Research article

Multi-Criteria Decision Support System for Recommendation of Ph.D. Supervisor

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Abstract:

A decision support system (DSS) is a computerized system used to discover determinations, judgments, and courses of action within a business or an organization. In every arena of life, DSS play an important role. In higher education, DSSs are recognized for diverse reasons, for example to conjugate data and intelligence, to pull off the unrivaled and likely interpretations, and to fine-tune decisions under hesitancy. The PhD supervisor selection is itself a very difficult and mind tickling task which makes the student very nervous and sometime make him desperate because he is unable to make the right decision. This work will facilitate the scholars to get proper guidance to make it successful. For the selection of particular supervisor there are some set of criterions which a supervisor should also follow while selecting a particular scholar. Though, the lack of information about the supervisor can hamper scholars in making the selection of the supervisor. Correspondingly, the identification of thought-provoking criteria might be stimulating for potential scholars due to their level of immaturity. Therefore, a system is required which can facilitate scholars in selecting the research work advisors in accordance with the research topic based on multi-criteria like relevancy of the supervisor's research area of interest and the relevance of the publications. In this research effort, a user-friendly conceptual DSS framework has been suggested to recommend the Ph.D. supervisor to scholars in academics. A multi-criteria DSS framework has been proposed for the facilitation of the scholars while selecting their Ph.D. supervisor. This recommendation is based on several criteria of selecting potential supervisor including the area of research interest along with the publications i.e., in journals and conferences in addition to number of Ph.Ds. produced so far. Finally, the publications of the Ph.D. produced so far and the research projects involved. Preliminary results of the proposed work has been discussed along with the future directions.

Keywords: Decision Support Systems, Multi-criterion Decision Support Systems, Supervisor Recommender, Decision Making, Decision Maker, Higher Educations.

1. Introduction

Education can be used as a tool to empower the individual. It is one of the most significant challenges all over the globe and an essential human quality which is a base of the good life and a sign of self-

determination. Education is crucial for the integration of distinct entities that not only offers a platform to succeed, but also the knowledge of social behavior, strength, character, and dignity. Institutions like schools, Colleges, Universities, and academies are struggling to provide quality education to both basic and higher-level classes. The perspective is an all-inclusive state of affairs in which academic institutes are struggling for superior enrollment with each other.

A DSS is an interactive, flexible, computerized framework which intend to facilitate executives in their decision-making activities and is capable of offering personal support for complex, direct and managerial level decisions. A decision support system receives and analyses data then synthesizes the information into reports offering a comprehensive view of the current situation. In this respect, a DSS differs from a normal operational application that is primarily used for data collection. Either a computerized or a human-powered DSS is available as an alternative. In some cases, the two can be used in conjunction with one another [26]. The ideal situation would be for systems to assess data and make decisions on the user's behalf. Human users will be able to make better decisions more quickly as a result of this technology. With any DSS, the fundamental objective for the end-user is to comprehend the information that is being delivered to them [27]. The adaptability of a DSS system enable us to provide a diverse range of reports that are adapted to the specific requirements of its customers. This information may be presented visually, such as in a bar chart displaying expected revenue, or vocally or may be in a written report, depending on the situation. The use of data analysis is no longer limited to big, heavy mainframe computers [6]. DSS programs can be accessed using mobile devices including tablet PCs and smartphones. It is the versatility of the DSS that appeal the users who are constantly on the move. When they have access to all of the information they require, they can make the best decisions possible for their company and their customers without any delay. There are many types of Decision Support Systems while some of them are shown in Figure 1.

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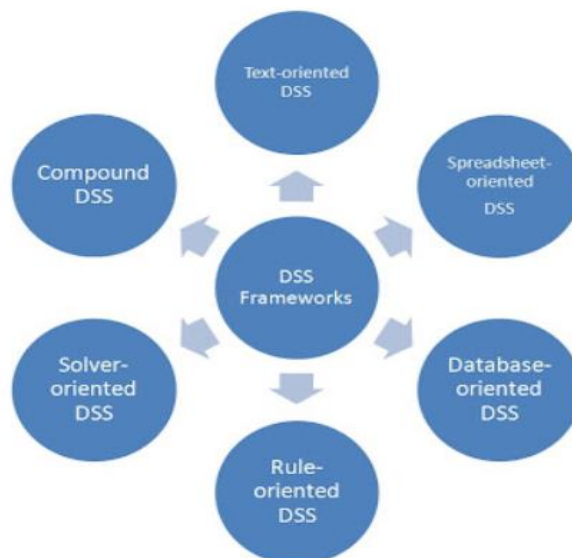
Figure 1: Decision Support System Types

