Multi-criteria as decisions

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Abstract. Multi-criteria derived from features have become character objects. When measurements are made of them by weighting methods, each criterion is a decision. Thus, criteria as object behavior may be static or dynamic. As a decision, multi-criteria require analysis and modeling to become an optimal decision. Various models and methods of finishing are available but require special attention. Therefore, this paper describes the relationships between them briefly. However, when each criterion is a decision, then modeling of multi-criteria is a decision, the use of the different methods and the results are also as a decision.

1. Introduction

Each object from the information point of view consists of features [1]. Features form criteria and then become variables with the relationship forms an equation based on measurement [2]. Some features do not change, but there are changes based on the importance of using the object. On the one hand, features shape the behavior of objects [3]. Otherwise, some other behaviors change features [4]. Therefore, the measurement of feature behavior is by gives weight, and based on that weight gives a decision, that is, a criterion [5]. When interests change, features will also change, and behave dynamically [6]. Static and dynamic problems, therefore, accompany criteria. Static and dynamic always deal with multi-criteria. On the other hand, the various features of an object will initiate problems in optimization [7], which affect the industrial world and the world of trade [8, 9].

The method for analyzing the features to become a decision variable is a necessity in expressing the criteria as a decision [10]. However, the method for resolving the relationship between the criteria is also important to have a decision outcome [11]. If there is a decision model, the method adapts to the model. This paper will review the relationships between criteria, models and methods. Criteria are a decision, the model is also a different decision, and the choice uses the method of a decision and produces a decision.

2. A Review about definitions

A decision is a suitable choice and optimally made to implement [12, 13]. Making the right decision is the first step towards success, and it considers the alternatives [14]. Therefore, every decision depends on the right amount of information [15]. Choice in this case is more appropriately identified in alternatives, that is, a thing that depends on different actions, hypothetically different in the character of a feature, or a different set of features, and other things [16]. Decisions are choices among those alternatives.
Alternatives formed from the characters of the object in which they become the target of industrial activity or production [17]. It is a criterion. The term “criteria” is the plural form of criterion. A criterion is a basic entry of a decision that can be measured and evaluated in the form of quantitative or qualitative [18, 19]. Thus, a correct decision naturally does not depend on emotion or is subjective [20]. There is a close relationship between criteria and decision [21], namely that a decision is related to evidence of the best balance between all selected criteria [22, 23]. Such criteria require a way of choosing, and it depends on the decision. Therefore, as a result, the criteria are of two types, namely factors and constraints: The factor is a criterion that is more in the position of various suitable alternatives based on consideration. The first consideration is the link flow at equilibrium. The second consideration refers to importance. The third consideration is the number of pairs of origin-destination relations as a place of service [24]. In short, factors are the main alternative. Alternatives that become a criterion become useful variables in expressing evaluation in decision-making [25]. Thus, in mathematical programming literature, factors as decision variables [26, 27], or in linear programming literature as structured variables [28]. Constraints are restrictions on alternatives that are being considered [29]. Constraints exist because of more than one criterion for an item requiring various objects [30]. Constraints like this are often stated as goal [31] or target [32]. The goal is to optimize one metric while respecting the constraints on other metrics [33, 34]. In the interim, the target is the way to forming a share of resources. That is by following the metric of the object in the decision [35]. However, both forms of constraint have the same final meaning.

In simple terms, objects such as chairs, for example, require boards and nails. Suppose chair type I requires \( a \) cm\(^2\) boards and chair type II requires \( b \) cm\(^2\) boards, while chair type I requires \( c \) nails and chair type II requires \( d \) nails. Available boards are \( n_1 \) cm\(^2\). Available nails are \( n_2 \) pieces. In simple terms, there are two criteria, namely chair type I represented as \( x_1 \), and chair type II expressed as \( x_2 \). Constraints formed on the availability of raw materials for boards and nails. In simple terms, the linear equation is

\[
\begin{align*}
ax_1 + bx_2 &= n_1 \\
cx_1 + dx_2 &= n_2
\end{align*}
\]

where \( a \leq n_1, b \leq n_1, c \leq n_2, \) or \( d \leq n_2 \). The solution to linear equations can be done through algebra when factors balance occurs, i.e., the number of variables expressed is equivalent to the number of rows. However, there are many features of the object which give rise to different criteria. For example, chairs like it are with the addition of different raw materials, such as Jepara furniture. Besides, the design or demand for an object with multiple features involving the information space \( \Omega \) may influence and augment that criterion. It is what is meant by multi-criteria. Multi-criteria is two or more sustainability assessment selection of the best alternatives based on different weights, by using a more effective and systematic way, and for solving uncertainty phenomena [36, 37]. However, these features need to be continuously consideration as additional alternatives that influence the decision.

