# Investigating the effect of software quality on quality of care

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**Abstract: Background:** In recent years numerous studies have been conducted on effect of information systems on quality of care; nevertheless, literature review shows that no study has focused on the effect of software quality on quality of care. This study aims to investigate software quality based on ISO 9126 standard model and its impact on quality of care. It also aims to determine the most prominent characteristic which is effective on quality of care index. **Methodology:** In this study quality characteristics of software according to ISO 9126 standard are considered as independent variables and quality of care index is considered as dependent variable. To check the effect of independent variables on dependent one, a questionnaire was designed including 44 questions. The Likert scale was utilized for responses (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree). Score 1 was assigned to strongly disagree and score 5 was assigned to strongly agree. Validity of questionnaire and its reliability were determined to be 95% using medical informatics experts' point of view and Cronbach's alpha test, respectively. Our statistical population was all nurses inside wards. Thus, population volume was available samples. The total number of nurses was 150 and questionnaires were distributed between them during a two month period. After completion and collection of the questionnaires the data was analyzed using SPSS V. 16 software. To investigate the effect of software quality characteristics on quality of care index, multiple linear regression was utilized. **Results:** The obtained results demonstrated that based on Beta coefficients suitability, operability, maturity and maintainability sub-characteristics, respectively in functionality, usability, reliability and changeability characteristics were the most effective ones. Finally, among characteristics, functionality was the most influential one on quality of care. **Conclusions:** In this study, the effects of characteristics and sub-characteristics on quality of care were weighted. In this way the most prominent characteristic and sub-characteristic were determined which must be considered by managers and software designers.

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## Introduction:

Hospital information systems are electronic tools which facilitate communication and preserving patients' profiles and support the performance of organizations. These systems collect, classify and maintain financial, administrative and clinical data of patients. They are also able to recover this information using computer capabilities and provide it for decision makers where it is needed. Presenting patients' information and history to service providers, the hospital information system improves decision making in heath care issues as well as developing organizational performance [1-5].

Recently, vast number of research works have focused on the effect of information systems on quality of care; however, literature review demonstrates that no study has focused on the effect of software quality on quality of care. This study aims to investigate software quality based on ISO 9126 standard model and its impact on quality of care. It also aims to determine the most prominent characteristic which is effective on quality of care index. Health electronic files may play a significant role in improving quality of care by accessing patient's information and standardizing clinical decision making. Therefore, patient care concept could be defined as creating more value for patients through eliminating all non-added-value steps and attempts [6,7].

The emphasis of current management is on resource utilization management, controlling the cost and effectiveness of patient care and improvement of quality and responsiveness as well as reinforcement of efficient patient care. The prerequisite of efficient patient care is that patient's information must be completely and precisely registered and accessible. Undoubtedly if the medical files of patients are utilized as a communication tool between health service providers, they may employ them as a unique tool for planning, coordination and organizing patient care [8-10]. The time needed for patient care associates with complete, on-time and enough medical information; thus, efficient patient care needs on-time, precise and up to date information. For this purpose it

is necessary to choose good and efficient software which matches to standards [11-14].

Some studies demonstrated that some qualitative characteristics of software such as Usability (complete documentation, attractive user interface, simple mechanism for feeding data, simplicity of the software), efficiency (response time, system speed) and functionality (system adequacy, complete software, precision and accuracy of software outputs) impact on health care processes and service providing and as a result they affect quality of care [15-18].

Researchers have shown that by implementing patient tracking system in hospitals of Salt Lake City in Utah, the information of patients could be accessed on time. The results of this study revealed that using this system they could access information related to 40% of patients as they refer to emergency unit. It means that this system was able to improve accessibility to patients' information [19,20]. Moreover, this study demonstrated that repeated reception of patients is reduced by 20%. In this study accessibility of the system and its functional capabilities has led to such improvements [21-24].

