **S5** until $(0.0 \leqslant P \leqslant 1.0)$ *and* $(P \geqslant Q)$

**Step 6:** Algorithm terminates

### 3.2. Model description and results

In this section, we describe the model based on the algorithm outlined in Section 3.1. We also utilize collected data in explaining the algorithm, leading to the development of the neuro-fuzzy evaluation model. Section 3.2.1 considers organizational variables, while 3.2.2 explains the generation of the matching function. In Section 3.2.3, the fuzzy logic and neural networks are applied in the final model development.

#### 3.2.1. Establishment of the significant organizational variables for evaluating DSSA

In this research, the organizational variables needed to evaluate the performance of DSSA were established using questionnaire. The variables defined in the questionnaire are the organizational variables expected to influence the decision of software developers while designing DSSA. These variables were gotten from literatures such as (Chiemeke, 2003; Microsoft Patterns & Practices, 2009; Verville & Halington, 2002; Gray, 1984; Uzoka, 2008; David & Williams, 1994) and through face to face interviews with software developers and end users of various online applications. The respondents to the questionnaire were the software developers and users of software applications who are staff (management and operational) of organizations (private and public) that deplore services using software applications. Other categories of users that responded to the questionnaire were customers of various organizations that use online applications for their transactions. As a software developer or an end-user of DSS, he/she was requested to examine each variable in terms of its suitability and then to tick the degree of his/her agreement to each variable, whether in his/her opinion it would influence the design of the DSSA components attributed to it. He/she might recommend new and delete unnecessary items from the existing scale. Also data were gotten from the staff of National Information Technology Development Agency (NITDA) in Nigeria using the questionnaire. A sample of this questionnaire is presented in Appendix A.

The questionnaire consisted of two parts. The first part captured the respondent's characteristic such as *respondent's age group, gender, profession, level in organization, type of organization, age of* *organization, size of organization, type of software used in the organization, and category of software user*. The second part of the questionnaire measured 77 organizational variables and they were classified under 16 factors. The factors are: *User Interface, User Process, Presentation Logic, Business Workflow, Business Entity, Data Access, Service Agents, Security Implementation, Information/Data Communication, and Service Layer, User Involvement, Awareness of Users, Users Interest and IT Experience, Preparedness of the Client Organization, Software Product Factors and Hardware Platform Factors*. The variables were measured using a 5-point Likert-type scale. It ranges from 1 = strongly disagree to 5 = strongly agree. A total of 370 questionnaires were distributed physically and electronically via e-mails. A total of 150 questionnaires (40.54%) were correctly filled and used for this research.

The analysis of the data collected through the questionnaire was in two parts. The first part of the analysis involved the use of descriptive statistics showing the percentages of the respondent's characteristics. Table 3 presents the descriptive statistics of the respondent's characteristics based on the data captured using the questionnaire. It shows that the respondents were mostly people between ages 25 and 40 which accounts for 66% of respondents. Both male (73.3%) and female (26.7%) actively participated in the survey with a wide margin in favor of the male counterparts. Majority (41.3%) of the respondents have software usage experience ranging from 5 years to 10 years. The highest respondent profession is Information Technology (50.7%) while Accounting and Finance had the least (8.7%). 29.3% of the respondents were from the Information and Communication Technology (ICT) industry. 43.3% of the respondents were software developers while 56.7% were software users. The users were classified into expert users (29.3%), casual users (4.0%) and end users (23.4%).

The second section of the analysis involved the use of exploratory factor analysis using maximum likelihood extraction method to reduce the organizational variables to a set of significant variables that we proposed in this work as organizational factors that software developers should consider during the Software Development Life Cycle (SDLC). The factor analysis was carried out using Statistical Package for Social Sciences (SPSS) version 17.0. Bartlett's test produced $X^2$ (Chi-Square) of 2363.310 with Significance of 0.000; KMO produced a measure of 0.746 (this is greater than 0.5), which indicate that the correlation matrix is not an identity matrix. These results confirm that: the sample population is adequate for the factor analysis and the application of factor model on the data is suitable because the correlation matrix is not an identity matrix. The initial factor extracted was achieved by two different approaches for replication purpose, namely: mineigen criterium (Mcriterium) and Ncriterium. Ten factors were extracted in more than 25 iterations with convergence = 0.146. Applying the Social Science rule on the initial factor matrix generated, this did not give a meaningful factor loading. In order to obtain a meaningful factor loading, the initial factor matrix was rotated by orthogonal transformation by varimax (*variance maximixing*) with Kaiser Normalization and a rotated factor matrix was produced. The rotated factor matrix provided a clear pattern of loading and was more meaningful for interpretation and therefore it is used for the purpose of this analysis. The rotated factor matrix is presented in Table 4. The rotation converged in 10 iterations. Ten factors were generated, namely: *business entity, preparedness of client organization, service agent, process and presentation logic, users' interest and IT expertise, user involvement, user interface, data access and security, business workflow and service layer*. The variables loaded on each factor are as follows:

**Table 3**
Descriptive statistics showing distribution of respondents.

| Characteristics | Number | Percentage (%) |
|---|---|---|
| *Respondents' Age* | | |
| Over 40 | 33 | 22.0 |
| 25–40 | 99 | 66.0 |
| Less than 25 | 18 | 12.0 |
| *Respondents' Sex* | | |
| Male | 110 | 73.3 |
| Female | 40 | 26.7 |
| *Type of Organization* | | |
| Communication | 44 | 29.3 |
| Hospitality | 2 | 1.3 |
| Insurance | 19 | 12.7 |
| Legal | 2 | 1.3 |
| Mining | 1 | 0.7 |
| Manufacturing | 15 | 10.0 |
| Government Parastatal | 14 | 9.3 |
| Others | 53 | 35.3 |
| *Job Classification* | | |
| Accounting & Finance | 13 | 8.7 |
| Human Resources Management | 19 | 12.7 |
| Sales & Marketing | 9 | 6.0 |
| Information Technology | 76 | 50.7 |
| Others | 33 | 22.0 |
| *Software User Category* | | |
| Software Developer | 65 | 43.3 |
| Expert User | 44 | 29.3 |
| Casual User | 6 | 4.0 |
| End User | 35 | 23.4 |
| *Software Usage Experience (x years)* | | |
| Over 15 years | 55 | 36.7 |
| 10–15 | 23 | 15.3 |
| 5–10 | 62 | 41.3 |
| Less than 5 | 10 | 6.7 |

**Table 4**
[a] Rotated Factor Matrix by Varimax with Kaiser Normalization.

| Variables | Factors | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| CRE1 | .643 | | | | | | | | | |
| DCRO | .580 | | | | | | | | | |
| WUIT | | .600 | | | | | | | | |
| ITIF | | .564 | | | | | | | | |
| BSPJ | | .518 | | | | | | | | |
| FSTU | | .515 | | | | | | | | |
| SODB | | .499 | | | | | | | | |
| PIN1 | | | .990 | | | | | | | |
| DMEB | | | .970 | | | | | | | |
| UDI1 | | | | .770 | | | | | | |
| DVSC | | | | .647 | | | | | | |
| DUOG | | | | .615 | | | | | | |
| ISO1 | | | | .410 | | | | | | |
| PQUS | | | | | .881 | | | | | |
| AQUS | | | | | .531 | | | | | |
| UFST | | | | | .405 | | | | | |
| USDE | | | | | | .824 | | | | |
| USOP | | | | | | .658 | | | | |
| PUOS | | | | | | .811 | | | | |
| TTUS | | | | | | .581 | | | | |
| UIRF | | | | | | | .746 | | | |
| OGTS | | | | | | | .544 | | | |
| OPTF | | | | | | | .502 | | | |
| ODFI | | | | | | | .440 | | | |
| DUAR | | | | | | | | .692 | | |
| BRDP | | | | | | | | .541 | | |
| ODS1 | | | | | | | | .477 | | |
| OGTS | | | | | | | | | .471 | |
| DFP1 | | | | | | | | | .549 | |
| DTSO | | | | | | | | | .469 | |
| ESEO | | | | | | | | | | .722 |
| MCC1 | | | | | | | | | | .598 |

*Factor 1 – Business Entity* ($y_1$)
(a) Communication rules with external organizations (CRE1) → ($x_1$)
(b) Data communication rules and semantics within the client organization (DCRO) → ($x_2$)

*Factor 2 – Preparedness of the Client Organization* ($y_2$)
(a) Willingness of users for IT training (WUIT) → ($x_3$)
(b) IT infrastructure available in client organization (ITIF) → ($x_4$)
c. Budget of the client organization for software project (BSPJ) → ($x_5$)
d. Feasibility study done by the project team in client organization (FSTU) → ($x_6$)
e. Expected size of the organization database (SODB) → ($x_7$)

*Factor 3 – Service Agent* ($y_3$)
(a) Policies for interoperability (PIN1) → ($x_8$)
(b) Defined mapping of data with external business entity and services (DMEB) → ($x_9$)

*Factor 4 – Process and Presentation Logic* ($y_4$)
(a) Users definition for input data and the format for input (UDI1) → ($x_{10}$)
(b) Data input validation strategy/procedure defined by client organization (DVSC) → ($x_{11}$)
c. Developers' understanding of the organization's goal and task (DUOG) → ($x_{12}$)
d. Internal services of the client organization and their relationships (ISO1) → ($x_{13}$)

*Factor 5 – Users Interest and IT Expertise* ($y_5$)
(a) Professional qualification of users (PQUS) → ($x_{14}$)
(b) Academic qualification of users (AQUS) → ($x_{15}$)
c. Involvement of users in feasibility study (UFST) → ($x_{16}$)

*Factor 6 – User Involvement* ($y_6$)
(a) Involvement of users in system design (USDE) → ($x_{17}$)
(b) Involvement of users in system operation (USOP) → ($x_{18}$)
c. Population of users expected to use/operate the system (PUOS) → ($x_{19}$)
d. Thinking time of users (TTUS) → ($x_{20}$)

*Factor 7 – User Interface* ($y_7$)
(a) Information requirements of users and the format in which it expected (UIRF) → ($x_{21}$)
(b) Organization goals and tasks (OGTS) → ($x_{22}$)
c. Organization policies/procedure for transaction flow (OPTF) → ($x_{23}$)
d. Organization defined functions required in the user interface (ODFI) → ($x_{24}$)

*Factor 8 – Data Access and Security* ($y_8$)
(a) Organization defined access right for users of applications (DUAR) → ($x_{25}$)
(b) Business rules associated with the data to be processed (BRDP) → ($x_{26}$)
c. Data security measures put in place by the organization (ODS1) → ($x_{27}$)

