Application of Multi-Criteria Decision-Making Methods for Human Resource's Task Scheduling in Multi-Sided Platforms

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Abstract

The Multi-Sided Platforms (MSPs) play the role of the matchmaker between customers and service providers (i.e., two main entities of each MSP). To maximize the MSP's service rate, in this research, by prioritizing the tasks offered to the service providers, it has been tried to propose a new scheduling plan using the results of PROMRTHEE, ANP, ELECTRE methods integrated by using the Ensemble ranking method. Furthermore, to investigate the efficiency of the proposed method, a real-life case study and several comparisons with the different dispatching rules, such as Longest Processing Time (LPT), First-Come-First-Served (FCFS), and Shortest Processing Time (SPT) are studied.

Keywords

Task scheduling, Human Resources, Multi-Sided Platforms, Multi-Criteria Decision-Making.

Introduction
Multi-Sided Platforms (MSPs) have been formed to be the matchmakers, which connect two or more independent users (Abdelkafi et al. 2019). That is, MSPs bring together the demands of many groups of consumers who are interconnected in some way. MSPs must account for interactions between the needs of several groups of consumers when developing pricing and investment strategies. In principle, the best price for customers on one side of the platform is not determined by a markup formula like the Lerner condition, and pricing does not follow marginal cost. When consumer groups are linked by interdependent demand and a platform acts as an intermediary, it internalizes the associated indirect network externalities, resulting in platform competition (Poniatowski et al. 2021).

The more electronic markets grow, the more MSPs go under the spotlight of researchers (McIntyre and Srinivasan 2017). To address different problems in this field, several valuable pieces of research have been done, a few of which will be investigated in the following paragraph:
Using blockchain technology, Yu et al. (2021) proposed a financing strategy analysis for MSPs. They studied the effectiveness of MSPs by designing an analytical model to coordinate four actors, including customers, MSP, banks, and multiple transportation service providers. By applying optimization models, de Matta et al. (2017) modeled an MSP to study price competition and revenue/cost-sharing. Lehmann et al. (2021) presented the application of MSPs in healthcare systems with a case study. Tan et al. (2016) described the role of MSPs in information technologies by investigating Alibaba.com as a real case study. Campbell-Kelly et al. (2015) analyzed the role of smartphones in MSPs. They provided real case studies of Apple and Google's mobile companies and showed their relative success after using MSPs.
Multi-Criteria Decision-Making (MCDM) techniques are among the most well-received techniques to solve problems in which several different objectives have to be taken into account (Goodarzi et al. 2022; Alipour-Vaezi et al., 2021; Mohammadnazari et al., 2022). MCDM can be used in several various fields and industries and will help the Decision-Makers (DMs) to reach a more rational decision by considering the knowledge and opinions of experts (Tavakkoli-Moghaddam et al. 2020; Goodarzi et al. 2022; Mohammadnazari et al. 2022). This leads these techniques to overcome uncertainties and reach reliable results (Alipour Vaezi and Tavakkoli-Moghaddam 2020; Bari et al. 2022). MCDM techniques have been used for systems' scheduling beyond counting, but in the following paragraph, a few of the most recent studies in this field will be discussed:

Kumar et al. (2021) developed a workflow scheduling algorithm benefiting from an MCDM technique to minimize the makespan, cost, and energy. Nayak et al. (2020) applied an MCDM technique and presented a task scheduling method for cloud computing to reach better resource utilization. Also, Alhubaishy and Aljuhani (2020) used MCDM techniques to prioritize and schedule tasks in a cloud environment according to the customers' preferences. Afshar and Zenozi (2021) proposed a new MCDM approach to evaluate and schedule the construction projects of the contractors.

As one of the main applications of MCDM is on prioritizing the options; Mohammadnazari and Ghannadpour (2021) proposed a hybrid MCDM approach for the identification of the best place for warehouse construction. Mamoudan et al. (2021) presented a methodology for insurance companies to find the weights of insurance companies' charges, and thereafter they found the importance of variables that influence companies' costs Mohammadnazari and Ghannadpour (2018) worked in a special field of construction supply chain management using the TOPSIS method, in this wise they discussed the success rate and possibility of construction success.

