Evaluation of LMS Quality Based on ISO-9126
A Partial Least Squares Path Modelling Approach

Roohollah Mohammadi[1] **Bijan Bidabad**[2] **Mahshid Sherafati**[3]

Abstract

The main purpose of this paper is to study the quality of e-learning system in Iran's Industrial Management Institute by applying the ISO-9126 standards. This model is based on six main variables, which are measured by other indicators. To measure the indicators of the model, a questionnaire was prepared and distributed amongst 168 experts to fill out. According to the results, there is a direct and significant relationship between the quality of LMS in Industrial Management Institute and the six effective factors of the model. It was perceived that the quality of LMS depends on its efficiency and functionality.

Keywords: ISO-9126, E-learning, System Quality, Partial Least Squares (PLS)

1- Introduction

LMS is the abbreviation of "Learning Management System", which is also known as e-learning. LMS is a class of software applications that are used for administration and documentation of educational contents and products. These applications are able to remotely provide some features such as tracking of submissions, reporting to professors, and delivering electronic educational courses or training programs to groups of students and trainees.

Evolution of IT and ICT has led to a great shift in learning and also substantial changes in local education systems. In general, LMS applies modern teaching techniques with the aid of the latest information and communication technologies to create programs for students. In this regard, the raised interests have ended up in expanding the e-learning concept among students as a common and easy-to-use framework for all types of information including the systems for testing and evaluation of the knowledge gained by trainees.

LMS can be defined from different perspectives and in various technologies; but in general, it represents a teaching solution for distance education with the aid of the massive penetration of communication technologies. Nichols (2003) defines this concept as "the use of various technological tools that are either Web-based, Web-distributed or Web-capable for the purposes of education." Nichols' main focal point and perspective lies in the main component of the phenomenon of e-learning, Internet and web-based technologies, which allow the transfer of information at any time in any location, to as many people as needed.

The American Society for Education and Development defines e-learning as "any form of information transmitted, facilitated or provided by electronic technologies to explicitly support the process of learning." A different approach in terms of participation in the process of e-learning is found in Jackson's work (quoted by Partridge, 2005), where he talks about two secondary concepts: technologically distributed e-learning and technology-facilitated e-learning. While the first situation arises in the case of distance education, the second one describes the process of traditional education using various technical means.

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[1] CEO of Novin Pajoohan Research Institute, Tehran, Iran. http://www.imif.ir, rmohamadi58@gmail.com
[2] Economic Consultant of Fars & Khuzestan Cement Company, Tehran, Iran. http://www.bidabad.com, bijan@bidabad.com
[3] Master student at Graduate School of Management, Multimedia University, Malaysia. mahshidsherafati@yahoo.com

Many researchers have investigated the influence of LMS on education. Petrakou (2009), Dalgarno et al. (2009), Limniou et al. (2008), and Berta (2009) worked on different aspects of LMS systems including the advantages and the features. Added to them, some others studied the challenges of implementing the system (Sadeghi, 2008). In most of the studies, there are some factors more noticeable among all the other aspects, which are organizational factors, infrastructure (Dalgarno et al., 2009), feasibility issues, planning, and policy-making subjects. Moreover, a number of studies have discussed the effectiveness of LMS in education (Berta, 2009). Meanwhile, only a few studies have concentrated on the quality of LMS systems, in which ISO-9126 is one of the models for measurement of the system quality.

ISO-9126 was originally developed in 1991 and refined over a decade, and provides a framework for evaluating software quality (Abran et al., 2003). It should be indicated that many studies have criticized ISO-9126 for not prescribing specific quality requirements, but instead defining a general framework for evaluation of software quality (Valenti, 2002).

The authors of the present paper believe that the criteria and sub-criteria presented in ISO-9126 offer a more accurate model for evaluating any software system. In addition, Abran et al. (2003) claimed that even though this model does not consist of sufficient details and possibilities, the combination of the suggested criteria is the best model for assessing the system quality of any LMS software.