*Factor 9 – Business Workflow* ($y_9$)
(a) Organizations goals and tasks (OGTS) →($x_{22}$)
(b) Data flow procedure (DFP1) → ($x_{28}$)
c. Defined timeout for services/operations (DTSO) → ($x_{29}$)

*Factor 10 – Service Layer* ($y_{10}$)
(a) External services requested by the client organization from external organizations (ESEO) → ($x_{30}$)
(b) Message contract for communication between organizations (MCC1) → ($x_{31}$)

The reliability of the loaded factors was measured using the Cronbach's alpha, which is based on the average correlation of items within an instrument or scale; and is regarded as an indication of internal consistency (Cronbach, 1951; UCLA, 2007). Presented in Table 5 is a summary of the reliability analysis for the variables loaded on the factors. The result shows a good level of internal consistency with Cronbach's alpha coefficients greater than 0.5 and the correlation coefficient above 0.2. Moreover the *alpha-if-item-deleted* shows values above 0.3, thus if any one item is removed from the loaded variables, alpha for the remaining variables may be worse than alpha for all the variables. Therefore it is worth retaining all the variables for the factors.

### 3.2.2. Generation of the factor matching function

Multiple regression analysis was carried out in order to establish the relationship between DSSA factors ($y_1, y_2, \ldots, y_{10}$) and their corresponding loaded variables ($x_1, x_2, \ldots, x_n$). The matching function generated was used in the developed model.

The generalized form of multiple linear regression equation with n number of explanatory variables is (Agresti, 2007):

$$\mu_y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_n x_n \tag{7}$$

where $\alpha, \beta_1, \beta_2, \beta_3, \ldots, \beta_n$ are parameters.

The stepwise method was used for selecting the explanatory variables for multiple linear regression functions and also for assessing the relative contribution of each explanatory variable in the function. The stepwise method was used because, the number of data collected for this research was relatively large ($n = 150$) and therefore there could be minor variations in the data due to sampling errors which can have a large effect on the order in which variables were entered and the likelihood of them being retained. Therefore there was the need to enter each variable in sequence and assess its value to the function. With the stepwise selection method, if adding a variable contributes to the function, then it is retained, while all other variables in the function are then re-tested to establish if they are still contributing to the success of the function. If they no longer contribute significantly they are removed. The use of the stepwise method helps to ensures that the smallest possible explanatory variables are included in the function.

Adapting Eq. (7), the DSSA factors ($y_j$) and the corresponding loaded decision variables ($x_{i,k}$) were related in a general form as follows:

$$y_j = c_j + \sum_{k=1}^{n} a_{j,k} x_{j,k} \tag{8}$$

where: $y_j$ is the $j$th DSSA factor on which the set of variables, $x_{j,k}$, are loaded while $a_{j,k}$ and $c_j$ are parameters.

Each factor variable ($y_1, y_2, \ldots, y_{10}$) was regressed over its corresponding loaded variables ($x_1$, $x_2, \ldots, x_k$) in order to produce the matching functions required in the proposed model. Each of the factor variables ($y_1, y_2, \ldots, y_{10}$) represents a particular software component while the corresponding loaded variables ($x_1, x_2, \ldots, x_k$) represent the defined contextual organizational variables needed by the software engineer in the design of the associated software component. The dependent variables are ($y_1, y_2, \ldots, y_{10}$) while independent variables are ($x_1, x_2, \ldots, x_k$). The matrix of the matching functions generated after the regression analysis has been stated in the NFPEM algorithm described in Section 3.1.

Testing the significance of each function: $F$-value > 0.00; $P$-value < 0.05; 0.00 < Adjusted $R^2$ < 1.00. The Adjusted $R^2$ tends towards 1.00; 0.00 < Tolerance value < 1.00. The Tolerance value tends towards 1.00. Thus $H_o$ (Null hypothesis) was rejected while $H_1$ (Alternative hypothesis was accepted); multicollinearity between the predictor variables is low and the functions are significant.

