Analytic Hierarchy Process based Methodology for Ranking Healthcare Management Information Systems

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Abstract: Ranking of Healthcare Management Information System (HMIS) help practitioners to select the best from the trivial many for the success of the organization. The objective of this study is to rank the CSF of HMIS using a suitable Multi-Criteria Decision Making technique (MCDM). Here, Analytic Hierarchy Process (AHP) is the tool used to determine the relative importance of the CSF in influencing the adoption and use of HMIS. In order to rank the factors, this study is planned and performed in two stages. At the first stage to identify the critical success factors of HMIS, a through literature review is made. At the second stage, a pair wise comparison is designed based on AHP method. The weightage got from AHP can also be used for ranking of various HMIS installations in different hospitals.

Keywords: Critical Success Factors, Healthcare Management Information System, Multi Criteria Decision Making, Analytic Hierarchy Process.

I. INTRODUCTION

Critical Success Factors (CSF) are those measures which have direct bearing on the success of an organisation (Ketelhohn 1998). Every organization has an unique environment, therefore identifying the critical factors of Healthcare Management Information (HMIS) which are common to several such implementations has been the subject of previous studies (Hanafizade and Ghafori 2007). Identifying and ranking the critical success factors in this research propose to give a solution for the ranking of various HMIS installations in different hospitals.

This research aims at identifying CSF for the HMIS implementation. An effective tool is required for identifying and prioritizing relevant criteria and sub-criteria. Analytic Hierarchy Process (AHP), Multi Criteria Decision Making (MCDM) technique proposed by Saaty (1987) is used for ranking in this research. The main strength of this study is the application of a formal method for ranking CSF in HMIS implementation. The presentation about this study is organized as follows. Section 2 presents an extensive literature review on the topic followed by review of methodology as given in Section 3. Analytic Hierarchy Process methodology is briefly dealt with in the Section 4.. Managerial implications and conclusions in Section 5 and Section 6, respectively.

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II. LITERATURE REVIEW

2.1. Healthcare Management Information System

The term HMIS used here is synonymous with Healthcare Planning System and Hospital Information System. Its development dates back to 1960 with its limited domain of use in administration alone. In the late 1970s, big hospitals gradually set up internal information sectors and subsequently, private information companies started to develop information systems with high commercial value which fostered development of the HMIS to its present state (Tsai et al. 2004). The development of the system engulfed healthcare diagnosis, symptoms, cause analysis, healthcare target and measurements. Such systems provide healthcare professionals with the necessary contents, healthcare plans, and additional functions including addition, revision, inquiry and printing (Mehmart et al. 1987). Simpson and Weaver (2005) state that by integration of the hospital system, clinical care and administration in the HMIS enhances the efficiency of the system. Many scholars have adopted different methods to evaluate the efficiency of such systems. Hortman and Thompson (2005) carried out surveys using both questionnaires and forms to identify user's satisfaction and opinion, while Lee et al. (2002) used one-to-one or one-to-many quality interviews to carry out in-depth analysis of the user's opinion about a system. HMIS has been evaluated using questionnaire surveys, in-depth interviews, individual case studies or material collections. The questionnaire method is most widely used one which is generally targeted at user satisfaction and attitudes relevant to demographic characteristics like respondent's age, seniority, education, and satisfaction (Lee et al. 2005, Alquraini et al. 2007). In recent years, the application of HMIS, CSF in its implementation and relevant research results are gaining prominence to improve systems and their performance.

2.2. Critical Success Factors

Critical Success Factors (CSF) can be defined as key areas of performance that are essential for the organization to accomplish its mission. CSF are those relatively few things that must be accomplished for the individual or the organization to be considered successful by important stakeholders. CSF are important to identify and understand because they focus attention on the things that matter most rather than on the trivial things that consume most of the manager's time (Stahl and Michael, 2004). A broad range of factors that can influence the success of HIS have been mentioned in the literature. This section consists of the details of empirical studies carried out previously on success factors area which support the current research theoretically to derive the critical success factors for the HIS. Perceived

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usefulness is the most frequent success factor encountered in the literature (29 studies). Ease of use was the second most significant success factor (17 studies). Attitude has been considered highly relevant in 9 studies, Self efficacy and Training in 7 studies each, top management support in 8 studies and facilitating conditions in 9 studies, System Reliability and Information quality, Service care quality in 5 studies each are all other factors determining the success of HIS implementation. Summary of reviewed articles is shown in Table 1.