Several DSSs have been developed for decision-makers that have the potential to execute the activities involved in the decision-making process in a very smooth way. DSSs have been used in a variety of different fields in executing the accurate plus proper conclusion. DSS is widely used in agriculture, business organizations as well as in energy sector [4–15]. Several literature and applications have studied approaches and theories related to the decision-making for alternatives including simple to advance, intelligent, and smart systems [16, 17]. For enhancing the potentiality of DSS new approaches for evaluating diverse criteria, suggesting frameworks that are robust and intelligent have been found during the research procedures. Owing to the success of DSS in the decision-making progression, different studies are attempting to devise more reliable, effective, and vigorous mechanisms to solve the current as well as upcoming issues.

An important type of DSS designed to help structure and solve a problem involving a Multi-Criterion Decision Making (MCDM) is called as a Multi-Criteria DSS (MCDSS). These systems are devised to solve decision problems that involve various, and sometimes conflicting, objectives or criteria has been one of the most active and interdisciplinary fields of research in management science and operations research. Such systems allow decision-makers to examine multiple criteria and to incorporate the decision-makers' preferences over these criteria into the analysis. It seeks to support the modeling and structuring of decision problems [28, 29]. MCDSS has a significant role in the decision-making process for a specific situation based on miscellaneous criteria. The transformation of the source code is done for different objectives such as to optimize the efficiency of the source code. Several DSSs are available for making decisions that have the potential for supporting the activities of decision-making and provide solutions for it. In its most essential structure, MCDM expects that a chief should pick among a bunch of options whose goal work values or characteristics are known with certainty [18-21]. Numerous issues in MCDM are formed as various targets like straight, number, or non-direct numerical programming issues, and a considerable lot of the strategies proposed for their answer are intuitive. Decision-making based on multi-criterion is the main issue for practitioners and researchers in the area of academics [30]. Table 1 depicts the list of acronyms used in this article for convenient referencing.

Table.1 List of Acronyms

ANP	Analytical Network Process
DM	Decision Maker
DSS	Decision Support System
MCDSS	Multi-Criteria Decision Making

COPRAS-G	Complex Proportional Assessment of alternatives to grey relations
TF/IDF	Term Frequency/Inverse Document Frequency
MCDM	Multi-Criterion Decision Making
Ph.D.	Doctor of Philosophy
RAKE	Rapid automatic keyword extraction
RAF-E	Research Analytics Framework for Education

Researchers are required to perform studies in order to finish higher education programs like Masters and Ph.D. programs. Students must choose their supervisors based on their field of study and area of research in order to properly finish their research work; this is particularly useful in the computer science arena. Students' success rates in their early stages of research studies are greatly influenced by their choice of most appropriate Ph.D. supervisors. As a result, the student should consider their own areas of interest while selecting a suitable supervisor for their thesis or research projects [31, 32]. In addition, students must be aware of the requirements and their own limitations of any prospective supervisors before beginning their research project. Explicitly, Phillips et al. recommends looking for good responses to at least some of the given questions: "Have they produced research publications recently?" Do they have any research funding or contracts to their credit? Whether or not they are invited to speak at conferences beside from the quality of the journals and conferences where professors generally publish their research progressions.