**Table 5**
Summary of factors' reliability analysis.

| Constructs | Variables | Corrected Item-Total Correlation Coefficient | Reliability Statistics | |
|---|---|---|---|---|
| | | | No. of Variables | Cronbach's Alpha |
| Factor 1 – Business Entity | Communication rules with external organizations ($x_1$) | .377 | 2 | .548 |
| | Data communication rules and semantics within the client organization ($x_2$) | .377 | | |
| Factor 2 – Preparedness of the Client Organization | Willingness of users for IT ($x_3$) | .529 | 5 | .758 |
| | IT infrastructure available in the client organization ($x_4$) | .558 | | |
| | Budget of the client organization for the software project ($x_5$) | .552 | | |
| | Feasibility study done by the project team in the client's organization ($x_6$) | .489 | | |
| | Expected size of the organization database ($x_7$) | .511 | | |
| Factor 3 – Service Agent | Policies for interoperability ($x_8$) | .973 | 2 | .986 |
| | Defined mapping of data with external business entities and services ($x_9$) | .973 | | |
| Factor 4 – Process and Presentation Logic | User defined input data and the format for input ($x_{10}$) | .624 | 4 | .709 |
| | Data input validation strategy/procedure defined by the client organization ($x_{11}$) | .463 | | |
| | Developers' understanding of the organization's goal and tasks ($x_{12}$) | .511 | | |
| | Internal service of the organization and their relationships ($x_{13}$) | .394 | | |
| Factor 5 – Users Interest and IT Expertise | Professional qualification of users ($x_{14}$) | .587 | 3 | .709 |
| | Academic qualification of users ($x_{15}$) | .550 | | |
| | Involvement of users in feasibility study ($x_{16}$) | .448 | | |
| Factor 6 – User Involvement | Involvement of users in system design ($x_{17}$) | .591 | 4 | .787 |
| | Involvement of users in system operation ($x_{18}$) | .610 | | |
| | Population of users expected to use/operate the system ($x_{19}$) | .545 | | |
| | Thinking time of users ($x_{20}$) | .629 | | |
| Factor 7 – User Interface | Information requirements of users and the format in which it is expected ($x_{21}$) | .527 | 4 | .651 |
| | Organizational goals and tasks ($x_{22}$) | .437 | | |
| | Organization's policies/rules/procedures for transaction flow ($x_{23}$) | .429 | | |
| | The organization's defined functions required in the user interface ($x_{24}$) | .350 | | |
| Factor 8 – Data Access and Security | Organization's defined access right to users of the application ($x_{25}$) | .513 | 3 | .642 |
| | Business rules associated with the data to be processed ($x_{26}$) | .494 | | |
| | Data security measures put in place by the organizations ($x_{27}$) | .363 | | |
| Factor 9 – Business Workflow | Organizational goals and tasks ($x_{22}$) | .267 | 3 | .536 |
| | Data flow procedure ($x_{28}$) | .423 | | |
| | Defined timeout for services operation ($x_{29}$) | .371 | | |
| Factor 10 – Services Layer | External service requested by the client organization from external organization ($x_{30}$) | .486 | 2 | .652 |
| | Message contracts for communication between organizations ($x_{31}$) | .486 | | |

*3.2.3. Development of Neuro-fuzzy procedures for the performance model*

The neuro-fuzzy model was developed based on a process that carried out a fuzzification/defuzzification of values obtained in the previous sub-section and passing such values through a neural net engine in order to generate the final evaluation model. The processes are described below.

*Process 1*: *Normalization of Users' Rating Confidence*
The contextual organizational variables are to be rated by users in order to evaluate the performance of DSSA. Each user is to indicate his/her rating confidence level for each variable. Proposed value for rating confidence level ranges from 0.1 (lowest) to 1 (highest). The rating confidence of users is normalized with the view of getting the appropriate value of the rating confidence that will be used to adjust (that is inflates or deflates) users' rated value for each organizational variable $x_i$. This helps to reduce the level of bias exhibited by users while rating the variables. Knowledge Assessment Methodology (KAM) normalization procedure presented in (Chen and Dahlman, 2005) was adapted in this research to normalize the rating confidence of users. Each of the decision variables is given the optional imprecise linguistic values: *'Strongly Satisfied', 'Satisfied', 'Fairly Satisfied', 'Dissatisfied' and 'Strongly Dissatisfied'*. The matrix of the weight attached to a linguistic value that is presented in (Uzoka, 2008, 2009) was adopted and this is presented in Table 6. Thus the rated value for each variable is converted to a triplet: *lower bound, median point, upper bound* ($u_{t-1}$, $u_t$, $u_{t+1}$).

*Process 2*: *Adjustment of Users' Rated Value for Each Variable*
The process of adjusting rated value defined in (Pereira, Tonelli, Barros, and Ortega, 2002 and Uzoka, Osuji, & Obot, 2011) was adopted to adjust of the users' rating for each variable based on the normalized rating confidence,

**Table 6**
Matrix of the weight attached to linguistic values.

| | Strongly satisfied | Satisfied | Fairly satisfied | Dissatisfied | Strongly dissatisfied |
|---|---|---|---|---|---|
| Upper bound ($u_{t+1}$) | 5.5 | 4.5 | 3.5 | 2.5 | 1.5 |
| Median Point ($u_t$) | 5 | 4 | 3 | 2 | 1 |
| Lower bound ($u_{t-1}$) | 4.5 | 3.5 | 2.5 | 1.5 | 0.5 |

$\alpha_{i,j}$, either to the left or right of the linguistic rating scale defined in Table 6.

The normalized rating confidence of $i$th respondent for $j$th variable, $\alpha_{i,j}$, is used to multiply the following in a set:

(i) Lower bound of the value of the linguistic rating directly below the actual rating ($u_{t-1}$)
(ii) Median point of the value of the actual linguistic rating ($u_t$)
(iii) Upper bound of the value of the linguistic rating directly above (if exists) the actual rating ($u_{t+1}$)

This enables the computation of possible triplets ($\varphi_{i,j}$), whose membership function would be utilized in determining the crisp value. Therefore the adjustment function is;

$$\varphi_{i,j} = \alpha_{i,j}\{u_{t-1}, u_t, u_{t+1}\} \tag{9}$$

*Process 3*: *Fuzzification of Adjusted Rated Value of each Variable*
The users' linguistic judgment for each organizational variable is fuzzy and in this research, triangular fuzzy number (TFN) was adopted. It is defined by a triplet $\{u_{t-1}, u_t, u_{t+1}\}$. It is assumed that triangular fuzzy number starts rising from zero at $x = u_{t-1}$; reach a maximum at $x = u_t$ and decline to zero at $x = u_{t+1}$. The membership function $\mu_x(X)$ of a TFN is defined in (Fuller, 1995; Siler & Buckley, 2005; Zhao & Bose, 2002) as follows:

$$\mu_X(x) = \begin{cases} \frac{x-l}{m-l} & l < x \leqslant m \\ \frac{u-x}{u-m} & m < x \leqslant u \\ 0 & x \leqslant l \text{ or } x > u \end{cases} \tag{10}$$

where *l = lower bound*, *m = median point and u = upper bound*.
Eq. (10), which was adapted in (Pereira et al., 2002; Uzoka et al., 2011), was also adapted in this research; thus the triangular fuzzy membership function presented in Table 7 was developed and used to compute the membership values of the linguistic organizational variables defined in the DSSA assessment form. The function presented in Table 7 is a modification of fuzzy membership function developed in (Uzoka et al., 2011).