Objectives
However, to the best of our knowledge, no precedent study investigated the role of MCDM techniques in scheduling an MSP's project. Therefore, this study has been established to propose a new application of MCDM to pave the way for MSPs by scheduling their projects. Four accurate MCDM methods will be used in this research and their integrated results will be compared with the classic dispatching rules.

The rest of the article is organized as follows. In Section 2, the problem considered in this research tries to resolve and describes comprehensively. Section 3 explains the proposed methodology and Section 3 investigates the real-life case study. Section 5 conveys the results alongside a valuable discussion. Section 6 devotes a few comparative studies to investigate the efficiency of the proposed method. Finally, Section 7 provides a concise conclusion.

1. Problem Description

As an electronic market, MSPs have been intensively popular in recent years (Saaty 1986). However, the management problems in this field are rarely addressed. One of the problems that these markets are encountering is the efficient time management of their agents. That is, MSPs need to develop an effective scheduling plan for their agents to maximize their service rate (Alipour-Vaezi et al. 2021).

In each MSP at least two entities are involved: the customer and the service provider. Customers send their requests upon receiving a service, and the platform suggests the proper service provider. Customers search for a specific service, and the MSP helps them to find the proper service provider (usually using recommendation systems). The main question here is if the MSP receives several requests from their customers about a service provider, in what order, and based on which plan the system should respond. In another word, the problem is proposing an efficient scheduling plan to maximize the utilization of the service providers' time and the system's service rate.

It has to be mentioned that in this research it has been assumed that there is no predefined priority for customers in the MSP system. That is to say, there are no VIP customers in the investigated MSP system.

2. Methodology

In this section, the task scheduling methodology will be proposed. As has been mentioned before, different MCDM techniques will be employed to prioritize the tasks for service providers of an MSP to maximize their utility rate. In MSPs design one of the main objectives that designers follow is that they try to recommend the best and most appropriate tasks to the service providers to facilitate the process of scheduling and fasten the aforementioned process. Figure 1 depicts a summary of the proposed methodology.

The criteria extracted based on the literature and interviews for the tasks' importance identification are summarized in Table 1. Based on the criteria, three MCDM techniques, including Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Analytic network process (ANP), and ÉLimination et Choix Traduisant la REalité (ELECTRE) are applied to present the ranking for tasks' importance in an MSP. It has to be mentioned that all three above-mentioned MCDM techniques have been comprehensively introduced in Appendixes I to III.

In the second step of the proposed methodology, the results of PROMRTHEE, ANP, and ELECTRE will be integrated using recent MCDM techniques named Ensemble Ranking which has been developed by Mohammadi and Rezaei (2020).

In the final step of the proposed methodology, After the integration of the results and determining the tasks' priorities, an efficient scheduling plan will be designed and the tasks will be proposed to the service providers based on it.

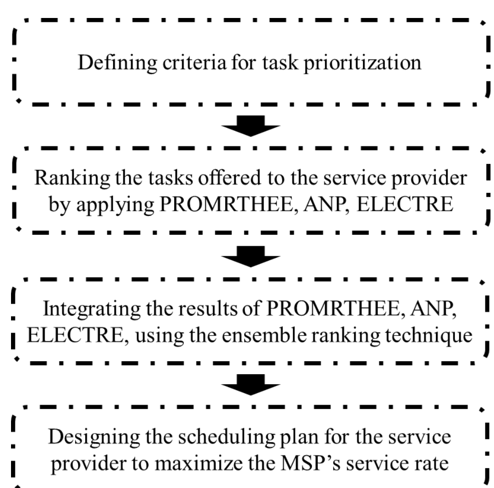

Figure 1. Summary of the proposed methodology

It is worthwhile to note that identifying and ranking the tasks are based on several criteria. Criteria are extracted based on surveys that have been conducted with the great help of experts in this field of research. The criteria in this regard can be found in Table 1.