Another study investigated the effect of electronic clinical reminders on improvement of quality of care for Diabetes and Coronary Artery disease. It illustrated that 75% of physicians believe that these systems could improve quality of care for Diabetes and Coronary Artery disease [25,26]. Customization of display, the ability of user interface to guide nurses for documentation and appropriate response time has facilitated tracking the course of disease and care services provided by medical team which results in improvement of quality of care [27,28]. Considering several definitions presented for software quality, this study aims to investigate the effect of software quality on quality of care index according to ISO9126 standard.

Table1. The definition of software quality characteristics and sub characteristics based on ISO9126

| Characteristics | Sub-characteristics | Definition |
|---|---|---|
| Functionality | Suitability | Can software perform the tasks required? |
| | Accurateness | Is the result as expected? |
| | Interoperability | Can the system interact with another system? |
| | Compliance | Compliant capability of software with laws and guidelines |
| | Security | Does the software prevent unauthorized access? |
| Reliability | Maturity | Have most of the 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 | does 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? |
| Efficiency | Time behavior | How quickly does the system respond? |
| | Resource behavior | 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 if changes are made? |
| | Testability | Can the software be tested easily? |
| Portability | Adaptability | Can the software be moved to other environments? |
| | Install ability | Can the software be installed easily? |
| | Conformance | Does the software comply with portability standards? |
| | Replace ability | Can the software easily replace other software? |

**ISO9126 model-** ISO9126 standard model was provided by ISO international standard organization and International Electrotechnical Commission in 1991. It presented a framework for evaluation of software products quality. Then, it was redefined and developed. It suggested six characteristics as qualitative characteristics of a software including functionality, reliability, usability, efficiency, maintainability and portability [29-31]. Table 1 represents characteristics and sub-characteristics of ISO9126 standard and their definition.

**Methodology:**

In this study qualitative characteristics of the software according to ISO9126 standard (table1) are considered as independent variables while quality of care index is considered as dependent variable. To examine the effect of independent variables on dependent one a questionnaire was designed based on previous studies. Afterwards, the questionnaire was checked by three experts in medical informatics. To determine questionnaire validity 30 questionnaires were distributed between users (nurses) and their

points of view led to some modifications. To determine reliability of the questionnaire Cronbach's Alpha test was performed which demonstrated a reliability of 95%. The questionnaire included 44 questions. The Likert scale was utilized for responses (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree). Score 1 was assigned to strongly disagree and score 5 was assigned to strongly agree. Statistical population was whole nurses in Shahid Motahari hospital; so, sample size was available samples. The total number of nurses was 150 and questionnaires were handed out during a two month time span. All 150 nurses answered the questionnaires. Subsequently, obtained data was fed to SPSS V. 16 software and was analyzed.

**Achievements:**

To investigate the effect of quality characteristics of the software (based on ISO9126 standard) on quality of care index, multiple linear regression was exploited. Usually in regression we want to estimate the mathematical relation between variables and analyze them so that the quantity of an unknown variable could be derived using known variables. Since here the effect of a few variables on one variable is examined multiple regression was utilized. Using regression needs some assumptions without which the regression could not be applied. These assumptions are as follows; the errors are stochastically independent and they have a normal distribution. In order to examine whether errors are independent or not (difference between actual values and values estimated by regression equation), Durbin-Watson d test was used. If the independency assumption is rejected and errors are correlated, it is impossible to use regression. If the correlation between errors is shown by P, Durbin-Watson statistic is calculated by $DW = 2(1 - P)$. Durbin-Watson statistic lies between 0 and 4. If it is 2 it means that errors are independent. If it is 0 and 4, it respectively means that errors have positive and negative auto-correlation. If this statistic is between 1.5 and 2.5 the errors are still considered as independent and linear regression could be used.

Another assumption is that errors have normal distribution with zero mean. Obviously, if this prerequisite is not satisfied the regression could not be used. To check this assumption error standard values must be calculated; then, data distribution diagram and the normal diagram should be plotted and compared. The third prerequisite is investigating data distribution which is done by Kolmogorov-Smirnov test. The results of this test showed that data distribution is normal (P>0.05).

**Hypothesis 1:** functionality variable with interoperability, accurateness, suitability, security and compliance as its sub-characteristics, affects quality of care.