*Process 4*: *Defuzzification Process*
Defuzzification is the process of obtaining a crisp value which corresponds to the fuzzy membership value mapped to a linguistic variable (Fuller, 1995; Siler & Buckley, 2005). Thus:

$$\hat{z} = \text{Defuzzifier}(x) \tag{11}$$

where $\hat{z}$ is the crisp output and *Defuzzifier* is the deuzzification method that operates on fuzzy number, x.

In this research, *Centre of Area (CoA)* defuzzification method was adopted because it is more accurate in defuzzifying fuzzy sets of any shape (Siler & Buckley, 2005). Thus the triangular membership values, $\mu_x(\varphi_{i,j})$, computed using TFN functions defined in Table 7, are defuzzified using the CoA function given below:

$$\hat{z}_{i,j} = \frac{\sum \varphi_{i,j}[\mu_x(\varphi_{i,j})]}{\sum \mu_x(\varphi_{i,j})} \tag{12}$$

where: $\hat{z}_{i,j}$ = crisp value, $\varphi_{i,j}$ = adjusted rated values in triangular number format, $\mu_x(\varphi_{i,j})$ = triangular fuzzy number

*Process 5*: *Neural Network (NN) Function of the Performance Model*
The matching functions are linear and thus the Single Layer Perceptron (SLP) is the form of NN adopted in this research. The SLP is a form of NN with no hidden layer and it is able to classify linearly separable functions (Negnevitsky, 2002). SLP is a processing unit with threshold $\theta$ which, when receiving the $n$ real inputs $x_1, x_2, \ldots, x_n$ through edges with associated synaptic weights $w_1, w_2, \ldots, w_n$, outputs $P$ if the inequality $\sum w_i x_i \geqslant \theta$ holds and otherwise the delta training rule is executed and the process start again (Fuller, 1995; Rojas, 1996).

The NN topology adopted is feed-forward topology. The delta learning rule defined in (Rosenblatt, 1957; Rosenblatt, 1958; Fuller, 1995; Rojas, 1996) is used to train the network.

In this research, performance value is assumed to range between 0.0–1.0. Therefore, the closer it is to 1.0, the better the DSSA performance. In the course of evaluating the summation function (that is Eq. (4)), the value of $P$ could be very large (that is $P > 1.0$) or very small (that is $P < 0.0$) or less than Q (defined threshold value for performance); in any of these cases, the sigmoid function, $f(P)$, is executed (that is Eq. (5)) in order to normalize the output $P$ (that is $0.0 \leqslant P \leqslant 1.0$).

If a threshold performance value is defined for the DSSA (say Q in the range 0.0–1.0), then the output $P_T$ is fired **if** $(0.1 \leqslant P_T \leqslant 1.0)$ *and* $P_T \geqslant Q$. Otherwise, the NN commence a training process and the weight $w_j$ is adjusted using Eq. (6) and the process starts again until the conditions for $P_T$ to be fired is met.

## 4. Discussion and conclusion

A comparison between NFPEM and the existing machine-centric models for the evaluation of DSSA shows that the NFPEM is by far, more user –centric and organization oriented. The comparison is presented in Table 8.

In developing a software system, the software developers do not only have to develop the system in a professional manner, but also need to ensure that the software system satisfy the performance requirements of the client and all users of the software. The users' requirements definition guides the software architect in the course of designing the system architecture, however in practice

**Table 7**
Triangular fuzzy membership functions for fuzzification of the adjusted variables.

| | Lower bound (l) | | Median point (m) | | Upper Bound (u) | |
|---|---|---|---|---|---|---|
| | Value | Condition | Value | Condition | Value | Condition |
| Strongly Dissatisfied ($\varphi_{i,j}$) | 0 | $(\varphi_{i,j}) < 0$ | $1.0 - \varphi_{i,j}$ | $0 < \varphi_{i,j} < 1$ | 1 | $\varphi_{i,j} = 1$ |
| Dissatisfied ($\varphi_{i,j}$) | 0 | $(\varphi_{i,j}) < 1$ | $(4 - \varphi_{i,j})/5$ | $1 < \varphi_{i,j} < 2$ | 1 | $\varphi_{i,j} = 2$ |
| Fairly Satisfied ($\varphi_{i,j}$) | 0 | $(\varphi_{i,j}) < 2$ | $(6 - \varphi_{i,j})/5$ | $2 < \varphi_{i,j} < 3$ | 1 | $\varphi_{i,j} = 3$ |
| Satisfied ($\varphi_{i,j}$) | 0 | $(\varphi_{i,j}) < 3$ | $(\varphi_{i,j} - 1)/4$ | $3 < \varphi_{i,j} < 4$ | 1 | $\varphi_{i,j} = 4$ |
| Strongly Satisfied ($\varphi_{i,j}$) | 0 | $(\varphi_{i,j}) < 4$ | $(\varphi_{i,j} - 0.2)/5$ | $4 < \varphi_{i,j} < 5$ | 1 | $\varphi_{i,j} = 5$ |