Table 1. Criteria for finding tasks' importance

Criteria	Notation	Description
Service provider's distance to the place	C1	The distance that service providers should travel to reach the place.
The salary for a specific task	C2	The wage that is assigned to a service provider for task completion.
Previous feedback from the customer	C3	In some cases, a service provider has had experience with some customers, and the level of satisfaction from some customers is significant.
The relevance of the task to service provider expertise	C4	How relevant the task is to service provider expertise

3. Real-Life Case Study

The application of the proposed methodology is delineated in this section using a real-life case study, and the results and managerial insight are explained thereafter. Our implication of the methodology is related to one of the MSPs in Iran named Ostadkar. In this MSP company, customers search for a certain service (plumbing, house cleaning, auto mechanics, nursing, etc.), and after finding their desirable math, they send their request to receive the service. As it is obvious, for Ostadkar DMs, it is essential to develop an optimal scheduling method with which the customers receive their services as soon as possible. For instance, consider a situation where several customers have sent their request to receive a service from a certain serviceman. The problem that needs to be solved here is the serviceman's tasks scheduling.

Although this platform receives hundreds of service requests during a day, here we investigate the tasks assigned to one random service provider as an example. The service provider under study has received nine different tasks (J1-J9) for one of their shifts. Table 2 shows the details of each task. It has to be mentioned that the order of receiving tasks has been depicted by its notation's number (J1 and J9 are the first and last tasks respectively). Furthermore, the expert's opinion about the criteria defined in Table 1 has also been listed in Table 2.

Table 2. Summary of the investigated case study

Task	Processing Time (minutes)	C1	C2	C3	C4
J1	29	1	5	5	3
J2	67	5	3	9	7
J3	15	1	3	1	1
J4	45	1	9	5	5
J5	43	5	1	7	3
J6	27	7	7	9	1
J7	51	5	7	3	5
J8	31	9	1	7	9
J9	36	3	3	5	1

Numerical Results

In this section, first, the importance of each task will be identified using three MCDM methods, including PROMRTHEE, ANP, and ELECTRE. This research benefitted from General Algebraic Modelling System (GAMS) software in a Microsoft Corei5 Laptop with 2.6 GHz and 8 GB RAM to solve the problem.
The ranking results of the PROMRTHEE, ANP, and ELECTRE based on the criteria identified in Tables 1 and 2 are listed in Table 3.

Table 3. Tasks' ranking using MCMD methods

ELECTRE		ANP		PROMRTHEE	
Alternative	Rank	Alternative	Rank	Alternative	Rank
J9	1	J7	1	J1	1
J6	2	J4	2	J8	2
J1	3	J9	3	J9	3
J8	4	J3	4	J5	4
J4	5	J8	5	J6	5
J2	6	J1	6	J2	6
J5	7	J2	7	J4	7
J7	8	J5	8	J3	8
J3	9	J6	9	J7	9

Based on the Table 3 results, the aggregation process will be started using the Ensemble ranking approach by Mohammadi and Rezaei (2020). The results of the integration process have been shown in Table 4.

Table 4. Results of the integration method

Alternative	Rank
J9	1
J8	2
J1	3
J6	4
J7	5
J2	6
J5	7
J4	8
J3	9

Using the Ensemble ranking approach, we emphasize two factors: (i.e., the confidence index and the trust level). These two characteristics are important indicators of the aggregation method's validity. The confidence level in this case study is 0.828, with a trust level of 0.861. We may deduce that the MCDM techniques have similar rankings since the factors are high. The second argument that can be drawn from this is that Ensemble ranking will provide the average result in this scenario. This is because the HQ functions in this case follow the Euclidean norm. Another thing that readers should be aware of is the fact that the number of outliers (i.e., alternative rank) is lower than in other circumstances where the confidence index and trust level are not as high.

One of the most important factors for evaluating scheduling plans is the mean completion time ($\bar{C}$) (Braune et al. 2022). For the scheduling plan determined by the proposed method and listed in Table 4, this factor would be equal to 188.22 minutes.

4. Comparative Studies

One of the most commonly used methods for task scheduling is using dispatching rules. In this section three dispatching rules, including Longest Processing Time (LPT), First-Come-First-Served (FCFS), and Shortest Processing Time (SPT), will be employed for extracting the scheduling plan and comparing them with the results of the proposed method. Table 5 shows the investigated dispatching rules (Alipour-Vaezi et al. 2022). Based on this table, the scheduling plan of the service provider's tasks and the mean completion time ($\bar{C}$) for each plan would be as listed in Table 6.