ISO-9126 assesses e-learning systems from different aspects, including the technical requirements for human interaction. Having considered this characteristic, it is attempted in this paper to apply this model for assessing the quality of virtual training system in Industrial Management Institute of Iran.

2- Virtual training quality models and ISO/IEC 9126

In terms of system structure, the quality standards of a software are divided into two major groups of hierarchical and non-hierarchical. Hierarchical models mostly consist of two levels, where the quality features and the sub-characteristics are placed on the first and the second levels, respectively. The most important hierarchical models are: McCall, Boehm, FURPS, Dromey, and ISO-9126 (Calero 2005, 649; Dromey 1995, 13). A brief comparison based on the strengths and weaknesses of these models is shown in Table 1.

Table 1- Comparison of quality models

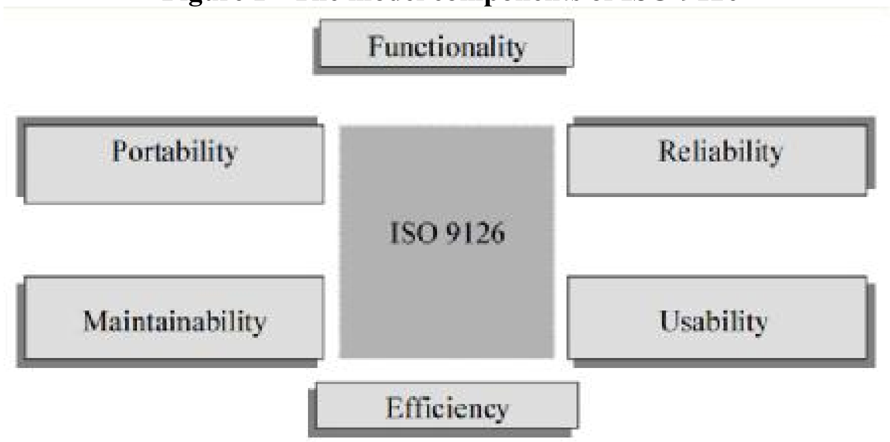
Quality model	Structure	No. of levels	Disadvantages	Advantages
McCall	Hierarchical	Two	Overlapping components	Having an evaluation criterion
Boehm	Hierarchical	Two	No evaluation criteria	Having hardware-related characteristics
FURPS	Hierarchical	Three	No attention to portability	Splitting the operational and non-operational requirements
Dromey	Hierarchical	Two	Disintegration of model components	Presenting the model in terms of the special features of the software
ISO	Hierarchical	Three	-	Providing universal quality features Having an evaluation criterion
Star	Non-hierarchical	-	No evaluation criteria	Offering quality features from several viewpoints
BBN	Non-hierarchical	-	No evaluation criteria	Presenting high precision due to the weighted quality features

Source: ISO/IEC 9126, Software engineering, Product quality, 2001

With regard to Table 1, the ISO model, due to fewer disadvantages, is more complete than the other models. This model was employed for the current study because of its special features such as the universality of qualitative features, understandability in the hierarchical structure, common phrases and titles, precise and clear definition of components, and having measurement criteria.

The quality of software products can be categorized into six main qualitative characteristics according to international standards. Each of the characteristics comprises of several minor features. The relationship between the first level of characteristics and 21 minor ones under the second level, due to the minimum overlaps, is of a one-to-many type. There are many studies criticizing ISO-9126 for not prescribing specific quality requirements, but instead defining a general framework for evaluation of software quality (Valenti 2002). In fact, this is a positive point since it is more adaptable and can be used across many systems, including LMS. The model is shown in Figure 1.

Figure 1 - The model components of ISO-9126



Source: (Chua and Dyson, 2004)

3- Methodology and findings

In this research, the virtual training system of Industrial Management Institute of Iran was studied using the ISO-9126 standards. Accordingly, seven variables, including quality variables of the virtual training system in general, operationalization of the system, system reliability, system performance, system usability, system maintainability, and system transmissibility, were applied. The main variables are not typically measurable per se; hence, some indicators were designed for measuring the variables in the defined model, in conformity with each index of the question/s in the form of dive choices of the Likert range. The designed questionnaire was handed out to 168 experts to fill out, including professors and those who were in connection with the virtual training system of Industrial Management Institute. The questionnaires were then collected and the obtained information was analyzed.