**Table 8**
Comparison of NFPEM with existing machine-centric models.

| S/N | Parameters used for comparison | Existing DSSA Performance Models | Developed Model (NFPEM) |
|---|---|---|---|
| 1. | Variables used for evaluation | Machine variables | Organizational variables |
| 2. | Nature of evaluation variables | Objective | Subjective |
| 3. | Evaluation Techniques | Hard computing and soft computing techniques | Soft computing techniques |
| 4. | Involvement of users | No user involvement | Users are actively involved |
| 5. | Source of data | DSS processes and the computer systems that runs the software system processes | Users of the DSS |
| 6. | Performance metrics | System throughput, response time of system, resource utilization, turnaround time, latency of system, error rate. The listed metrics are tied to the machine conditions). | System responsiveness. This metric is tied to the organizational services defined during requirement definition stage of the software life cycle. |
| 7. | Goal | To establish the extent to which the DSSA satisfies machine requirements defined for it to run. | To establish the extent to which the DSSA respond to the organizational (end user) services. |
| 8. | Mapping DSSA components with organizational variables | Non of the models does this. | This was done: $y_j = f(x_1, x_2, x_3 \ldots x_k)$; where $y_j$ is the $j$th DSSA component mapped with the organizational variables; $x_1, x_2, x_3 \ldots x_k$ |

today; total involvement of end users in all phases of software development process is not given utmost priority. Various empirical research works had established the gap between software developers and end users and the negative effect on system acceptability and usability. In many respects, our model presents a basis for evaluating the performance of a DSSA using qualitative organizational variables. Often times, software developers are concerned about the efficiency and use-case effectiveness of their systems. The use-case effectiveness is seen as a basis of meeting user requirements.

Organizational concomitants play a great role in the acceptability and usability of the system. Our model ties the system responsiveness to organizational services/goals defined during the requirement definition stage of the life cycle. We also apply softcomputing techniques, which are able to handle vague information and respond to changes in the organization through the neural net engine. The NFPEM permits the evaluation of a DSSA performance based on the organizational variables in order to measure the extent to which the DSSA respond to the organizational (end user) requirements. This is unlike the existing machine-centric performance evaluation models that evaluate DSSA performance using machine parameters in order to establish the extent to which the DSSA meet the defined machine requirements needed for it to run efficiently on the machine.

## Appendix A

### *A.1. Part of survey instrument relating to matching of software factors with organizational factors*

As a software developer or an end-user of DSS, you are requested to examine each item/variable in terms of suitability and then to tick the degree of your agreement to each item/variable whether, in your opinion, it would influence/affect the design of the DSS (distributed software system) architectural components attributed to it. You may recommend new and delete unnecessary items from the existing scale. Your in-time response will be appreciated. Please, use the scale below to mark (√) your response in the area provided.

| | Attributes | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | Remark |
|---|---|---|---|---|---|---|---|
| **1** | **User Interface Component** – (*The applications visual elements used to display information to the users and accept user input*) | | | | | | |
| 1.1 | Identification of the software users | | | | | | |
| 1.2 | Users' definition of input data and the format of input | | | | | | |
| 1.3 | Definition of user interface requirements | | | | | | |
| 1.4 | Organizational goals and tasks | | | | | | |
| 1.5 | Level of users competence/experience in Information Technology | | | | | | |
| 1.6 | Information requirements of users and the format in which it is expected | | | | | | |
| 1.7 | The organization's defined functions required in the user interface | | | | | | |
| 1.8 | Internal service of the organization and their relationships | | | | | | |
| 1.9 | External services required by the organization | | | | | | |
| 1.10 | Message contracts for communication between organizations | | | | | | |
| **2** | **Users Process Component**–(*Predictable process through which users interact with the system to perform an activity/task/job*) | | | | | | |
| 2.1 | Organization's policies/rules/procedures for transaction process flow | | | | | | |
| 2.2 | Data flow procedure | | | | | | |