For each sub-characteristic metrics were defined using Likert scale (strongly disagree, …, strongly agree) and scores were considered to be between 1-5. To confirm regression prerequisites Durbin-Watson test was performed and the statistic was derived (DW=1.701). It showed that errors are independent and regression could be utilized. Then, error distribution was examined. Comparing the error frequency distribution diagram and normal distribution diagram, demonstrated that error distribution was normal (hence, linear regression can be used) (figure1).

To calculate regression backward elimination method was used. In this method, first off, all independent variables are included in regression equation; then, if they do not have necessary criteria for staying in the model (variables with smaller correlation coefficient with dependent variable were eliminated), they were eliminated one by one. Table 1 shows three presented models, finally three variables (interoperability, accurateness and suitability) remain in the table and security and compliance variables are eliminated. In this table R is multiple correlation coefficient, R Square is Coefficient of determination (variability in dependent variable), Adjusted R Square is adjusted coefficient of determination and Error of Estimate Std is standard error of estimation (standard error of estimation is an index which measures dispersion around regression line. The larger this index, the higher dispersion around regression line).

**Table1:Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | 0.805[a] | 0.648 | 0.636 | 2.475 | |
| 2 | 0.805[b] | 0.648 | 0.638 | 2.467 | |
| 3 | 0.804[c] | 0.646 | 0.639 | 2.466 | 1.701 |
| a.Predictors:(Constant).Security,Suitability,Interoprability,Accurateness,Compliance | | | | | |
| b.Predictors:(Constant).Security,Suitability,Interoprability,Accurateness | | | | | |
| c. Predictors:(Constant). Suitability,Interoprability, Accurateness | | | | | |
| d. Dependent Variable: Quality Patient Care | | | | | |

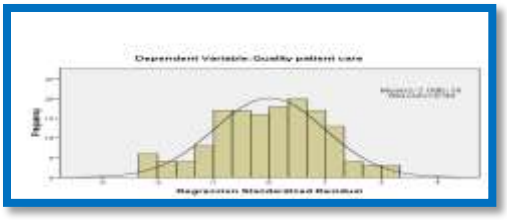

**Figure 1.** Comparison between error frequency distribution diagram and normal ditribution diagram

Subsequently, to examine the certainty of a linear relation between variables, analysis of variance for regression was utilized. In table 2 regression row states the variations of dependent variable which is determined by independent variables. Residual row illustrates variations of dependent variable which is determined by other factors.

**Table2. Analysis of Variance for regression**

| ANOVA | | | | | |
|---|---|---|---|---|---|
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 1619.724 | 3 | 539.908 | 88.802 | .000 |
| Residual | 887.669 | 146 | 6.080 | | |
| Total | 2507.393 | 149 | | | |

As can be seen the value of sig is less than 5 %; thus, the assumption of linear relation between variables is confirmed. When the linearity of relations is confirmed, constant value and coefficients of independent variables in regression equation were calculated. These coefficients are presented in table 3 and the regression equation is derived as shown in equation 1:

1) $Y=10.533 +0.558X_1+0.972X_2+0.296X_3$

T**able 3. Independent variables coefficients**

| Coefficients | | | | | |
|---|---|---|---|---|---|
| **Model** | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
| | **B** | **Std. Error** | **Beta** | | |
| (Constant) | 10.533 | 1.396 | | 7.547 | .000 |
| Suitability | .558 | .051 | .576 | 10.963 | .000 |
| Accurateness | .972 | .135 | .372 | 7.189 | .000 |
| Interoperability | .296 | .126 | .118 | 2.348 | .020 |

Coefficients table includes two groups of coefficients; non-standard (β) and standardized (Beta).

In non-standard coefficients the scales of variables are not the same; whereas, in standard ones the scales are equalized and the variables could be compared. Considering above mentioned explanations, standard coefficients are utilized to compare effects of multiple independent variables on a dependent one. Therefore, if suitability changes one unit the quality of care changes 0.576; while the changes of quality of care for the same changes in interoperability and accurateness are 0.118 and 0.372, respectively. According to coefficients (Beta), suitability variable is the most effective variable on quality of care.