As mentioned before, the $\bar{C}$ was 188.22 minutes for the proposed method. Although it is relatively higher than STP and FCFS dispatching rules but using the proposed method has considered the customers' priority of receiving services. This results in a higher level of customer satisfaction.

Table 5. Investigated dispatching rules

Dispatching Rules	
FCFS	First-come-first-serve
SPT	Shortest processing time first
LPT	Longest processing time first

Table 6. Scheduling plan of each dispatching rule Scheduling plan

FCFS	SPT	LPT
J1	J3	J2
J2	J6	J7
J3	J1	J4
J4	J8	J5
J5	J9	J9
J6	J5	J8
J7	J4	J1
J8	J7	J6
J9	J2	J3
$\bar{C} = 169.66$	$\bar{C} = 155.11$	$\bar{C} = 227.11$

5. Conclusion and Managerial Insights

Among applied methods, the ANP (Analytical Network Process) is similar to the AHP (Analytical Hierarchy Process) method, except that there are relationships and correlations between decision criteria and decision options. The AHP is a special case of the ANP method. This method was also presented by Saaty (1986). The network analysis method allows the decision-maker to build a network instead of a hierarchy. This also makes it possible to examine the internal relationship between the elements. The nodes in this network are equivalent to the criteria and options and the branches that nodes connected are also equivalent to the degree to which they are interdependent. Determining the relationships in the network structure or determining the degree of interdependence between criteria and options is the most important task of network analysis. The ANP is one of the best and most complete multi-criteria decision-making methods. If there is an internal relationship between the elements of the network structure, this method provides far better and more accurate answers than other multi-criteria decision-making methods. In another way, the application of the ELECTRE has two main parts: first, the construction of one or more non-rank relationships, the purpose of which is a comprehensive comparison between the two actions (pairwise comparison). Second, a method of exploitation is provided to describe the proposals obtained in the first stage. The nature of the proposals depends on the issue under consideration: selection, ranking, or sorting.

Compliance with Ethical Standards:

Ethical approval: We confirm that all the research meets the ethical guidelines, including adherence to the legal requirements of the study
country.

Funding: No funding is received by this study.

Conflict of Interest: The authors declare that they do not have any conflict of interest of other works.

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Appendix I: ELECTRE-III

Let us say we want to evaluate choices A and B and decide which is the superior option. Electrification is a process that does not need compensation. Non-compromising procedures are usually divided into two parts. Outranking is the first stage, and exploitation is the second. We want to evaluate if option A is superior to option B in the first phase. In the second stage, we try to figure out what they like.

To do so, we must first look at the structure of preferences within the ELECTRE family. P,I,R signify the structure of preferences in the ELECTRE. The issue is that we strive to separate superiority from superiority. We state that option A is preferable to option B during the procedure under discussion. When we arrive at a decision, however, we employ the word preference, implying that choice A is better to option B. Equations (A-1, 2, 3, and 4) depict this preference structure, which we shall discuss. Option A is superior to option B, as shown in Equation (A-1), while option B is not superior to option A. As a result, option A is selected above option B (Mohamadghasemi and Hadi-Vencheh 2021).

$$aSb \,\&\, not\ bSa,\ ie,\ aPb \text{ (a is strictly preferred to b)} \tag{A-1}$$

Equation (A-2) shows that option B is superior to option A, and option A is not superior to option B. As a result, option B is strictly preferred to A.

$$bSa \,\&\, not\ aSb,\ ie,\ bPa \text{ (b is strictly preferred to a)} \tag{A-2}$$

Equation (A-3) shows that both Option A is superior to Option B and Option B is superior to Option A, so Option A and Option B are equivalent or indifferent to each other.

$$bSa\ and\ aSb,\ ie\ ,aIb \text{ (a is indifferent to b)} \tag{A-3}$$

Equation (A-4) shows that neither option A is superior to option B, nor is option B superior to option A. This relationship does not mean that the two options are indifferent to each other, but it does mean that the two options are not comparable.

$$not\ bSa \,\&\, not\ aSb,\ ie,\ aRb \text{ (a is incomparable to b)} \tag{A-4}$$

When there is not enough information regarding an issue's alternatives, we can add one or more criteria to the options. Adding one or more criteria to the mix may be enough to solve the problem.