| | Attributes | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | Remark |
|---|---|---|---|---|---|---|---|
| 2.3 | Data input validation strategy/procedure defined by the client organization. | | | | | | |
| 2.4 | Developers' understanding of the organization's goal and tasks | | | | | | |
| **3** | **Presentation Logic Component**– (*DSS code that defines the logical behavior and structure of the application in a way that is independent of any specific user interface implementation*) | | | | | | |
| 3.1 | Defined input data and the format for input | | | | | | |
| 3.2 | Internal services of the organization and their relationships | | | | | | |
| 3.3 | External services of client organization to other organization | | | | | | |
| 3.4 | Message contracts for communication between organizations | | | | | | |
| 3.5 | Understanding user interface requirements | | | | | | |
| **4** | **Business Workflow Component**– (*Defines and coordinates long-running, multistep business process and can be implemented using business process management tools*) | | | | | | |
| 4.1 | Business rules and polices | | | | | | |
| 4.2 | Business rules validation strategy | | | | | | |
| 4.3 | Complexity of business rules | | | | | | |
| 4.4 | Durability of business rules | | | | | | |
| 4.5 | Internal services of the organization and their services | | | | | | |
| 4.6 | External services of client organization to other organization | | | | | | |
| 4.7 | Organization defined constraints for accessing and processing data | | | | | | |
| 4.8 | Guidelines for data population | | | | | | |
| 4.9 | Protocol for requesting for internal services | | | | | | |
| 4.10 | Protocol for requesting for external services | | | | | | |
| 4.11 | Policies for interoperability | | | | | | |
| 4.12 | Payment procedure for services | | | | | | |
| 4.13 | Service delivery method | | | | | | |
| 4.14 | Defined timeout for services/operations | | | | | | |
| 4.15 | Data flow procedure | | | | | | |
| 4.16 | Data/Information security policies of the organization | | | | | | |
| **5** | **Business Entity Component** – (*Business objects, encapsulating the business logic and data necessary to represent real world elements e.g Customer or Order*) | | | | | | |
| 5.1 | Business rules and policies | | | | | | |
| 5.2 | Business rules validation strategies defined by the organization | | | | | | |
| 5.3 | Transaction rules for business entities | | | | | | |
| 5.4 | Complexity of business rules | | | | | | |
| 5.5 | Software developer's level of understanding of the business workflow | | | | | | |
| 5.6 | Business rules validation strategies | | | | | | |
| 5.7 | Communication rules and semantics within the client organization | | | | | | |
| 5.8 | Communication rules with external organizations | | | | | | |
| **6** | **Data Access Component**– (*Represents the logic required to access the underlying data stores)* | | | | | | |
| 6.1 | Business rules associated with the data to be accessed | | | | | | |
| 6.2 | Standard constraints laid down by the organization to access data | | | | | | |
| 6.3 | Organization's defined access right to users of the application | | | | | | |
| 6.4 | Required data access technology by the client organization | | | | | | |
| 6.5 | Clear definition of error handling strategy to manage data source exception | | | | | | |
| 6.6 | Defined mapping of data with business entities and their associated business activities | | | | | | |
| 6.7 | Data communication rules and semantics within the client organization | | | | | | |
| 6.8 | Data communication rules with external organizations | | | | | | |
| 6.9 | Data security measures put in place by the organization | | | | | | |
| 6.10 | Organizations' policies guiding interoperability | | | | | | |

(*continued on next page*)

(*continued*)

| | Attributes | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | Remark |
|---|---|---|---|---|---|---|---|
| **7** | **Service Agents Component**(*This isolates the unusual system behaviors that could result from calling diverse services from the software application. It provides additional services such as caching, offline support and basic mapping between the format of data exposed by the called services and the format the software application requires*) | | | | | | |
| 7.1 | Communication rules and semantics between business entities within the client organization | | | | | | |
| 7.2 | Communication rules between internal business entities and external business entities from other organizations. | | | | | | |
| 7.3 | Defined business rules | | | | | | |
| 7.4 | Defined policies on interoperability of organizations | | | | | | |
| 7.5 | Data and system security measures defined by the client organization | | | | | | |
| 7.6 | Clear definition of error handling strategy established in the client organization | | | | | | |
| 7.7 | Defined mapping of data with external business entities and services | | | | | | |
| **8** | **Security Implementation Component**– (*This entails the authentication, authorization, validation and encryption of data/ information and business services*) | | | | | | |
| 8.1 | Security policy adopted in the client organization | | | | | | |
| 8.2 | Defined trust boundaries within and outside of the organization | | | | | | |
| 8.3 | Organization's policy on interoperability | | | | | | |
| 8.4 | National/International policy on interoperability | | | | | | |
| **9** | **Information/Data Communication Component** – (*This entails the movement of data/signal/information within and outside of the organization via the software application*) | | | | | | |
| 9.1 | Organization's standard on data/information movement within and outside of the organization | | | | | | |
| 9.2 | National/International policy on interoperability | | | | | | |
| 9.3 | Data/Information security procedure put in place in the organization | | | | | | |
| **10** | **Services Layer Component**– (*this provides other clients and applications with a way to access business logic in the application, and make use of the functionality of the application by passing messages to and from it over a communication channel*) | | | | | | |
| 10.1 | Internal services of the organization and their relationship | | | | | | |
| 10.2 | External services requested by the client organization from external organizations | | | | | | |
| 10.3 | Services rendered by client organization to external organization | | | | | | |
| 10.4 | Message contracts for communication between organizations | | | | | | |
| 10.5 | Communication rules and semantics within client organization | | | | | | |
| 10.6 | Communication rules and semantics with external organizations | | | | | | |

A.2. Other identified organizational/users variables

| | Attributes | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | Remark |
|---|---|---|---|---|---|---|---|
| **A** | **Users Involvement** | | | | | | |
| a.1 | Involvement of users in software project planning | | | | | | |
| a.2 | Involvement of users in feasibility study | | | | | | |
| a.3 | Involvement of users in system design | | | | | | |
| a.4 | Involvement of users in system operation | | | | | | |
| a.5 | Think time of users | | | | | | |
| a.6 | Population of users expected to user/operate the system | | | | | | |
| a.7 | Involvement of users during requirement specification | | | | | | |
| **B** | **Awareness of Users** | | | | | | |
| b.1 | Awareness of the users on the importance of the software application towards the efficient performance of the organization. | | | | | | |