Table 1. Summary of Reviewed Articles

CSF related to HIS	Number of studies	References
Perceived usefulness	29	Al Farsi (2006), Connelly et al. (1992), Crowe and Sim (2004), D'Alessandro et al. (2004), Eley et al. (2005), Firby et al. (1991), Galligioni et al. (2009), Hier et al. (2004), Hou et al. (2006), Joos et al. (2006), Jousimaa et al. (1998), Kamadjeu et al. (2005), Keshavje et al. (2001), Kouri et al. (2005), Larcher et al. (2003), Marcy et al. (2008), Magrabi et al. (2007), Martinez et al. (2007), O'Connell et al. (2004), Ovretveit et al. (2007), Pagliari et al. (2003), Pare and Sicotte (2006), Popernack (2006), Pourasghar et al. (2008), Soar et al. (1993), Thoman et al. (2001), Vanmeerbeek (2004), Whittaker et al.(2009), Zheng et al.(2005)
Perceived ease of use	17	Connelly et al. (1992), Di Pietro (2008), Eley et al. (2005), Galligioni et al. (2009), Haynes et al. (1990), Kouri et al. (2005), Likourezo et al. (2004), Ovretveit et al. (2007), Pagliari et al. (2003), Pare and Sicotte (2006), Pourasghar et al. (2008), Pugh et al.(1994), Soar et al. (1993), Vanmeerbeek (2004), Verhoeven et al.(2009), Whittaker et al.(2009), Zheng et al.(2005).
Attitude	9	Eley et al. (2005), Firby et al. (1991), Haynes et al. (1990), Hier et al. (2004), Larcher et al. (2003), Lee et al. (2009), O'Connell et al. (2004), Thoman et al. (2001), Crosson et al. (2008)
Self efficacy	7	Cheng (2003), Firby et al. (1991), Yeh etal. (2009), Torkzadeh et al. (2002), Barbeite et al. (2004), Bedard et al. (2003), Hasan (2003).
Training	7	Barsukiewicz (1998), Cheng (2003), Haynes et al. (1990), Joos et al. (2006), Keshavje et al. (2001), Lai (2006), Marcy et al. (2008)
Management support	8	Haynes et al. (1990), Hou et al. (2006), Keshavje et al. (2001), Kouri et al. (2005), Lapointe (2006), O'Connell et al. (2004), Pare and Sicotte (2006), Travers and Parham (1997)
Facilitating conditions	9	Al Farsi (2006), Haynes et al. (1990), Joos et al. (2006), Jousimaa et al. (1998), Pugh et al.(1994), Soar et al. (1993), Ovretveit et al. (2007), Walji et al. (2009), Cumbers and Donald (1998)
System reliability	5	Connelly et al. (1992), Galligioni et al. (2009), Joos et al. (2006), Kouri et al. (2005), Rahimi et al. (2009)
Information quality	5	Chisolm et al. (2006), Hains et al. (2009) Pugh et al.(1994), D'Alessandro et al. (2004), Lai (2006), 79, 97
Service care quality	5	DeLone et al. (2003), Gillingham et al. (2002), Lu, et al. (2005), Sarker et al. (2005), Varshney (2003)

The present study considers ten factors that were adopted from literature. These include Perceived usefulness, Perceived ease of use, Attitude, Self efficacy, Training, Top management support, Facilitating conditions, System reliability, Information quality and Service care quality. Summary of factors and its definitions are in Table 2 (Venkatesh and Davis, 2000; Venkatesh et al., 2003; Chau, 2001; Goodhue and Thompson ,1995; Igbaria and Iivari, 1995; Bhattacherjee and Hikmet, 2008; Sutirtha Chatterjee et.al., 2009; Seddon and Kiew,1996; Brady et. al., 2002).