3. A Review of Methods
Eq. (1) is a model for the distribution of resources based on criteria. Each formula has a procedure or procedure for a decision to exist. The procedure by which the criteria combined to arrive at the assessment. Then it carried out also an analysis. It is known as the decision rule. Decision rules will be more complicated when dealing with information spaces, where multi-criteria play an active role in determining decisions. The decision rules typically provide procedures for combining all weighted criteria. Therefore, with various models, Eq. (1) can change into a choice function or choice heuristic, as revealed in many kinds of literature. The role of the choice function offers a variety of multi-criteria compositions.
Namely linear programming [38]. In general mathematical, linear programming is for finding solution to a multi-criteria \( x = (x_1, x_2, \ldots, x_n) \) as maximization function of \( a_{r,1}x_1 + a_{r,2}x_2 + \cdots + a_{r,n}x_n \) for all \( r \) as maximization objectives, or as minimization function of \( a_{s,1}x_1 + a_{s,2}x_2 + \cdots + a_{s,n}x_n \) for all \( s \) as minimization objectives, and satisfy \( a_{r,1}x_1 + a_{r,2}x_2 + \cdots + a_{r,n}x_n (\leq, \geq, =) b_t \) for all \( t \) as goals, and where \( x_1, x_2, \ldots, x_n \geq 0 \). By revealing that the variables representing the criteria take only integers, linear programming has another approach. That is a model known as integer programming by insisting on carrying out the following [39].

Optimize

\[
\sum_{j=1}^{n} c_j x_j
\]

subject to

\[
\sum_{j=1}^{n} a_{ij} x_{ij} \leq b_i, i = 1, 2, \ldots, m
\]

where \( c_j \) are constants or values, \( x_j \geq 0 \) for \( j = 1, 2, \ldots, n \), and \( x_j \) integer-valued for \( j = 1, 2, \ldots, p \leq n \). When \( p = n \), for all variables, the model in Eq. (2) and Eq. (3) is a pure integer-programming. Otherwise, the model is a mixed programming problem [40]. Let \( r_k(d) \) be the reward for making decision \( d \) at stage \( k \), \( t_k(s,d) \) be the new state when the old state is \( p \), the stage is \( k \), and decision is \( d \), with choice \( r_k(d) = 0 \) if \( d \) is "do not grant" or \( r_k(d) = c_k \) if \( d \) is "grant", and \( t_k(s,d) = s \) if \( d \) is "do not grant" or \( t_k(s,d) = s - c_k \) if \( d \) is "grant" where \( s \) is state at stage \( k \). It is the key to dynamic programming [41], which is to a problem that has not a solution in linear programming. In other words, in state \( s \) at stage \( k \), all decisions arrive at state \( s \), where in mathematics it express as \( P(k, s) = \max \{ d \in D_k(s) | r_k(d) + P(k+1, t_k(s,d)) \} \) where \( D_k(s) \) be the set of possible decisions.

The development of a multi-criteria formulation in the form of a matrix depends on making the decisions. Apart from the above models, the goal programming model provides decisions in different ways [42].

Suppose that all variables in bold are a matrix representation. For vector-maximum problem with maximize \( Z = Cx \), where \( Z \) is a fixed matrix, subject to \( Ax \leq b \) and \( x \geq 0 \), there is the minimum lexicography of

\[
a = \{g_1(\eta, \rho), \ldots, g_K(\eta, \rho)\}
\]

where \( K \) is number of priority levels \( (1+S) \), and \( S \) is number of original objectives. Subject to \( Ax + n^{(0)} - \rho^{(0)} = b \) where \( n^{(0)} \) and \( \rho^{(0)} \) are deviation variables associated with the original set of rigid constraints, \( Cx + n^{(S)} - \rho^{(S)} = z^{(0)} \) where \( n^{(S)} \) and \( \rho^{(S)} \) are deviation variables associated with the original set of objectives, and \( z^{(0)} \) is aspiration levels associated with the original set of objectives,

\[
x, \eta, \rho \geq 0.
\]

Eq. (4) to Eq. (5) to be the linear goal programming [43].