**Hypothesis 2:** usability variable with understandability, learnability and operability as its sub-characteristics affects quality of care variable.

Similar to explanations provided regarding first hypothesis, the results for second one are as follows. As shown in table 4 statistic of Durbin-Watson test is 1.724 which validates independency of errors. As all three variables are highly correlated with the dependent variable, they remained in regression model.

The comparison between error frequency distribution diagram and normal distribution diagram, illustrated that error distribution is normal; thus, linear regression was utilized (figure 3) (it must be figure 2 I think you made a mistake).

**Table4: Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .346[a] | .120 | .102 | 3.888 | 1.724 |
| a. Predictors:(Constant). Understandability, Learnability, Operability | | | | | |
| b. Dependent Variable: Quality Patient Care | | | | | |

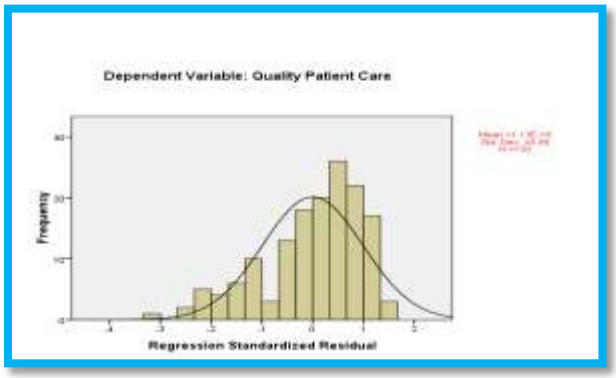


**Figure 2. Comparison between error frequency distribution diagram and normal distribution diagram**

Analysis of variance for regression also confirmed linear relation between variables. The value of sig was 0 which is less than 0.05 and validates the linear relation (table5).

**Table 5. analysis of variance for regression**

| ANOVA | | | | | |
|---|---|---|---|---|---|
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 300.930 | 3 | 100.310 | 6.637 | .000[a] |
| Residual | 2206.463 | 146 | 100.310 | | |
| Total | 2507.393 | 149 | | | |

P<0.05 confirms linearity of relations. When the linearity was confirmed constant value and coefficients of independent variables were calculated. Table 6 includes these coefficients and the following equation shows the regression equation:

$$Y=21.669 +0.058X_1+0.177X_2+0.601X_3$$

**Table 6. Independent variables coefficients**

| Coefficients | | | | | |
|---|---|---|---|---|---|
| **Model** | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
| | **B** | **Std. Error** | **Beta** | | |
| (Constant) | 21.669 | 1.962 | | 11.044 | .000 |
| Understandability | .058 | .032 | .142 | 1.815 | .007 |
| Learnability | .177 | .071 | .194 | 2.485 | .014 |
| Operability | .601 | .196 | .239 | 3.059 | .003 |

Standard Beta coefficients demonstrate that one unit change in understandability causes quality of care to change 0.142. Besides, the changes of quality of care for the same changes in operability and learnability are 0.239 and 0.194, respectively. Considering the Beta coefficients operability variable is the most influential one.

**Hypothesis 3:** efficiency variable affects quality of care

According to table 7 the statistic of Durbin-Watson test is 1.760 confirming the independency of errors. The comparison between error frequency distribution diagram and normal distribution diagram, illustrated that error distribution is normal; thus, linear regression was utilized (figure 5).