Problems that can be addressed with the ELECTRE should contain at least three and no more than thirteen criteria. It is also preferable if the criteria are diverse or have a precise numerical value. Each criterion in the ELECTRE is compared to itself.

The ELECTRE technique is based on two criteria being calculated. The distinction between the ELECTRE kinds arises from the specification of these two requirements. For example, let us imagine we wish to compare choices *A* and *B* and say whether option *A* is preferable to option B, we must consider the following two conditions:

- **Concordance**. This condition tells us that to show the superiority of option A over option B, we must show the concordance of this pair. Let us show the set of evidence that shows the superiority of option A over B.
- **Non-discordance.** In this condition, we gather evidence that speaks of the superiority of option A over B.

These two requirements imply that choice A must first satisfy the concordance criterion before it can be considered better to option B. That is, we have proof that choice A is preferable to option B. Second, there is no proof that Option A is better than Option B. Option A is therefore preferable to Option B. The goal is that the criteria have a total weight of one.

Another aspect to consider is the absence of a veto. We obtain the disadvantages in the non-discordance circumstance. If an alternative surpasses most of the criteria but not in a vetoed criterion, that criterion might veto the supremacy of all criteria when criteria are vetoed. Equation (A-5) illustrates this.

$$g_j(b) - g_j(a) \le v_j \qquad \text{(A-5)}$$

This relationship illustrates that option A is preferred to option B as long as the veto criterion difference between the two alternatives does not exceed v_j. In this sense v_j is referred to as a veto limit. In this criterion, the difference between alternatives A and B should be smaller than the veto limit. We utilized ELECTRE-III to tackle this problem since it takes uncertainty into account.

Suppose we claim that option A is superior to option B. Also, for criterion j, which is a measure of profit, we assume that $g_j(b)$ is variable and $g_j(a)$ is constant. $g_j(b)$ Is our variable and the vertical axis of our discordance, as shown in Figure A.1. In this diagram, discarded is made of non-superiority. The non-superiority is zero before p_j. After that, relative superiority begins and continues until v_j. From v_j onwards, we declare the complete non-superiority. That is, we combine the condition of no-veto condition with the Non-discordance condition. Equation (A-6) represents the relationships in Figure A.1.

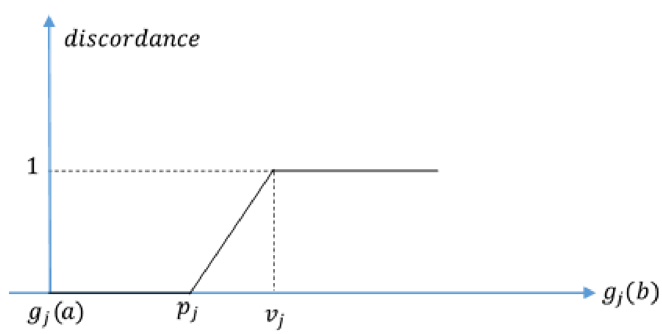

Figure A.1. Preference function in ELECTRE-III.

$$d_j(aSb) = \begin{cases} 1 \quad if \quad g_j(b) > g_j(a) + v_j(g_j(a)) \\ 0 \quad if \quad g_j(b) \le g_j(a) + p_j(g_j(a)) \\ \dfrac{g_j(b) - g_j(a) - p_j(g_j(a))}{v_j\left(g_j(a)\right) - p_j(g_j(a))} \quad O.W \end{cases} \qquad \text{(A-6)}$$

The bigger the $g_j(b)$, as stated in Equation 6, the larger the proportion. That is our sense of inferiority that grows. The closer $g_j(b)$ approaches p_j, the less we lack. Finally, we construct a parameter or variable called *p*, which is termed validity, to analyze the superiority of *A* over *B*. That is Equation (A-7) that equals the validity of our assertion, in which Option *A* is preferable than Option B:

$$p(aSb) = c(aSb) \prod_{j \in J:\, d_j(aSb) > c(aSb)} \frac{1 - d_j(aSb)}{1 - c(aSb)} \qquad \text{(A-7)}$$

If the difference between options A and B in criterion j exceeds a veto limit, it becomes $p = 0$ and $d = 1$, which means that our claim that option A is superior to B have no validity.
If none of j is in the form of Equation (A-8), this claim is eliminated, and we measure the value of this claim only by the value of concordance.

$$d_i(aSb) > c(aSb) \quad \text{(A-8)}$$

where p is the degree to which option A claims superiority over option B in the fuzzy set of preferences. The higher this p, the higher the degree of belonging. This ELECTRE goes out of sight of zero and one because it takes into account uncertainty. When we say accept q_j, we are defining a safe margin for j.