The above model was estimated and its validity was examined using the Partial Least Squares (PLS) Path Modeling Technique. At first, having extracted the answers, the manifest variables were normalized in such a way that the original items Yi (scaled from 1 to 5) were transformed into the new normalized variables X_i=100/4(Y_i-1). The minimum possible value of X_i was 0 and its maximum possible value was equal to 100. If there was any missing data for variable X_i, they were replaced by the mean of the variable.

After specifying the relationship between the variables of the model, using the PLS Path Modeling Technique, all the coefficients and parameters were estimated using Visual PLS 1.04 software in order to estimate the relationship between the latent variables of the model.

A PLS path model consists of a structural model as well as a measurement model. In the next stage, it is taken into account that the validation of a PLS path model requires the analysis and interpretation of both the structural and measurement models. This validation can be regarded as a two-stage process: assessment of the measurement model, and the structural model discussed below (Henseler et al., 2009).

3-1- Assessing the structural model

According to Chin's theory, R^2 is measured for endogenous variables and shows the variance of the endogenous latent variables. In any specific model, which includes endogenous latent variables with only one or two exogenous latent variable(s), the average value of R^2 is acceptable (Trujillo, 2009). In this study, R^2 value was equal to 0.838, which is acceptable. Also, the average redundancy of the model was estimated to be 0.63. In here, high redundancy means a high ability to predict (Trujillo, 2009).

3-2- Assessing the measurement model

Thereafter, we evaluated the three aspects of reflective measures, including:

- The unidimensionality of the indicators;
- Whether the indicators are well explained by their latent variables;
- Assessing the degree to which a given construct is different from the other constructs.

3-2-1- Unidimensionality of the indicators

Recently, some tools have been proposed to evaluate the unidimensionality of the PLS-PM reflective blocks (Shamir et al., 2005). However, the most common methods employed for this purpose are the following three indicators (Jafari Samimi & Mohammadi, 2011):

- Checking the first eigenvalue of the MVs correlation matrix;
- Cronbach's alpha;
- Dillon-Goldstein's ρ.

In this paper, unidimensionality of the indicators was measured using Cronbach's alpha coefficient. If the coefficient is more than 0.7, the reliability of the model will be high and if the coefficient is smaller than 0.6, the model will have low reliability (Henseler et al., 2009). Although Cronbach's alpha coefficient for maintainability and efficiency was less than 0.6, since the average Cronbach's α coefficient of the model was higher than 0.7, the reliability of the model was generally confirmed.

3-2-2- Checking that the indicators are well explained by their latent variables

It was checked by means of the three following tools whether the indicators are well explained by their latent variables:

- Communality: is calculated to check whether the indicators in a block are well explained by its latent variable (Trujillo, 2009). The mean communality of the model was estimated 0.6189, which is the average of all block communalities.
- Composite reliability: is the measure of model reliability. For this criterion, the values less than 0.6 indicate the lack of reliability (Henseler et al., 2009). The value of this criterion in this study was much more than 0.6, which signifies the high reliability of the model.
- AVE: To calculate the convergent validity, Fornell and Larcker suggested the AVE. The AVE values larger than 0.5 mean that 50% or more variance of the indicators should be accounted (Henseler et al., 2009). In this study, the AVE of the model was higher than 0.5, so the convergent validity of the model was confirmed.