Table7: Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .429[a] | .184 | .179 | 3.718 | 1.760 |

| |
|---|
| a.Predictors:(Constant). Efficiency |
| b. Dependent Variable: Quality Patient Care |

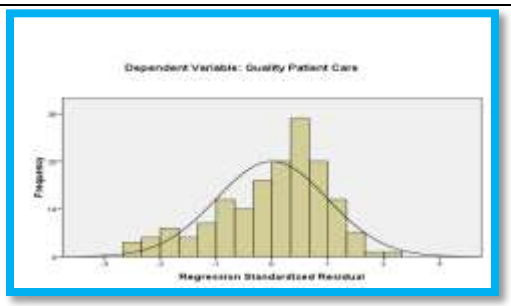


**Figure 3. Comparison between error frequency distribution diagram and normal distribution diagram**

P<0.05 confirms linearity of relations. When the linearity was confirmed constant value and coefficients of independent variables were calculated. Table 8 represents these coefficients and undergoing equation illustrates regression equation:

$Y=20.730 +0.8.2X_1$

**Table 8. Analysis of Variance for regression**

| ANOVA | | | | | |
|---|---|---|---|---|---|
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 461.763 | 1 | 461.763 | 33.408 | .000[a] |
| Residual | 2045.631 | 148 | 13.822 | | |
| Total | 2507.393 | 149 | | | |

**Table 9. Independent variable coefficients**

| Coefficients | | | | | |
|---|---|---|---|---|---|
| **Model** | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
| | **B** | **Std. Error** | **Beta** | | |
| (Constant) | 20.730 | 1.665 | | 12.450 | .000 |
| Efficiency | .802 | .139 | .429 | 5.780 | .000 |

Beta standard coefficients indicate that for one unit change in efficiency variable quality of care changes 0.429.

**Hypothesis 4:** reliability variable with fault tolerance, maturity and recoverability as its sub-characteristics affects quality of care.

As shown in table 10 statistic of Durbin-Watson test is 1.724 which validates independency of errors.

The comparison between error frequency distribution diagram and normal distribution diagram, illustrated that error distribution is normal; thus, linear regression was utilized (figure4).

Table10: Model Summary

| **Model** | **R** | **R Square** | **Adjusted R Square** | **Std. Error of the Estimate** | **Durbin-Watson** |
|---|---|---|---|---|---|
| 1 | .685[a] | .469 | .458 | 3.020 | 1.634 |
| a. Predictors: (Constant), Fault tolerance, Maturity, Recoverability | | | | | |
| b. Dependent Variable: Quality Patient Care | | | | | |

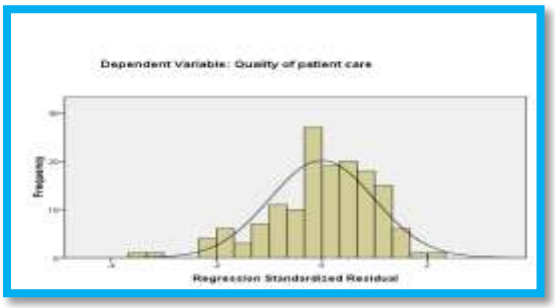


**Figure 4. Comparison between error frequency distribution diagram and normal distribution diagram**

Furthermore, analysis of variance for regression confirmed linear relation between variables. The value of sig was 0 which is less than 0.05 (table 11).

Table 11. Analysis of variance for regression

| ANOVA | | | | | |
|---|---|---|---|---|---|
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 1176.196 | 3 | 392.065 | 43.000 | .000[a] |
| Residual | 1331.198 | 146 | 9.118 | | |
| Total | 2507.393 | 149 | | | |

When the linearity was confirmed constant value and coefficients of independent variables were calculated. These coefficients are shown in table 12 and equation () shows the regression equation:

Y=15.565 +0.915X1+0.763X2+570X3

Table12. Independent variables coefficients

| Coefficients | | | | | |
|---|---|---|---|---|---|
| **Model** | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
| | **B** | **Std. Error** | **Beta** | | |
| (Constant) | 15.565 | 1.348 | | 11.550 | .000 |
| Maturity | .802 | .177 | .350 | 5.162 | .000 |
| Recoverability | .763 | .180 | .325 | 4.250 | .000 |
| Fault tolerance | .570 | .237 | .177 | 2.408 | .017 |

Standard Beta coefficients demonstrate that one unit change in maturity cause quality of care to change 0.350. Additionally, the changes of quality of care for the same changes in recoverability and fault tolerance are 0.325 and 0.177, respectively. Considering the Beta coefficients maturity is the most effective one.