Consequently, scholars might well take benefit from a DSS that classifies useful standards that directs them while assessing supervisor. There are many types of research on recommender approaches, expert search and collaborator recommendations. They all talk about the problem in selection of supervisors for Ph.D. scholars. A conceptual framework has been proposed in this study for the selection of the appropriate supervisors for Postgraduate students. This conceptual framework is based on the MCDSS. We have identified the different decision variables, which denote the expertise and experience of the potential supervisor for the postgraduate students. These decision variables are including; (1)- area of research interest; (2)- publications (in journals and conferences); (3)- no of Ph.D. produced so far; (4)- publications of the Ph.D. produced so far; (5)- research projects involved. Based on these decision variables most appropriate supervisor will be presented to the postgraduate students, matching their research interests. The decision support framework initially recovers the profiles of the supervisor for the coordination between the students and professors. The framework implements the Analytical Hierarchy Process for the identification of criteria and sub-criteria and TF/IDF that lets the user select the recovery to demonstrate to implement when advising the potential advisors. Scholars can use the framework to discover a list of key advisors using their mutual interests while concerning the publication of the respective supervisor, inquire about grants, and collaborate. At that point to learn approximately their personality and accessibility before

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making the final decision, the student can consult the supervisors, ask about their present and prior scholars, and meet and take courses with them on the off chance that that's a possibility. Therefore, the main contribution of this study are summarized as follow;

1. A comprehensive study on the different approaches to the discovery of the potential supervisor to the postgraduate students to complete their research studies successfully.
2. A conceptual framework for the identification of the potential supervisor
3. Enlisting the different decision variables for the devised decision framework
4. Preliminary results are reported on the developed conceptual decision support framework
5. Comparison of the proposed MCDSS with the existing MCDSS presented in [6]

The remaining part of this article is organized as follows. Related work in the problem domain has been provided in Section 2 while the Section 3 presents a conceptual Multi-Criterion-based framework for the discovery of the supervisor to higher-level studies, Ph.D. Section 4 offers the preliminary results obtained from the conceptual framework.

2. Related Work

This section presents the literature of the current research works related to supervisor selection using DSS.

A recommender system is used for the selection of students' thesis advisors according to their research interest area. To address this issue, the authors purposed a recommendation system for topic conformity to scholars regarding the final allocation of the supervisors who has experience in the research in accordance with the topic of the scholar final assignment or to design a system which can offer supervisory lecturer recommendations in accordance with their research topics. Their study used the TF/IDF method to measure the similarity between two aspects, this will give a supervisor's recommendation to the student relevant topic. They scored an accuracy of 75% in the result by comparing with the data but failed to apply the list of research topics from the perspective of the research supervisor [1].

Since Scholars acquire significant knowledge from their supervisors during their research, selecting a suitable advisor is a key aspect in defining success in the education field. Most existing researchers deal with the matching of objective information but ignore other critical aspects such as subjective personality matching-aided recommendation was introduced to help in supervisor selection. The technique used consisted of objective measurements and subjective personality matching. Different studies are on the selection of supervisors show below in (Table 1). Evaluation of the effectiveness and efficiency of this system by the use of a preliminary study showed promising results. In addition, to validate this should have been carried to validate the approach; a step this study failed to take [2].

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In this research paper, a recommender system is used for the scholars of different criteria when selecting a supervisor relevant to the domain. Supervisors play important role in students' research areas. A Rec Advisor recommender engine is used for students' interest area and give them the most relevant and informative data according to their needs. A rec advisor is a multi-criteria recommender system designed for the data maker to collect information about the supervisor's profile. Profile Analyzer gives a recommendation to a student in their thesis to select an appropriate Ph.D. supervisor [3].

With the immense amount of news available, obtaining relevant data is the need of the hour. Algorithm for the extraction of keywords such as Term Frequency Inverse Document Frequency (TF-IDF), Text-Rank, Rapid automatic keyword extraction (RAKE) has been successfully adopted in social network, text mining, and recommendation frameworks [4]. The paper proposes the use of keyword extraction and keyword scoring for providing news based on specific keywords in a specific time period. The authors propose an experimentally supported study design which demonstrates that given a specified time period, the recommender framework enhances the expected weight of the keyword and the keyword performs successfully. However, extracting and eliminating repeatedly-occurring words, including proper nouns, still requires advance research. In addition to that, the dataset used in this work is relatively limited to political categories.

The research project, based on the use of the Euclidean distance algorithm, helps in the matching of final year scholars with potential supervisors on the basis of areas of interest stated by the scholars. The study was designed to include the following 4 phases: initial preparation, data gathering, data modeling, and recommender engine (below in Figure 2). The project serves the purpose substantially, however, presents a few limitations [5].

