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Multi-Criteria Decision Analysis in Diabetes Mellitus: A Systematic Literature Review

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ABSTRACT

Decision-making process for diabetes patients is crucial and requires careful attention since it will impact the patient's safety and overall quality of care. There are many criteria that should be considered by the doctor or healthcare practitioners in making the decisions which make it more difficult for them. Therefore, a standard mechanism should be taken to ensure the consistency of the judgement for diabetes management. Multi-Criteria Decision Analysis (MCDA) is one of the approaches that can be used to produce a precise judgment with multiple factors. The aim of this study is to conduct a Systematic Literature Review (SLR) to examine the MCDA studies in diabetes mellitus domain which until now has been understudied. From 35 studies, further investigations were conducted in terms of the criteria for decision-making process, Multi-Criteria Decision Analysis (MCDA) techniques and evaluation techniques employed in the diabetes mellitus management. This study can be a fundamental reference for researchers, medical doctors and healthcare practitioners in diabetes mellitus management. In addition, researchers in MCDA also can benefit from this study to further improve the technique by incorporating the criteria to ensure that it can assist the decision-making process in diabetes management.

Keywords:

Multi-criteria decision analysis; Diabetes mellitus; Systematic literature review

1. Introduction

Malaysian National Diabetes Registry (NDR) reported that almost 1.7 million patients were registered in the registry, and by the end of the reporting year for 2020, there were 902,991 active diabetic patients in the NDR, of whom 99.33% had been diagnosed with Type-2 Diabetes Mellitus (T2DM). In addition, 0.59% are patients with Type-1 Diabetes Mellitus (T1DM) while others are reported 0.06%. Female patients were the highest population with 57.02% while male were 42.98% with diabetes [1]. The reported statistics are frightening, and the medical doctors or health

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practitioners are required to give the best advice and treatment plan to ensure that patient's safety and overall quality of care are preserved. There are multi factors that should be considered by medical doctors or health practitioners when it comes to advice and treatment either pharmacology or non-pharmacology perspectives. It is a difficult and complex decision-making process because each decision made will have significant impact on the patient's life and future.

Since decision-making process is important in the diabetes mellitus domain, a proper technique is required to ensure the smooth process of making the decision and at the same time it should be fast. This is because the medical doctors or health practitioners need to examine many patients in one day and each patient has unique health issues that correlate to diabetes disease. Knowledge and experience are essential in making decisions. However, a suitable technique is still in demand when making complex decisions to ensure that vagueness element can be reduced. Multi-Criteria Decision Analysis (MCDA) is one of the approaches which can be used or support the difficult and complex decision-making processes [2]. Therefore, an investigation of the MCDA approach in the diabetes mellitus domain should be done to understand the current scenario of multi-criteria decision-making process in this domain. The aim of this research is to present the SLR report based on the evidence found pertaining to the MCDA approach in the diabetes mellitus domain. The remainder of this paper is organized as follows: Section 2 describes the methodology employed in conducting the SLR. Section 3 presents the results, and the final section concludes our research work.

1.1 Multi-Criteria Decision Analysis (MCDA)

The goal of Multi-Criteria Decision Analysis (MCDA) is to make decisions better when there are conflicting objectives [3]. Kepner and Tregor are key people who formularized the problem-solving and decision-making process since 1965 which later in year 2000, the decision analysis step was rebranded as MCDA [4,5]. Multi-Criteria Decision Analysis (MCDA) is a method that supports complex and difficult decision-making processes in any area [2]. The decision-maker must consider a number of factors before coming up with a compromise answer. The criteria used in the decision-making process are too complicated for the decision-maker to come up with an optimal or best solution. Before they can decide anything, they must deal with a number of processes, for example, consider the prioritization process, conflicting objectives, decision types, stakeholder preferences, domain issues, and many more [2,6,7]. If there is no strategy plan used to make the final decision, the outcome of this tedious and long process may be questioned.

The MCDA method can be used to enhance the current methods for making decisions, which are ad hoc which is frequently rely on the preferences of the decision maker [2,8]. The disadvantage of the ad hoc approach is the credibility of the produced decisions since the strong evidence or justification are lacking. In contrast, with MCDA method, the process of producing the decisions has its own rationale, transparent and can be justified in more systematic ways [2,9]. Numerous techniques, such as the Analytical Hierarchy Process (AHP), Analytic Network Process, Multi-Attribute Utility Theory (MAUT), Multi-Attribute Value Theory (MAVT), and others, can be employed in the MCDA process and hybrid MCDM [2,10,11]. In the healthcare domain, an MCDA framework was developed by Inotai *et al.,* [12] for off-patent pharmaceutical tender decision-making. The framework consists of seven criteria for assessment. A study conducted by Nutt *et al.,* [13], used MCDA modelling to assess the drug harms which can notify the policy makers in health, policing and social care on the misuse impact and improve the drug classifications. The MCDA modelling involved with sixteen criteria in order to assess 20 drugs.