**Hypothesis 5:** Maintainability variable with Analyzability, stability, changeability and testability as its sub-characteristics affects quality of care.

According to table 13 statistic of Durbin-Watson test is 1.609 which validates independency of errors.

Three regression models were proposed. Since sig value for testability and analyzability variables was 0.881 and 0.881, respectively, they were eliminated from regression model and stability and changeability variables remained. The comparison between error frequency distribution diagram and normal distribution diagram, illustrated that error distribution is normal; thus, linear regression was utilized (figure 5).

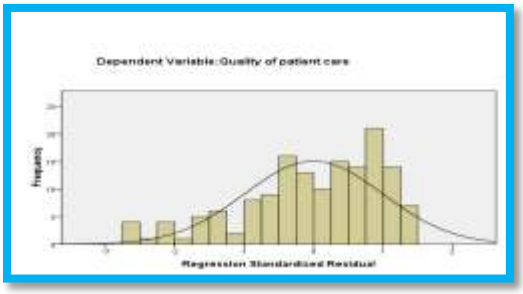


**Figure 5. Comparison between error frequency distribution diagram and normal distribution diagram**

Table 13: Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .247[c] | .061 | .048 | 4.002 | 1.609 |
| a. Predictors: (Constant), q37, q34, q36, q35 | | | | | |
| b. Predictors: (Constant), q34, q36, q35 | | | | | |
| c. Predictors: (Constant), q36, q35 | | | | | |
| d. Dependent Variable: Quality of patient care | | | | | |

Analysis of variance for regression confirmed linear relation between variables. The value of sig was 0 which is less than 0.05 (table 14). When the linearity was confirmed constant value and coefficients of independent variables were calculated. These coefficients are shown in table 15 and regression is as follows:

Y=29.783 +0.577X1-0.480X2

Table 14. Analysis of variance for regression

| **ANOVA** | | | | | |
|---|---|---|---|---|---|
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 152.601 | 2 | 76.301 | 4.763 | .010[c] |
| Residual | 2354.792 | 147 | 16.019 | | |
| Total | 2507.393 | 149 | | | |

Table 15. Independent variables coefficients

| **Coefficients** | | | | | |
|---|---|---|---|---|---|
| **Model** | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
| | **B** | **Std. Error** | **Beta** | | |
| (Constant) | 29.783 | 1.137 | | 26.197 | .000 |
| Changeability | .577 | .234 | .197 | 2.461 | .015 |
| Stability | -.480 | .247 | -.155 | -1.944 | .054 |

Standard Beta coefficients demonstrate that changes in quality of care for one unit change in changeability and stability are 0.197 and 0.155, respectively. Considering the Beta coefficients changeability is the most effective one.

Table 16 presents the summary of tests for five hypotheses. According to this table functionality characteristic has the most significant impact on quality of care (Beta=0.576). Among its sub-characteristics, suitability is the most effective one.

Table 16. Summary of results for five steps of analysis

| Number | characteristics | Subcharacteristics | Standardized Coefficients( Beta) |
|---|---|---|---|
| 1 | Functionality | Suitability | 0.576 |
| 2 | Usability | Operability | 0.239 |
| 3 | Efficiency | | 0.429 |
| 4 | Reliability | Maturity | 0.350 |
| 5 | Maintainability | Changeability | 0.197 |

**Discussion and conclusion:**

Complete and precise maintenance of medical files is the essential part of health care management. Electronic files are tools which play their roles in quality of care in the form of alarms, reminders, criticizers, interpreters, predictors and diagnosis while relying on decision making support systems [4,5]. As a result, evaluation of quality of such softwares must be noticed. The quality of software is assessed by different measures such as response time, precision and accuracy of results, efficiency of user interface and how it matches to users' requirements as well as quality of care which is a multi dimensional and complicated concept. In this study this impact was investigate using regression. It was seen that software quality directly influences quality of care. According to our results, functionality characteristic (which is one of the software quality characteristics) is the most effective characteristic on quality of care. These results may be considered by software designers and managers.

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