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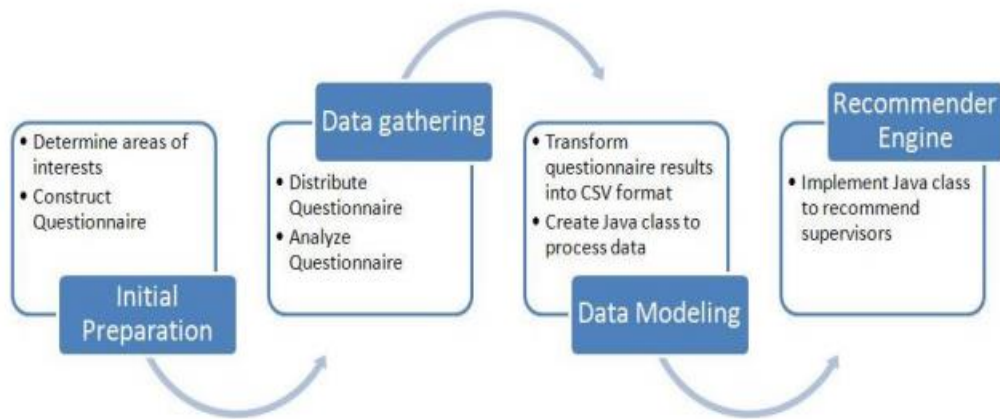
Figure 2: Recommender Engine for making Supervisor Methodology

Research is a scientific work that is required for the achievement of a Ph.D. degree. Advisor or supervisor selection considered as a critical phase must take by a scholars at an early stage in their higher studies for their research work. The selection of the final Ph.D. supervisor is an important factor in students' research work so that scholars can get proper guidance to make it successful. As soon as finalizing about a specific advisor which need to be selected as supervisor, scholar must review the contender using different criteria used for the selection. While selecting a supervisor in past a hectic and mind aching list of process was followed. However, the lack of the data about the advisors can hamper scholars in making the selection of the supervisor. Also, the identification of interesting criteria might be a complex task for prospective scholars due to inexperience. Thus, a system is needed that can facilitate scholars in selecting the research work advisors in accordance with the research topic based on multi criteria like relevancy of supervisor research area with your area of interest or relevancy of their publications to your area of interest. In this regard, to facilitate scholars in Ph.D. a multi-criteria decision support hybrid system has been designed for supervisor selection by recommending them according to their research area [6]. Multi-criteria decision framework will help scholars in making their decisions in supervisor selection for their research work by recommending them supervisors based on several criteria's accurately and quickly.

This paper proposes an approach for defining candidates that can be adjudicated as having similar tendencies based on the cosine similarity graph and clustering between candidates. With the cosine similarity graph used by the authors, the proposed method focuses on the inflection points of graphs when plotting by sorting the cosine similarities in descending order. In vectoring documents using either TF-IDF

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or Doc2Vec, the graph draws characteristic curves; hence, it was found that candidates can be filtered.

$$TF = \frac{No\ of\ occurences\ of\ workds\ in\ the\ Sentence}{Total\ No\ of\ words\ in\ the\ document} \qquad (1)$$

$$IDF = \frac{loglog\ (No\ of\ Documents)}{No\ of\ documents\ containing\ the\ words} \qquad (2)$$

$$TF - IDF = TF * IDF \qquad (3)$$

The equations show that the weight of regularly arising words in a specific document increases the value of TF increases, and the weight of frequently occurring words in a large number of documents decreased by the term IDF. Therefore, TF-IDF with high value given to a word gave more priority as the document characterizes by it [7]. Future direction may include investigating whether this tendency also occurs in other types and for other languages.

Selecting a supervisor for their research or thesis can be a difficult task for scholars and it should be done in a proper manner. The proposed DSS accepts a scholar dissertation proposal and consequently enlists potential advisors in descending order using their relevancy score. It has two phases called indexing and recommending. Their research was done to deal with supervisor selection through recommender system. Recommender system suggest a suitable supervisor according to the relevancy between student's research area and domain of their advisor. Initially, they collect the data and filter the data according to relevant user's profile. Then, a recommender system provides a profiled data of supervisor by their academic publication. The technique uses consisted of using an informative retrieval concept with a cosine similarity and a vendor space model needed. Student's success in thesis is not only depend on the topic matching with potential supervisor but also on the student's skills and their capabilities [8].