Table 2 - Reliability and AVE

Construct	Composite reliability	AVE	Cronbach's alpha
EFFIC	0.764572	0.530312	0.586771
RELIA	0.848709	0.659390	0.732002
USABI	0.789337	0.627955	0.860418
MAINT	0.843394	0.721001	0.590257
PORTA	0.710362	0.693173	0.619691
FUNCT	0.662367	0.758523	0.790208
ISO-9126	1.000000	1.000000	0.865429

3-2-3- Assessing the degree to which a given construct is different from the others

We evaluated the extent to which a given construct differentiates from the rest of constructs by verifying that the shared variance between a construct and its indicators is larger than the shared variance in other constructs. In other words, no indicator should load higher on the other construct than it loads on the construct it intends to measure. We calculated the correlations between a construct and the indicator beside its block. If an indicator loads higher with other constructs than with the one intended to measure, we might consider its appropriateness as it is still unclear that which construct(s) it is actually reflecting upon (Henseler et al., 2009).

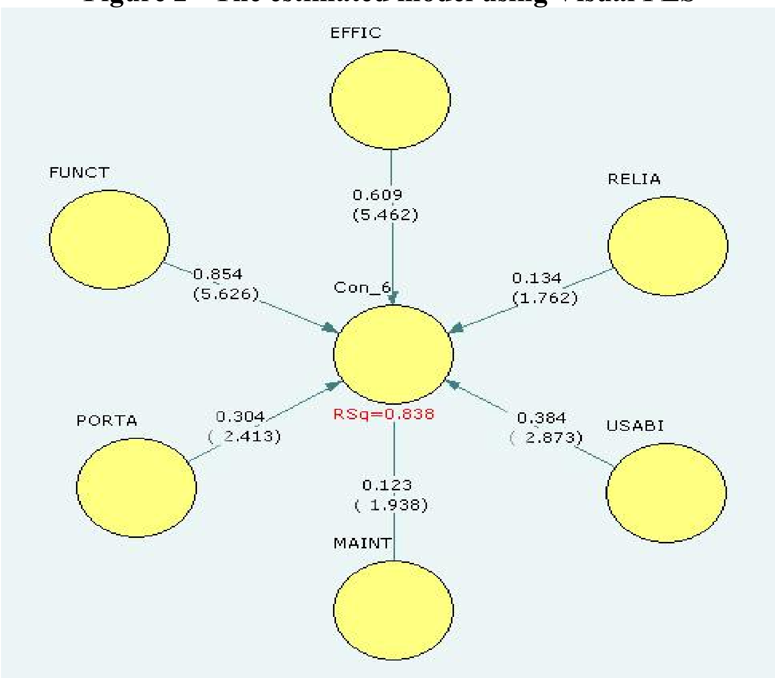
On this basis, U3 and P2 were not identified as appropriate indicators for latent variables and were excluded from the model. However, the other indicators of the model were confirmed.

Table 3 - Correlation of manifest and latent variables of the model

Items	EFFIC	RELIA	USABI	MAINT	PORTA	FUNCT	ISO-9126
F1	**0.5138**	0.3523	0.2116	0.3868	0.3496	0.0554	0.2764
F2	**0.8063**	0.5503	0.2127	0.3561	0.4828	0.2053	0.4802
F3	**0.8535**	0.4217	0.3520	0.4178	0.2746	0.4058	0.0838
F4	**0.6182**	0.2222	0.5854	0.2279	0.1891	0.1979	0.0426
R1	0.5836	**0.8113**	0.5800	0.3467	0.3457	0.1891	0.2160
R2	0.0505	**0.2826**	0.2307	0.0964	0.0008	0.1388	0.0459
R3	0.4549	**0.7174**	0.2174	0.1873	0.0614	0.2107	0.2772
U1	0.0371	0.0470	**0.1813**	0.0786	0.0699	0.0667	0.0978
U2	0.2868	0.5922	**0.9551**	0.4230	0.5081	0.6181	0.4360
U4	0.5236	0.4762	**0.8490**	0.1823	0.4076	0.3917	0.4242
E1	0.2418	0.1658	0.2265	**0.6650**	0.2179	0.3663	0.1213
E2	0.4725	0.3181	0.3906	**0.9709**	0.3317	0.4779	0.3838
M1	0.0937	0.2068	0.0278	0.1419	**0.3606**	0.2357	0.0524
M2	0.4576	0.3583	0.5063	0.4231	**0.6257**	0.5455	0.3434
M3	0.1764	0.4416	0.0132	0.0429	**0.6891**	0.4052	0.3553
M4	0.1565	0.3770	0.3528	0.2311	**0.4929**	0.4574	0.1412
P1	0.5506	0.5487	0.6599	0.4352	0.3909	**0.8230**	0.4736
P3	0.4038	0.5873	0.5707	0.3324	0.5640	**0.8504**	0.6992
P4	0.0976	0.0400	0.1264	0.0639	0.0057	**0.3406**	0.3032
SQ	0.1813	0.6071	0.4843	0.3949	0.4985	0.4965	**0.9161**