Table 2. Summary of factors and the corresponding definitions

Factors	Description of the factor
Perceived usefulness (PU)	The degree to which a person believes that using a particular computer system would enhance his or her job performance.
Perceived ease of use (PEOU)	The degree to which a person believes that using a particular computer system would be free of effort.
Attitude	User's affection, or liking, for HIS and for using them.
Self Efficacy	An individual's perception of his or her ability to use a computer system in accomplishing a job task.
Training	Extent to which an individual has been trained about HIS through courses, training, manuals, and so on
Management support	Top-management support for, and favorable attitude toward, HIS in general.
Facilitating conditions	The adequacy of the deployment of IT infrastructure (such as network, server, and database) in an organization to support job performance and to improve the quality of the users job.

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System reliability	The extent to which the system can be depended upon to complete a task without problems and breakdowns.
Information quality	Degree to which information produced has the attributes of accuracy, format, completeness, understand ability, and report timeliness for the user.
Service care quality	Perception of how a HIS provider delivers the service to user.

III. METHODOLOGY REVIEW

A number of methods have been applied to HIS or other information system (IS) evaluation or selection including ranking, scoring, mathematical optimization, and MCDM analysis. Buss (1983) proposed a ranking approach to compare computer projects. The scoring (Lucas and Moore, 1976) method is intuitive, but too simple to truly reflect opinions of the decision makers. Mathematical optimization such as goal programming, 0-1 programming, and nonlinear programming have been applied to resource optimization for IS selection. Santhanam and Kyparisis (1995) proposed a nonlinear programming model to optimize resource allocation allowing for the interaction of factors; their model considered interdependencies between projects in the IS selection process. Lee and Kim (2000) claimed that Santhanam and Kyparisis' model dealt with IS selection problems with limited criteria. They combined the analytic network process (ANP) and a 0-1 goal-programming model to select an IS project. However, the applicability of these methods is often weakened by sophisticated mathematic models or limited attributes to carry out in a real-world HIS selection decision, especially when some attributes are not readily quantifiable, as well as not too easy for managers to understand. The AHP method, introduced by Saaty (1980), directs how to determine the priority of a set of alternatives and the relative importance of attributes in a MCDP, and has been widely discussed in various aspects. For example, Schniederjans and Wilson (1991) utilized the AHP method to determine the relative weights of attributes and applied these weights to a goal programming model for IS selection. Lai et al. (1999) conducted a case study to select a multimedia authoring system using the AHP method. Teltumbde (2000) proposed a framework based on the nominal group technique and AHP to select an ERP system. Jose et al (2005) used the AHP method to rank critical success factors of executive information system. Loannis et al. (2011) proposes a methodology for creating an evaluation system of the passenger ferry services on the basis of key performance indicators derived through the analytic hierarchy process. But no study is found in the literature which makes use of AHP for ranking CSF of HIS. This has prompted the authors of this research to rank CSF of HIS using AHP.

IV. ANALYTIC HIERARCHY PROCESS BASED METHODOLOGY

AHP is used widely for various ranking applications based on MCDM and the technique is made use of here for ranking various HIS based on user preferences.

4.1 An overview of the AHP

The purpose of this study is to offer a business model framework for HIS. It is typical of such an approach to have decision-making problems with multi-criteria and multi-attributes. One of the optimal approaches to solve such a problem is using AHP (Saaty 1980, 1994, 2008). AHP which is a qualitative and quantitative method, is a useful approach for evaluating the alternatives of complex multiple criteria involving subjective judgment. AHP is a way that could transform complex problems into simple hierarchic structure, such as project screening (Chin et al., Xu, Yang, an Lam, 2008), evaluation of knowledge management (Ngai and Chan 2005) and so on. A decision-maker should determine the weights by conducting pair-wise comparisons between various criteria or among sub criteria.