The paper proposes a novel efficient hybrid system that concentrates on the user interests and provides more accurate and time-effective results. The hybrid system incorporates four innovative similarity measures: the user interest–user interest similarity measure, user interest–item similarity measure, hybrid similarity measure, and multi-interest–item similarity measure. The paper also proposes solutions to the cold start problem, which arises otherwise due to insufficient user data input in the system. However, the study does offer a few. The proposed similarity measures depend on the existence of a list of user interests. Another shortcoming to these similarity measures is the use of lexical similarity only when comparing user interests with item descriptions. In a few cases, the user- interest may not match terms in an item description

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but could be similar semantically to certain terms [9]. A limitation to the solution to the cold start problem is its performance when both the number of users and the number of used factors is large.

Thesis is a scientific work and a condition that must be taken in order to achieve a bachelor's degree. Thesis supervisor play a vital role in student's research because they have responsibility to ensure that scholar is able to complete their research so that it is ready for testing and quality. In higher education, a system is needed for the selection of supervisor in thesis. The aim is of this study is that the researcher will create a system that can help the Head of Study Program in mentoring according to the field of science, and can reduce the mismatch of the thesis supervisor with the title proposed by the student. So that the lecturer appointed to guide the topic of the title submitted by scholars has a different field of expertise from the student's title. In this determination, there are sometimes less than optimal decisions where the appointed lecturer is not in accordance with the thesis topic proposed by the student. This system is made using the AHP method so that the programmed system can be carried out more effectively. AHP method is one of the methods used in decision support systems with the calculation process by comparing each criterion [10].

The problem of information irregularity that primes scholars in making conclusions just grounded on partial information. A novel approach in this study has been devised aimed at discovering plus endorsing appropriate supervisors for new scholars [11]. There are two stages in the proposed method: filtering stage and ranking stage. This may result in mismatches between scholars and supervisors. In this study, a comprehensive student's centric approach named RAF-E (which is short for Research Analytics Framework for Education), leveraging advantages of content-based techniques and collaborative filtering technique. It consists of three factors, connectivity, relevance and quality. We further enriched the devised DSS within the context of the education and proposed on the basics of the research analysis framework to guide scholars through this process. A two-stage procedure consisting of a filtering stage and ranking stage was carried out to eliminate irrelevant supervisors and choose a compatible supervisor for scholars on the basis of thinking styles and social network connections. The outcome of this study showed that it was satisfactory as compared to other methods. This research, however, did not focus on the quality assessment of candidates.

Zhang and colleagues [10] developed a Research Analytics Framework for Education (RAF-E) to assist incoming postgraduate students in identifying and proposing supervisors. The RAF-E considers indicators from three dimensions: relevance, connectedness, and quality, and is divided into three categories. The results of prior research have led Zhang et al. to present a personality-matching assisted approach to advisor recommendation that incorporates objective metrics (relevance; connection; excellence) with particular character corresponding in order to provide list of adviso. The frequency and proximity of the candidate

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supervisor name to the consumer enquiry and advisor title produced by an underlying search engine are used to score results in the recommendation technique developed in earlier research.

3. Proposed Models for Multi-Criteria Decision Support System

In this section, we have discussed the conceptual framework for the recommendation of the supervisor to the Ph.D. level studies.

In order to suggest supervisors to the postgraduate student for their thesis supervision, we have proposed a conceptual framework using MCDSS. The framework is shown in Figure 3. The proposed approach is used to provide supervisor recommendation services for new research scholars. At the filtering phase, significance dimension is used for selecting potential supervisors through the supervisor's area of interest and match the supervisor and student network connection. It removes irrelevant supervisors through direct matching of a target student with supervisors and indirect matching of the student with supervisors' previous scholars. At the ranking stage, two measurements along with connectivity and quality measurements are calculated. Lastly, these dimensional wills match the similarity measurement on the basics of relevance, connectivity, and quality. Then the final list of the selected ranked candidates will be obtained.