On the other hand, considering the fact that the weights of manifest variables of the model are all positive, it was concluded that all measurement indicators have correctly explained their latent variables.

Figure 2 - The estimated model using Visual PLS



5- Conclusion and discussion

Based on the presented model, the relationship between usability, efficiency, portability, and functionality, and the system quality, and also, the relationship between the rest of variables (reliability and maintainability) and the system quality were confirmed at the confidence levels of 95% and 90%, respectively. Despite that, it was comprehended that the quality of university's LMS software was mostly affected by the functionality (0.85) and efficiency (0.61) of the system. After them, the variables' usability and portability had the highest impact on the quality of the system. Moreover, the effect of the variables' reliability and maintainability on the quality of the system was negligible compared to the other variables.

Table 4 - The structural model

	Entire sample estimate	Mean of sub-samples	Standard error	t-statistics
RELIA -> ISO 9126 QUALITY	0.1340	0.1304	0.0761	1.7616
EFFIC -> ISO 9126 QUALITY	0.6090	0.5999	0.1115	5.4620
FUNCT -> ISO 9126 QUALITY	0.8540	0.7666	0.1518	5.6262
PORTA -> ISO 9126 QUALITY	0.3040	0.2101	0.1260	2.4132
MAINT -> ISO 9126 QUALITY	0.1230	0.1005	0.0635	1.9381
USABI -> ISO 9126 QUALITY	0.3840	0.3233	0.1336	2.8732

Since the operationalization of the system and efficiency variables were identified as the most important effective variables on the quality of university's LMS, all the related effective indicators, including time behavior, utilization of resources, suitability, accuracy, interoperability, and security should be seriously taken into account. In addition, necessary attempts should be made in order to enhance the quality of LMS with respect to the above factors.

With respect to the importance of e-learning and its increasing application in Iran, the presented model in this research can be used as a basic model for evaluation of LMS in all organizations and institutions. Furthermore, varieties of models have been offered so far for evaluating the quality of LMS. The other mentioned models can be defined as a new research subject and be compared with the model results of this research.

Appendix 1:

Table 1 - ISO-9126 characteristic and sub-characteristics

Latent variables	Manifest variables
Functionality	**Suitability:** Can the software perform the tasks required? **Accurateness:** Is the result as expected? **Interoperability:** Can the system interact with the other systems? **Security:** Does the software prevent unauthorized access?
Reliability	**Maturity:** Have the majority of faults in the software been eliminated over time? **Fault tolerance:** Is the software capable of handling errors? **Recoverability:** Can the software resume working and restore lost data after failure?
Usability	**Understandability:** Can the user comprehend how to use the system easily? **Learnability:** Can the user learn to use the system easily? **Operability:** Can the user use the system without much effort? **Attractiveness:** Does the interface look good?
Efficiency	**Time behavior:** How quickly does the system respond efficiently? **Resource utilization:** Does the system utilize resources efficiently?
Maintainability	**Analyzability:** Can faults be easily diagnosed? **Changeability:** Can the software be easily modified? **Stability:** Can the software continue functioning in case changes are made?

	Testability: Can the software be tested easily?
Portability	**Adaptability:** Can the software be moved to other environments? **Installability:** Can the software be installed easily? **Conformance:** Does the software comply with portability standards? **Replaceability:** Can the software be easily replaced by another software?
System quality	**System quality:** Does the quality of the university's current system satisfy you?

Source: ISO 1991 (Chua and Dyson, 2004)

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