The main procedures of AHP are to: (i) determine the objective and the attributes of evaluation; (ii) develop hierarchical structure levels with goals, constructs, criteria or sub criteria and the alternatives; (iii) find out the importance of different attributes with respect to the goals.

4.2 A hierarchic framework

According to the AHP steps enumerated as above, objectives and attributes of evaluation have been determined based on reviewed the literature in Section 2, and have identified probable CSF. In order to rank the CSF related with HIS, identified CSF are classified in to four categories. They are Behavioural intention to use, Individual context, Organisational context and System context as summarized in Table 3. The hierarchy frame work is shown in Figure 1.

Table 3. Summary of Factors identified for the study

CRITERIA	SUB-CRITERIA
Behavioural intention to use	Perceived usefulness, Perceived ease of use
Individual context	Attitude, Self efficacy, Training
Organisational context	Top management support, Facilitating conditions
System context	System reliability, Information quality, Service care quality

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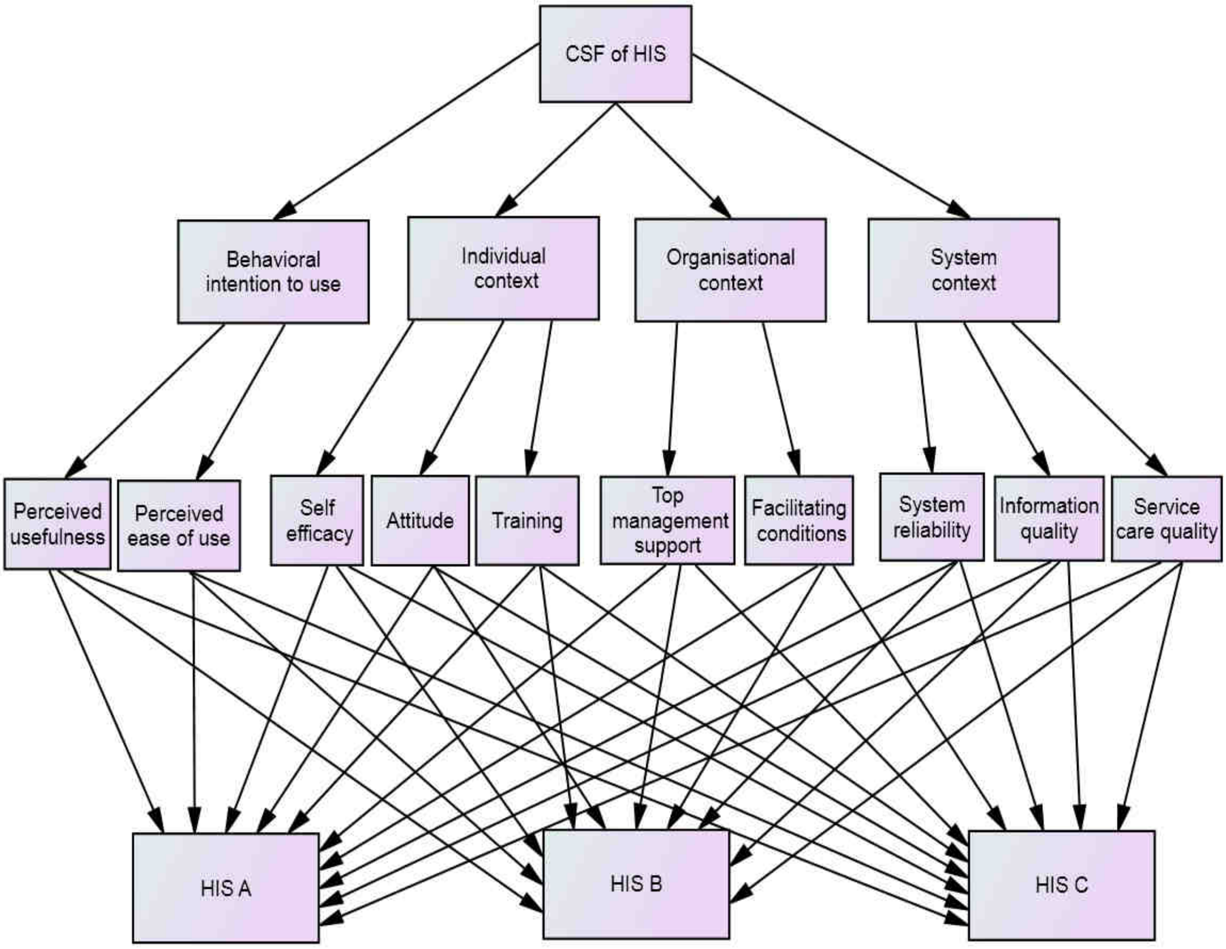