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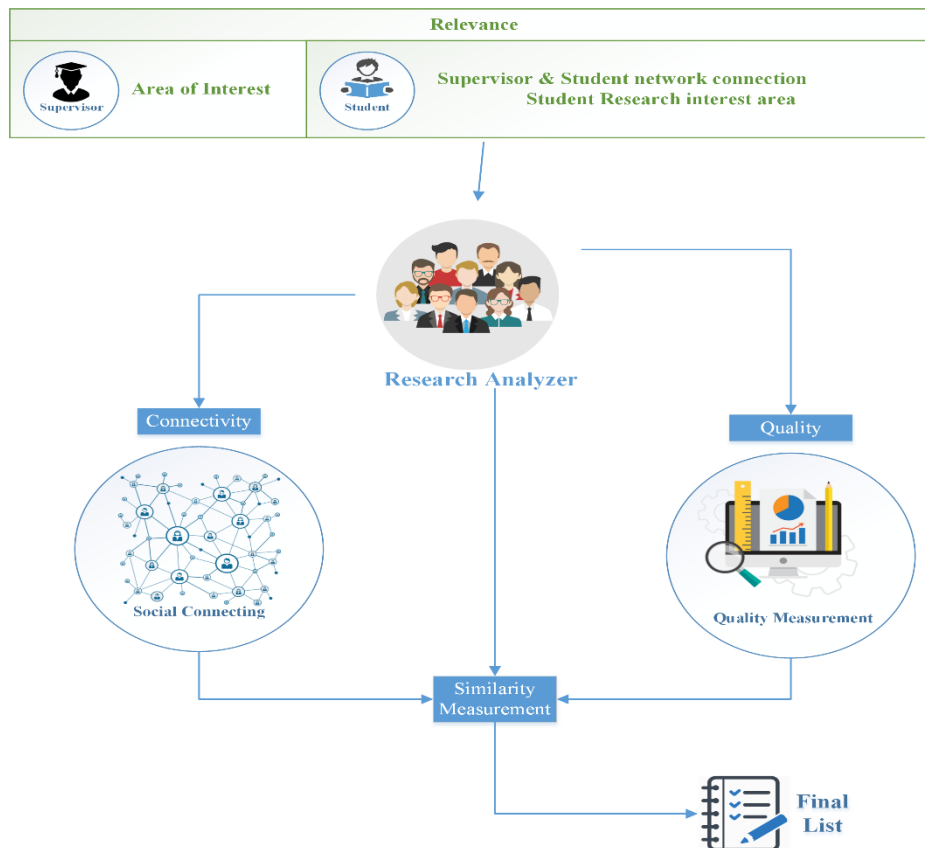
Figure 3: Projected Framework

In the subsequent subsections, the main components of projected conceptual MCDSS framework has been discussed.

3.1 Decision Variables

We have reviewed the different DSS and recommender systems to supervisor selection. From the reviews, as discussed in the Related work section, a comprehensive list of important factors has been build, which will be used as a decision variable in the suggested framework. These decision variables are including;

(1)- area of research interest;

(2)- Publications (in journals and conferences);

(3)- No of Ph.D. produced, shows success rate for producing the Ph.D. so far;

(4)- Publications of the Ph.D. Scholars so far;

(5)- Research projects involved.

The identified decision variables denote the expertise and experience of probable controller for the postgraduate scholars. On the basis of these decision variables most appropriate supervisor will be presented to the postgraduate students, matching their research interests.

3.2 Determining Weights of Different Criteria

This was most critical phase in the development of the proposed MCDSS. However, for preliminary results and simplicity, we have used the weight value for each decision variable as follows: for decision variable Publications, we have assumed weight = 2 for each publication in a journal indexed by Web of Science Group and has impact factor; weight = 1 journal indexed by Web of Science Group without impact factor and weight = 0.5 for each conference publications; for each successful Ph.D. scholar 1 score will be given to the potential supervisor; weight value will be 1 for each publication of the successful Ph.D. scholar of the potential supervisor; finally, we have assumed the weight =1, of each successful completed research project by the potential supervisor.