2. Methodology

A guideline from Kitchenham *et al*., [14] and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [15] were used to conduct the Systematic Literature Review (SLR). SLR is a well-established method in gathering evidence with systematic and transparent processes. It can be done with a wide variety of domains, not only in computing but also in other fields like building and planning [16], education [17], cognitive research [18] and many more. There are few steps in conducting the SLR which were described in detail in the sub sections 2.1 until 2.4.

2.1 Research Questions

The purpose of this study is to investigate the MCDA approach in the diabetes mellitus domain by using the SLR technique. Therefore, there are three research questions developed that are in line with the purpose of this research. The research questions and motivation are tabulated in Table 1.

Table 1
SLR Research Questions and Motivation

Research Question	Motivation
RQ1: What criteria from the MCDA studies were applied for decision support in the diabetes mellitus domain?	To identify the possible criteria of diabetes mellitus that have been used by other research studies in the MCDA which can support the decision-making process.
RQ2: What MCDA technique have been applied in diabetes mellitus domain?	Researchers and practitioners can identify the MCDA techniques that have been used so far in the diabetes mellitus area.
RQ3: What evaluation techniques employed?	The evaluation technique to verify or validate the MCDA techniques can be known by the researchers and practitioners.

2.2 Search Strategy

The search string was created based on the keywords which are Multi-Criteria Decision Analysis and Diabetes Mellitus. A pilot study was conducted several times to ensure that the created search string is appropriate to find the relevant studies. The created search string that was used for search strategy was ((“Multicriteria Decision Analysis” OR “Multi-Criteria Decision Analysis” OR MCDA) AND Diabetes). This search string was used in the five online databases which include IEEE Xplore, ScienceDirect, Springer Link, PubMed and ProQuest (Article). The rationale of selecting these online databases is because the journals area covers the healthcare and the computing topics.

2.3 Study Selection

This study adopted the PRISMA method in selecting the relevant studies for further investigation which are the identification, screening, eligibility and inclusion stage as illustrated in Figure 1. The first stage for the study selection is the identification. Based on the search string determined for this study which later was used in the five online databases, results obtained were 545 studies. The results were recorded in the Excel spreadsheet and Mendeley for future analysis and presentation. The next step is the screening process whereby the records were removed based on the duplication found and the irrelevant studies after screening the title and abstract.