Figure 1. CSF hierarchy model

The highest level with only one element is the goal to reach and the elements in the lowest level are the factors. Elements in the middle levels are the categories/criteria/constructs for evaluating those factors. In this work, the hierarchy of all criteria and sub-criteria were classified into four levels as depicted in Figure 2. At the highest level (Level 1) of the hierarchy are CSF. It is possible to classify the CSF into four major categories, namely, Behavioural intention to use, Individual context, Organisational context and System context. This taxonomy constitutes the second level. The third level shows the specific CSF within each category. Finally, there are four major constructs obtained from ten factors as listed in Table 1. Thus, these constructs and factors had considerable degree of content validity as described in earlier studies. Based on these contents, the definition of each of the probable CSF is as given in Table 2. CSF hierarchic model is given in Figure 2. The first layer is the ultimate goal, the second layer is the main criteria and the third layer is the sub-criteria. Under this framework there are fourteen pair wise comparisons to calculate each factor's weight by AHP. Finally, offer a referential framework for the hospitals to rank different HIS. This is the fourth layer in the hierarchy. The weights for the different criteria obtained by using the analytic hierarchy process method can be subsequently used to rank HIS A, HIS B and HIS C as shown in the fourth hierarchy level.

4.3 Pair-wise comparison matrix

Further details for the AHP process are as follows (Saaty, 1994; Saaty & Vargas, 2000): (a) Constructing a pair-wise comparison matrix with a scale of relative importance. An attribute compared with itself is always attributed to value 1, so all the main diagonal entries of the pair-wise comparison matrix are 1. Numbers 3, 5, 7, and 9 mean moderate importance, strong importance, 'very important', and 'absolutely important'; and 2, 4, 6, and 8 for compromise between 3, 5, 7, 9. If there are m attributes, then the pair-wise comparisons would yield a square matrix as Matrix A, pair-wise comparison is stated as the most effective way to better judgment as only two attributes are only compared at a time (Saaty, 1994) and 1-9 judgment scale has been recommended in the literature (Saaty, 1996). Table 4 shows the pair-wise comparison scale for AHP and its interpretation.

Table 4. Pair-wise comparison table for AHP with interpretation (Saaty, 1996)

Intensity of importance	Definition	Explanation
1	Equal importance	Two attributes contribute equally to the objective

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3	Weak importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed

The results of the comparisons are represented in a pair-wise comparison matrix which is a reciprocal matrix as shown below.

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1m} \\ 1/a_{12} & 1 & \cdots & a_{2m} \\ \cdots & \cdots & & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{1m} & 1/a_{2m} & \cdots & 1 \end{pmatrix}$$