4.   Result and Discussion

In this Section, we have discussed the dataset collection, framework implementation details along with the preliminary results.

4.1 Implementation

For the preliminary results, we have developed a prototype of the proposed MCDSS. We have used Java programming language using JDK 1.8 and NetBeans version 7.1.1 as a development tool. The code

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was run on the collected dataset. Experiments are executed on a 32-bit Intel Core i7-2600 CPU@3.40GHz machine with 8 GB RAM running on the Linux platform.

4.2 Dataset Collection

For the preliminary results, we have collected a small set of datasets, focusing on the decision variables discussed in the previous section, Proposed Model for Multi-Criteria Decision Support System. Total 85 potential supervisor details from different domains have been collected. Table. 2 shows the dataset details.

Table.2 Details of Dataset for Ph.D. Supervisor Recommender System Based on MCDSS

S#	Designation	Discipline	# of Records
1	Professor	Computer Science/Agriculture	20
2	Associate Professor	Software Engineering/Bioinformatics	25
3	Assistant Professor	Computer Science	40

To collect the details, we have used Google Scholar for retrieving the publication details, authenticity of the journals was verified from the Web of Science Group official web site; we also have collected the detailed resumes from the selected potential supervisors. Detailed resumes of the potential supervisors are analyzed to extract their affiliations, area of research interest, different research funded related project information, listing of the present and information of the successful Ph.D. scholars, and other relevant details,

4.3 MCDSS framework Evaluation

For the evaluation of results by projected MCDSS, various postgraduate students have been requested, total 25, who were going to take in admission in the upcoming semester. Based on their research interest, they were asked to evaluate the proposed MCDSS for the selection of the potential supervisors. In the developed framework, we used the following criteria for evaluating and suggesting the supervisors to the students involved in testing the developed MCDSS. Table 3 depicts the computed results.

Table.3 Proposed MCDSS Evaluation Results

S#	Matched Level	# of Students	% Matched
1	Perfectly Matched	17	68
2	Patial Matched	6	24
3	Mismatched	2	8

In Table 3, out of 25, 17 students when used the proposed MCDSS, they retrieved the results according to their manual selection. There were 6 students, who feedback that their selection and computerized DSS

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selection was partial matched. However, the reasons for the partial match was that they were only selected their supervisor based on the publication record without considering any significance of the type of the journal where they potential supervisors have published their article. Further, they also have no knowledge about the research grants and research funded projects of the too. Final, two students were unable to get their matching supervisors as per their manual selection, this was due to the comprehensive list of the decision variables used in the proposed MCDSS.

Further, we have also have evaluated our proposed MCDSS with the MCDSS proposed by Hasan and Schwartz [6]. The computed results are given in Table 4.

Table.4 Proposed MCDSS Vs MCDSS [6]

S#	Approaches	Matched Level		
		Perfectly	**Partially**	**Mimatched**
1	MCDSS [6]	11	13	1
2	Propsoed MCDSS	17	6	2

In Table 4, the comparative analysis of the proposed MCDSS and the MCDSS suggested in [6]is described. Results shows that proposed MCDSS offered more accurate supervisor recommendation to the students as compare to the MCDSS proposed by Hasan and Schwartz in [6].

Therefore, the proposed MCDSS proved to be very supportive for the scholars in the discovery and selection process of a Ph.D. advisor.

5. Conclusion

In this research study, we have presented a multi-criteria DSS for scholars for advisor choice, used for the explained information about domain of scholar research area. The proposed DSS discovers the potential supervisors using a list of different identified factors relevant to the potential supervisors. We collected a list of 85 supervisors, their related published articles, research grants and research funded project details, their present and successful Ph.D. candidates. We have authenticated the journal type from the Web of Science Group official web site. Further, we assigned different weights to the different discovered decision variables. The prototype was implemented in Java and tested using 25 students, where we noticed that 17 of them extracted fully matched supervisor's recommendation. Furthermore, we have also compare the proposed MCDSS with the existing MCDSS, showing that the proposed MCDSS perform well by suggesting the best match for the potential supervisors to the students. In future, we are aim to build more comprehensive supervisor list diverse field of studies.

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