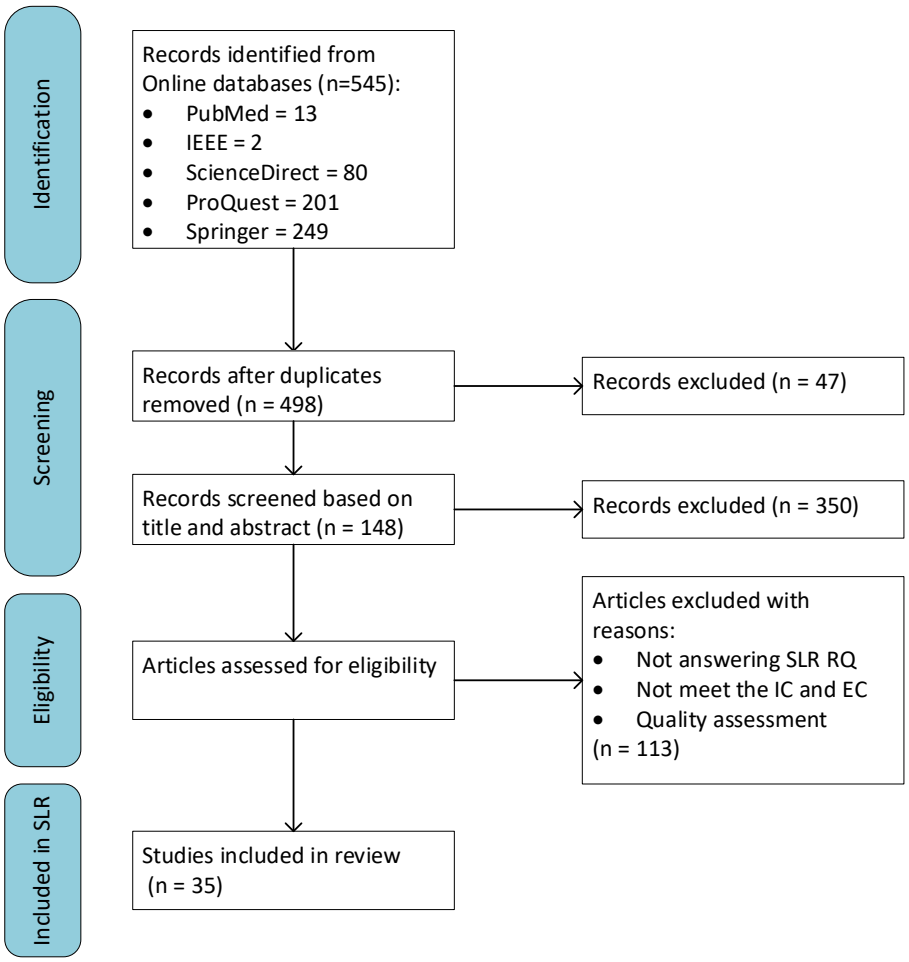

Fig. 1. Processes in Study Selection

After conducted the screening stage, a total of 148 articles were brought to the eligibility process. In eligibility process, careful examination according to the SLR research questions, Inclusion Criteria (IC) and Exclusion Criteria (EC) as well as quality assessment was conducted. In this stage, the final 35 articles are eligible for full text examinations and to record evidence based on the determined research questions. The IC and EC used in this study were outlined in Table 2.

Table 2
Inclusion and Exclusion Criteria

Inclusion Criteria
IC 01 – Studies that are related to MCDA and diabetes mellitus.
IC 02 – Articles have answered the research questions.
IC 03 – Refereed articles from journals and conferences.
IC 04 – Research articles with findings.
IC 05 – Articles fully written in English language.
Exclusion Criteria
EC 01 – Studies that lies outside MCDA and diabetes mellitus.
EC 02 – The full text of the articles is not available.
EC 03 – The type of articles is irrelevant for example, editorial paper, short paper, poster and others.
EC 04 – Articles that are written besides English language.

In order to ensure the quality of the selected studies, a quality assessment of the research was done based on these questions:

i. Is the aim of the research clearly stated?
ii. Is the research methodology described clearly?
iii. Are the findings reported clearly?
iv. Is the article refereed?

Each question can be scored in one of three ways: "yes" receives one point, "partially" receives 0.5 points, and "no" receives zero pints. These scores were referred to a study conducted by Zakaria *et al*., [19] and Abd Khalid *et al*., [20]. During the study selection, a total of 36 studies were identified for further assessment.

2.4 Data Extraction

In this study, a structured data extraction table was used to systematically extract relevant and useful information from the selected studies for ease of evidence synthesis and presentations. The essential data extracted from the selected studies are:

i. title
ii. author
iii. publication year
iv. type of publications
v. abstract
vi. criteria
vii. MCDA technique
viii. Evaluation techniques. The extracted information was kept in the Excel spreadsheet.

3. Results

3.1 Overview

The final 35 articles were eligible for further assessment after selection process was conducted that adopted from the PRISMA guidelines. Figure 2 shows the number of publications per year that was selected for this study. Only one publication selected in the year 2007, 2012, 2017 and 2021. There are two publications eligible to be included which were published in year 2010, 2011, 2013, 2015 and 2016. The peak publications regarding the MCDA and diabetes were in 2019 with 8 publications. For year 2018 and 2020, the number of publications were 6 and 7 respectively. The trend of publications is declined drastically after year 2020.