where a_{ij} = the relative importance of criteria i compared to criteria j; $a_{ij} = 1$ where i = j; and $a_{ji} = 1/a_{ij}$ where $i \neq j$. (b) Finding the relative normalized weight (w_j) of each attribute by calculating the geometric mean of the i^{th} row normalizes the geometric means of rows in the comparison matrix. The geometric mean method of AHP is used to find out the relative normalized weights of the attributes because of its simplicity and ease to find out the maximum eigenvalue and reduce the inconsistency in judgments. In Matrix A, the problem involves assigning a set of numerical weights w_1, w_2, ……., w_m to the m criteria a_1, a_2, ……., a_m that reflect the recorded judgments. If A is a consistency matrix, then the relations between weights w_j and judgments a_{ij} would be simply given by $w_i/w_j = a_{ij}$ (for i, j= 1, 2, …….., m). (c) After the formation of decision making matrix, the next step is to identify the priority weights of the elements through the maximum eigenvectors and eigenvalues. According to Saaty (1994), the eigenvectors can be computed as follows. **Aw** can be written as **nw** where n is the number of eigen values or elements and w is the vector of actual relative weights of **A**. Eigen vectors of λ are non zero solutions of **(A-λI)w**=0 where **I** is an identity matrix. Also, **Aw** = λ_{max} **w** where λ_{max} is the largest eigenvalue of A. (d) The consistency of the pair wise comparisons is checked in this step. In the pair wise comparison, the inconsistency is measured by consistency index (CI) and the coherence is measured by Consistency Ratio (CR) and is computed with the help of the formula, CI = (λ_{max} - m)/(m - 1), CR = CI/RI, where, m is the rank of the matrix. The maximum acceptable limit of CR is 0.1 (Saaty, 1994). If the values are more than 0.1 it will highlight that the pairwise comparison is inconsistent and hence, discarded. For different matrix size (m), the respective values of RI are depicted in Table 5. (e) After identifying the priority weights of each element, i.e. local weights of element, the next step is to identify the global weights of all elements with respect to the goal defined in the AHP model. (f) Finally, after calculating the global weights, all the elements are rearranged in the decreasing order according to the global prioritization.

Table 5. Matrix size versus Random Index

Size of the matrix	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Index	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

V. MANAGERIAL IMPLICATIONS

The practical implications of the study are as enumerated below. With the help of this study, the healthcare IS professionals become aware of the existence of CSF in HIS implementation along with their order of importance. AHP helps in quantifying subjective judgments of the users and gives numerical results which can be used by the healthcare IS professionals effectively. Ranking of CSF helps evaluation of HIS implementation in a more scientific way. Using this framework, the healthcare IS professionals will be able to identify the required capabilities and necessary resources in order to attain and sustain competitive advantage by developing more useful and productive HIS. Many times due to the lack of sufficient resources, it is not possible for the healthcare and IS professionals to deal with all CSF at the same time. So, with the prioritization of CSF, the IS developers and healthcare professionals will be able to realize that on which factors they have to work on the priority basis to achieve greater improvements in terms of productivity. Therefore, while designing the improvement plans, this relative importance can be very helpful for the organizations at the time of facing scarcity of resources. This model also can be used by the healthcare professionals for ranking different HIS implementations across different hospitals in a region or across different vendors supplying HIS.

VI. DISCUSSION AND CONCLUSIONS

Based on the exhaustive literature review of success factors for HIS, four categories of success factors are identified. AHP method for ranking critical success factors is used that ensures consistency measure of results. By using AHP which is a multi-criteria decision making technique, some inconsistencies may arise, giving way for reconsideration of judgements and unveiling some unclear thinking regarding

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the assessments of some of the attributes. However, this technique has not traditionally been applied for the analysis of CSF related with HIS. The results reveal the respondents' perceptions about the importance of CSF in HIS. This is a main issue, since it is possible to manage the development process with more information about the expectations of final users. From the analysis of AHP evidences, the study verified that the system factors and behavioural intention to use factors get higher values and ranks than organisational and individual factors. The most important finding that, information quality, perceived ease of use, system reliability and perceived usefulness are higher priority CSF in information systems is verified again here in this study too. The weights associated to these factors are higher than the priority of all the rest put-together. In general, this study confirms that organisational and individual factors are less critical than system and behaviour intention to use factors and is in line with the results found in literature. The weights for the different factors obtained by using the AHP can be subsequently used to rank different HIS implementations as shown in the hierarchy level four. This can be done using different techniques. For example, an index for each HIS implementation can be calculated simply by finding weighted sum of all factors for each HIS, namely, HIS A, HIS B and HIS C. The critical success factors priority scores will be used to weigh the specific value of each factor for each of the different HIS in such comparisons to finalize the index score for comparison between implementations.

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