In the data age, the point of view on objects, including the interests of clients, or different partners, is continually evolving. Ordinary characters may change, namely, get distorted by information, or maybe replaced with other characters. These characters are revealed from the features of the object recorded with them in the information space, and furthermore, it is possible to raise them through measurements, for example, by involving AHP [44]. There are several methods for weighting, namely Entropy [45, 46], Pair-Wise Comparison [47, 48], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [49, 50], Simple Multi-Attribute Rating Technique (SMART) [51, 52], Analysis Hierarchy Process (AHP) [53, 54], SIMOS [55, 56], Combination Weighting [57, 58], SWING [59, 60], or other [61, 62]. Meanwhile, to perform analysis involves, for example, the Weighted Sum Method (WSM) [63, 64], the Weighted Product Method (WPM) [65, 66], or other [67]. Several methods can have implementation as a weighting method, analysis method, or the synthesizing method [68], see Table 1.
Table 1. Category of ranking methods for multi-criteria.

| Streams       | Methods       | Streams       | Methods       |
|---------------|---------------|---------------|---------------|
| Categories:   |               | Categories:   |               |
| Subjective    | SMART(ER)     | Elementary    | WSM           |
|               | SWING         | WPM           |               |
|               | SIMOS         | Synthesizing  | AHP           |
|               |               |               | TOPSYS        |
|               | Pair-wise     |               | others        |
|               | comparison    |               |               |
| Objective     | Entropy       |               |               |
|               | TOPSYS        |               |               |
| Combination   |               | Vertical and  |               |
|               |               | Horizontal    |               |

Figure 1. (A) Classification of the multi-criteria models. (B) Graphical approach to model of linear programming.

4. A discussion for searching the methods
Every model of mathematical programming and operations research is a logical analysis of all decision problems considering criteria [69, 70]. Based on the measurement of each criterion, the model formed the following two categories with the least abstract or the most abstract, see Fig. 1(A). The features which become physical characteristics according to the measurement are a bit abstract to give birth to a physical model, whereas in contrast, it involves an abstract model [71]. These two categories classified into two parts, namely static models and dynamic models. Essentially, a model that considers the impact of change
is dynamic otherwise is static [72, 73]. The model then develops into a linear and non-linear depending on
the objective so that based on the interests, there are stable models, others are also unstable.
Among the features of an object, when they are variable, their relationship is not
always linear [74]. However, all solutions ask for the convex nature of functions. Thus, in changing
the criteria which results in a nonlinear relationship the function \( f(x) = 1, 2, \ldots, m \) of the \( n \) variables \( x = (x_1, x_2, \ldots, x_n) \) [75]. Criteria are the results of decisions based on ranking methods, but in analysis and systems,
one criterion and another criterion may have a relationship [76]. Therefore, it is always convex. Convex
function \( F(x) \) as stated in \( f(x) \) [77], the convex program is to minimize \( F(x) \) with constraints \( f_i(x) \leq 0 \) and
\[
x \geq 0.
\] (6)
The last equation states that constraints have limits. When Eq. (6) is not present, \( x \) be unrestricted. If \( F(x) \) and \( f_j(x) \) is not convex, it means concave, the minimization problem will be the maximum \( F(x) \) with the
constraint \( f_j(x) \geq 0 \).
The relationship between several criteria may be non-linear and expressed in equations for the sake of
equations that form factors or constraints [78]. Suppose that \( C \) is the \( (n \times n) \) symmetric coefficient matrix,
\( n \)-vector variables \( x \) and \( x' \) are scalar multiplication of row vectors, \( x'Cx \) is a quadratic [79]. Let \( F(x) \) be the
quadratic function \( Q(x) \) as follows
\[
Q(x) = q'x + x'Cx
\] (7)
where \( C \) is also a semidefinite, and \( q' \) is a coeffiencts matrix of \( x \). Suppose
\[
f_j(x) = a_j'x - b_j.
\] (8)
Where \( a_j' \) is the coefficient matrix. By involving linear constraints based on Eq. (8) namely \( a_j'x - b_j \leq 0 \)
where \( x \geq 0 \), then the basic model of a quadratic program is to minimize Eq. (7). Quadratic programming is
the basis of non-linear programming involving multi-criteria [80]. The solution, however, involves
increasingly complex approaches.
Linear programming consists of factors and constraints, which allow it to have a dual form. That is
converts maximization to minimization and vice versa. The dual form of linear programming also converts
rows into columns and vice versa in constraints. A home industry with limited workers makes two \( A \) and \( B \)
downstream products from raw paper towels over several hours of work and work procedures: cutting,
folding, and packaging. A product \( A \) takes 10 minutes to cut, 5 minutes to fold, and 1 minute to pack. A
product \( B \) takes 6 minutes to cut, 10 minutes to fold, and 2 minutes to pack. The time capacity available
each week is 2,500 minutes for cutting, 2,000 minutes for folding, and 500 minutes for packaging. The profit
for product \( A \) is 23 IDR, and the product \( B \) is 32 IDR. A decision model is a linear programming which
mathematically expressed as maximizing
\[
23x_1 + 32x_2
\] (9)
subject to
\[
10x_1 + 6x_2 \leq 2, 500
5x_1 + 10x_2 \leq 2, 000
x_1 + 2x_2 \leq 500
\] (10)
In two-dimensional graphs, a method to obtain optimal results, see Figure 1(B). However, the features of an
object change according to the wishes of its users or stakeholders. For example, the market requires a
product \( C \) with different criteria, that is, it takes 2 minutes to cut, 5 minutes for folding, and 2 minutes for
packaging but the time available is still the same according to the available labor. The profit earned is 18
IDR. The model is maximizing \( 23x_1 + 32x_2 + 18x_3 \) subject to
\begin{align}
10x_1 + 6x_2 + 2x_3 &\leq 2, 500 \\
5x_1 + 10x_2 + 5x_3 &\leq 2, 000 \\
x_1 + 2x_2 + 2x_2 &\leq 500
\end{align}