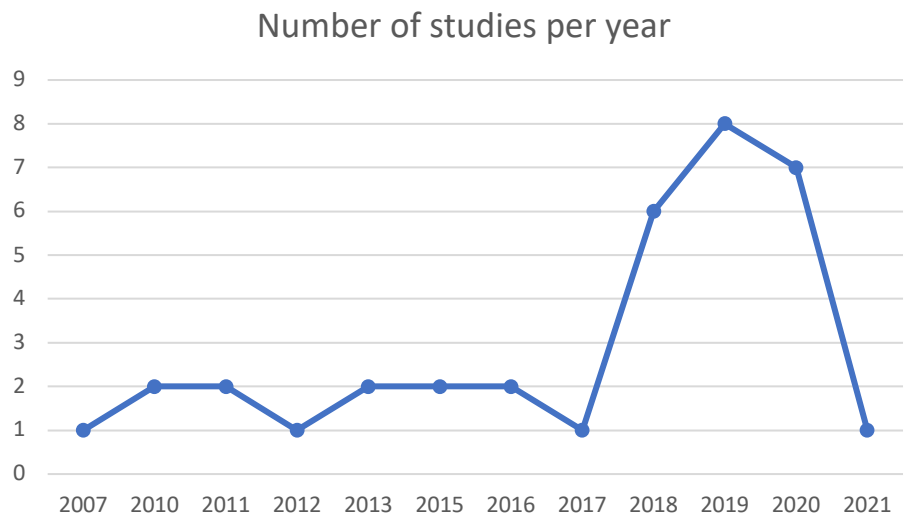

Fig. 2. Number of Publications

3.2 Criteria in Diabetes Mellitus from MCDA Studies

3.2.1 What criteria from the MCDA studies were applied for decision support in the diabetes mellitus domain?

This study attempts to identify what are the criteria used by other studies in the MCDA works for diabetes management. Out of 35 studies, there are 16 research works have outlined the input or criteria that they used in the MCDA according to their research purposes. There is several decision-making pertaining to diabetes mellitus for example the dietary, treatment personalization, therapy, social support and many more. There are 101 criteria that were identified from the 16 research articles. The list of the criteria is tabulated in Table 3.

Table 3
Criteria used in MCDA for Diabetes Mellitus

Source	List of Criteria
[21]	user height and weight heart rate burned calories daily physical activity level daily food intake expert's knowledge such as food composition tables and food's exclusion criteria
[22]	emotional support informational support tangible support
[23]	patient preferences disease outcomes medication efficacy and safety profiles
[24]	HbA1c Reduction Fracture Weight change GI symptoms Severe hypoglycaemia CHF Acute pancreatitis Bladder cancer

[25]	Efficacy (HbA1c reduction) Risk of fracture weight gain G1 symptoms Acute pancreatitis Severe hypoglycaemia CHF Risk Risk of bladder cancer Cost Patient preference (non-injectable)
[26]	Limb Amputation Blindness Influenza and Pneumonia Glucose Control Disparity Cardiac Diabetic Prevalence Renal Failure Mortality
[27]	Designing a personalized treatment, (medication_time) Patient preference (times_per_day, pills_per_day, number_of_medical_visits, medical_visits_duration, treatment_duration) Medical Inst. preference (drug_cost, laboratory_test_cost, RX_study_cost, medical_visit_cost, hospitalization_cost)
[28]	Relevance to multi-morbidity non-redundancy Preference independence Operationalizability Sensitivity to short-term intervention effect
[29]	convenience pain risk duration cost
[30]	Possible hypoglycaemia Adjustment of long-term blood glucose level risk of genital framework possible weight change risk of urinary tract infection risk of gastrointestinal problems additional healthy life years additional cost
[31]	hypoglycaemic events glycated haemoglobin (A1c) weight loss mental health functioning glycaemic stability cardiovascular health
[32]	System criteria Educational module Activity tracking module Medication reminder module Meal recommender module

[33]	disease severity unmet needs comparative efficacy / effectiveness comparative safety / tolerability comparative patient-reported outcomes comparative cost consequences-cost of treatment comparative cost consequences-other medical costs quality of evidence opportunity costs and affordability
[34]	Reduce HbA1c Risk of fracture Weight gain GI symptoms Severe hypoglycaemia CHF risk Acute pancreatitis Risk of bladder cancer
[35]	Scale of disease household financial impact of disease health equity cost-effectiveness multimorbidity burden
[36]	Efficacy Safety Cost Organizational impact Economic impact

3.3 MCDA Techniques Applied in Diabetes Mellitus

3.3.1 What MCDA techniques have been applied in diabetes mellitus domain?

The aim of this research question is to identify what the MCDA techniques are used by the researchers in conducting their studies. As we know that there are various techniques in MCDA that can be used for decision-making process as tabulated in Table 4. Most of the studies (12 studies) implemented the general MCDA technique in their research. This involves identification of multi-criteria, alternatives, stakeholder, weight and performing the weighting process.

One study has used TOPSIS as a single technique in the MCDA while another five studies extend or combined TOPSIS with other decision techniques for example AHP, WSM and PROMETHEE. By identifying the current techniques used by other researchers, we are able to identify what other techniques that still not used and further research works can be done to find the advantages and disadvantages of that techniques.