**Other Identified Organizational / Users Variablesidentified organizational/users variables** (*continued*)

| | Attributes | Strongly Agree | Agree | Not Sure | Disagree | Strongly Disagree | Remark |
|---|---|---|---|---|---|---|---|
| b.2 | Awareness of users that the software system is an aid to human expert | | | | | | |
| C | **Users Interest and IT Experience** | | | | | | |
| c.1 | Users interest in the software project | | | | | | |
| c.2 | Willingness of users for IT training | | | | | | |
| c.3 | Academic qualification of users | | | | | | |
| c.4 | Familiarity of users with IT tools | | | | | | |
| c.5 | Users experience in the problem area of the software system | | | | | | |
| c.6 | Professional qualification of users | | | | | | |
| **D** | **Preparedness of the client organization** | | | | | | |
| d.1 | Data survey and collection procedure defined by the organization | | | | | | |
| d.2 | Strategic plan of the client organization for the software application | | | | | | |
| d.3 | Objective of the software application defined by the client organization | | | | | | |
| d.4 | Feasibility study done by the project team in the client's organization | | | | | | |
| d.5 | Professional competence of the project team in the client organization | | | | | | |
| d.6 | Budget of the client organization for the software project | | | | | | |
| d.7 | IT infrastructure available in the client organization | | | | | | |
| *E* | **Software Product Factors** | | | | | | |
| e.1 | Expected size of the organizational database | | | | | | |
| e.2 | Complexity of the software project | | | | | | |
| e.3 | Volume of required operational services of the organization to be represented in the software | | | | | | |
| **F** | **Hardware Platform Factors** | | | | | | |
| f.1 | Service execution time constraint | | | | | | |
| f.2 | Main storage constraint | | | | | | |
| f.3 | Turnaround time of the computer | | | | | | |
| f.4 | Bandwidth size available | | | | | | |
| f.5 | Strength of the communication devices | | | | | | |

## Appendix B

### *B.1. Software performance assessment form*

As an end-user of distributed software system (DSS), you are requested to examine each item in terms of suitability and then to tick the degree of your agreement to each item whether, in your opinion, your organization's DSS meets your requirements. You are also expected to indicate your confidence level (rating confidence) for each item. Your rating confidence value range between 1 – 10. Highest valua of rating confidence level is 10 and the least confidence level is 1. Your in-time response will be appreciated. Please, use the scale below to mark (√) your response in the area provided.

| | Items | Strongly Satisfied | Satisfied | Fairly Satisfied | Dissatisfied | Strongly Dissatisfied | Rating Confidence (1–10) |
|---|---|---|---|---|---|---|---|
| 1 | The DSS of your organization satisfies all communication rules that are established to relate with external organizations | | | | | | |
| 2 | The DSS of your organization satisfies the laid down communications rules and semantics for the units within the organization to relate | | | | | | |
| 3 | The DSS of your organization provides friendly features that gear the willingness of the users to embrace its usage | | | | | | |
| 4 | The DSS of your organization supports the IT infrastructure that are available in the organization | | | | | | |
| 5 | The DSS of your organization is developed within the limit of the organization's budget for it | | | | | | |
| 6 | The feasibility study done by the DSS project team in your organization is adequate | | | | | | |

(*continued on next page*)

**Appendix B** (*continued*)

| | Items | Strongly Satisfied | Satisfied | Fairly Satisfied | Dissatisfied | Strongly Dissatisfied | Rating Confidence (1–10) |
|---|---|---|---|---|---|---|---|
| 7 | The DSS of your organization supports the expected size of the organization database | | | | | | |
| 8 | Your organization's policies for interoperability are meet by the DSS | | | | | | |
| 9 | Your organization's data structure is well mapped with the business entities and services | | | | | | |
| 10 | The DSS of your organization meets the users' data input format and also the report format | | | | | | |
| 11 | The data input validation procedure defined by your organization is satisfied by the DSS | | | | | | |
| 12 | Your organization's DSS developers have a good understanding of the organization's task and goal. | | | | | | |
| 13 | The DSS of your organization adequately represents the organization's defined internal services and their relationships | | | | | | |
| 14 | The Professional qualifications of the users are put into consideration in the course of developing your organizations' DSS | | | | | | |
| 15 | The Academic qualification of the users are put into consideration in the course of developing your organization's DSS | | | | | | |
| 16 | The users are involved in the feasibility study carried out for the DSS project of your organization | | | | | | |
| 17 | The users are involved while designing the DSS | | | | | | |
| 18 | The users are involved in the DSS operations | | | | | | |
| 19 | The DSS of your organizations supports the expected number of users | | | | | | |
| 20 | The DSS satisfies the expected thinking time of users | | | | | | |
| 21 | The DSS meets the information requirements of the users | | | | | | |
| 22 | The DSS meets the goal and objectives of the organization | | | | | | |
| 23 | The DSS satisfy the organization laid down rules/ policies for transaction flow | | | | | | |
| 24 | The DSS satisfies the organization's requirements for the user interface | | | | | | |
| 25 | The user's access right is well implemented by the DSS | | | | | | |
| 26 | Business rules associated with your organization's data are implemented by the DSS | | | | | | |
| 27 | The DSS implements all the data security measures put in place in your organization | | | | | | |
| 28 | The DSS implements your organization's data flow procedure | | | | | | |
| 29 | The DSS implements the defined timeout for all the services in your organization | | | | | | |
| 30 | The DSS carries out the services requested by your organization from other external organizations | | | | | | |
| 31 | The DSS implements the message contract for communication between organizations | | | | | | |

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