(11)

It adds variables to linear programming [81]. When the variable increases, the graphical solution cannot be done anymore. On that basis, other methods emerged, such as the simplex method [82], Karmakar’s method [83], and others [84]. On the other hand, production problems always related to discretization, in this case, integer programming. The model of Eq. (9) and Eq. (10) yields $x_1 = 185.7$ units and $x_2 = 107.1$ units with a profit of 7,700 IDR. Changes to output in integer programming require the addition of constraints. First add $x_1 \leq 185$, which makes $x_1 = 185$ units and $x_2 = 107.5$ units with a profit of 7,695 IDR. Second, change the limit of $x_1$ to $x_1 \geq 186$, there is the result of $x_1 = 186$ units and $x_2 = 106.7$ units with a profit of 7,691.3 IDR. There is still a product number $x_2$ which is not an integer. Next, for the constraint $x_1 \leq 185$ and add the constraint $x_2 \leq 107$, which confirms $x_1 = 185$ units and $x_2 = 107$ units, but makes only profit 7,679 IDR. By changing the constraint $x_2$ to $x_2 \geq 108$, the profit will be bigger, which is 7,688 IDR. The next option is to specify that for the constraint $x_1 \geq 186$ by adding the constraint $x_2 \leq 106$, where $x_1 = 186$ units and $x_2 = 106$ units, the profit is less than 7,688 IDR, that is 7,670 IDR. Meanwhile, for $x_2 \geq 107$ represents no feasible solution. The decisions are $x_1 = 184$ units and $x_2 = 108$ units. This decision involves the branch-and-bound method [85].

Although the multi-criteria modeling pattern in non-linear programming has similarities with linear programming, there are dual, for example. However, settlement methods evolved differently from attempts to linearize them. Among them are (i) Beale’s method is a method of extending simplex in linear programming, which is particularly suitable in computing [86]; (ii) Wolfe’s method is a method for completing a quadratic program using the simplex algorithm with a trivial modification [87]; (iii) The Hildreth and D’Esopo method is an asymptotically related method of solving a quadratic program [88]; (iv) The Theil and Van de Panne method is a method that uses a system of equations that filled with constraints (strictly definite) [89]. Besides that, some methods developed from the principle of optimization, namely gradients [90].

5. Conclusion
An object has a fixed feature and a change feature. The features form the criteria by which one has a relationship. The relationship reflected in factors or constraints. Changes in features can take place dynamically. Therefore, the relationship model is either static or dynamic. All of this has to do with decisions. The features of an object can add depending on stakeholder interests. So too are the relationships between those features and then the decision models. Therefore, the model can be linear programming, integer programming, goal programming, or non-linear programming. Likewise, the method of solving it adapts the problem as the criterion adapts features to the variables, and all of that is a decision.

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