Table 4
MCDA Techniques Employed in Diabetes Mellitus

Source	MCDA Technique
[21]	AHPSort
[22]	Analytical Network Process (ANP)
[23]	Unified treatment decision support tool
[24,34,37]	Analytical Hierarchy Process (AHP)
[25]	Hybrid Multi-Criteria Decision Making (MCDM) Model step-wise weight assessment ratio analysis (SWARA) and modification of fuzzy multi-objective optimization on the basis of a ratio analysis plus the full multiplicative form (FMULTIMOORA)

[27,28,33,35,36,38-43]	General MCDA
[44]	Neutrosophic TOPSIS
[45]	The Fuzzy PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations)
[41]	Improved AHP and TOPSIS
[46]	PROMETHEE II-based Single-Layer Perceptrons (SLP)
[47]	Integrated multi-layer for analytic hierarchy process (MLAHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)
[48]	TOPSIS Single-Layer Perceptrons (SLP)
[49]	Intuitionistic Fuzzy Set
[50]	Fuzzy DEMATEL (Decision-Making Trial and Evaluation Laboratory)
[51]	AHP and TOPSIS
[52]	Weighted Sum Method (WSM), PROMETHEE and TOPSIS
[53]	PROMETHEE-based single-layer perceptron (PROSLP)
[54]	ANP-based classifier with Genetic Algorithm (GA)
[55]	PROAFTN

3.4 Evaluation Techniques

3.4.1 What evaluation techniques employed in the MCDA?

To address this research question, the selected articles were examined to identify if they have described the evaluation techniques that they employed in the studies. The evaluation techniques applied in the MCDA are outlined in Table 5. Case study and experimental evaluation are the most evaluation techniques employed in the MCDA research studies. Other than that, evaluation techniques such as cognitive interview and process evaluation, perform sensitivity analysis, TOPSIS evaluation, feedback survey and group discussion were conducted. Most of the studies employed only one technique for the evaluation purposes. However, there is one study that combined more than one technique to conduct the evaluation whereby the techniques are group discussion and feedback survey.

Table 5
Evaluation Techniques Employed in MCDA

No.	Source	Evaluation Technique
1	[21,38,56]	Case study
2	[24]	Cognitive interview and process evaluation
3	[25]	Perform sensitivity analysis
4	[27,32,44,46-48]	Experimental evaluation
5	[28]	Perform sensitivity analysis
6	[29]	Evaluate using TOPSIS
7	[51]	Feedback survey
8	[34]	Group discussion and feedback survey

4. Conclusions

The aim of this study is to review research works that have been done in MCDA in the diabetes mellitus domain. We have conducted the SLR method whereby a systematic searching, screening, classification and synthesis of the relevant studies were done. We have attempted to answer the research questions pertaining to the:

i. criteria that have been used for decision support in diabetes mellitus
ii. techniques in MCDA applied in diabetes mellitus domain

iii. evaluation techniques employed in MCDA. In this study, we included 35 studies that fulfil our selection criteria and relevant to answer the research questions. All studies included in our review were journal papers started in year 2007 until 2021. The highest number of publications were identified in year 2019 with eight publications which after that the studies were declined until year 2021. In year 2018 and 2020 the studies included in our review were six and seven respectively. Publications were stagnant in year 2010, 2011 and in three consecutive years in 2013, 2015 and 2016. Least publications were identified in year 2007, 2012 and 2017.

There were 101 criteria identified in the included studies which have used it as a decision support in diabetes area. From these criteria, it can be seen that they can be categorized in terms of treatment decisions in pharmacology or non-pharmacology. For MCDA techniques used in diabetes domain, there were 20 studies used single techniques while another 11 studies used hybrid. To name few of the single technique are AHP, general MCDA, ANP and Unified treatment decision support tool. Example of the hybrid techniques are hybrid MCDM and AHP and TOPSIS. The final research question in this review is the evaluation technique employed in MCDA. We found that most of the studies used experimental evaluation (six studies) and the second highest was case study with three studies. There were two studies used hybrid evaluation techniques which were cognitive interview and process evaluation, and group discussion and feedback survey.

Our review may support the medical doctors, health practitioners and researchers to understand the trends in diabetes area and MCDA. Meanwhile, researchers in MCDA may benefit to identify the gap found from this review especially the employed technique. For future work, we are going to validate and categorized the criteria identified in the relevant studies with experts in the diabetes management. In addition, further analysis will be made to identify the suitable technique to be used to develop a model to support the decision-making process that used the MCDA approach in diabetes domain.

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