Appendix II: PROMPETHEE-II

PROMPETHEE is a compromise approach that uses the preference function to choose the best choice. It is applied in a variety of disciplines. In general, this technique presents alternatives and criteria, converts qualitative indications into quantitative indicators, and weights the indicators so that the sum of the weights equals one. The PROMPETHEE-II technique is used. This approach assigns a numerical value to each choice.
Due to the distance between the two alternatives, the preference function P is used to compare the two possibilities a_i and a_j in index k. That is, as demonstrated in Equations (B-9 and 10), it is dependent on the distance between the two possibilities.

$$P_k(a_i,a_j) = P[\overset{d_k}{(a_i,a_j)}] \quad \text{(B-9)}$$

Equation (B-10) shows that the preference function p, for comparing the two options a_i and a_j in terms of the index k, is due to the distance between the two options. That is, it depends on the distance between options a_i and a_j. D in this respect represents distance. The distance between the values of option a_i and the value of option a_j is stepwise. In general, this preference function is shown in Table A.1.

$$d_k(a_i,a_j) = f_k(a_i) - f_k(a_j) \quad \text{(B-10)}$$

Table A. 1. Preference function

	$f_1(0)$	$f_2(0)$	…	$f_i(0)$	…	$f_a(0)$
a_1	$f_1(a_1)$	$f_2(a_1)$	…	$f_i(a_1)$	…	$f_a(a_1)$
a_2	$f_1(a_2)$	$f_2(a_2)$	…	$f_i(a_2)$	…	$f_a(a_2)$
…	…	…	…	…	…	…
a_i	$f_1(a_i)$	$f_2(a_i)$	…	$f_i(a_i)$	…	$f_a(a_i)$
…	…	…	…	…	…	…
a_n	$f_1(a_n)$	$f_2(a_n)$	…	$f_i(a_n)$	…	$f_a(a_n)$

Suppose A and B are two hypothetical options, and we denote the performance of option A for criterion j by $g_j(a)$. Our dominance relationship between the two available options can be shown by one of the Equations (B-11, 12, 13):

$$aPb \Leftrightarrow \begin{cases} g_j(a) \geq g_j(b); \forall\, j \in J \\ g_k(a) > g_k(b); \exists\, k \in j \end{cases} \quad \text{(B-11)}$$

where F means complete superiority or mastery. When one option has complete precedence or dominance over the other that for each criterion Option A is better than B and there is a criterion called k in which criterion Option A is strictly superior to Option B.

$$aIb \Leftrightarrow g_j(a) = g_j(b); \forall j \in J \qquad \text{(B-12)}$$

Equation (B-13) says that two options are equal when they are the same for each number under different criteria.

$$aRb \Leftrightarrow \begin{cases} g_s(a) \geq g_s(b); \exists\, s \in J \\ g_r(a) > g_r(b); \exists\, r \in J \end{cases} \qquad \text{(B-13)}$$

where *R* denotes incomparability in relation (B-12). We cannot determine which choice is better when Option A has absolute supremacy over Option B in a set of criteria, while Option B has absolute superiority over Option A in a set of criteria.

When Option A is superior to option B, the magnitude of such superiority is not discernible from the aforementioned relationships. Preference functions are used in the Prometheus technique to eliminate this flaw and influence the intensity of the superiority of the choices. The larger the gap between the two possibilities in one criterion, the higher the degree of preference, according to several preference functions. The difference between the two alternatives with $d_j(a,b)$ in the *J* criteria is positive if the criterion is positive.

$$d_j(a,b) = g_j(a) - g_j(b) \qquad \text{(B-14)}$$

Appendix III: Analytic Network Process (ANP)

The Analytic Hierarchy Process (AHP), introduced by (Wind & Saaty 1980) has been proven a successful decision-making technique. The AHP concept breaks decision problems into several levels of hierarchy. Each element is assumed to be independent. Despite the broad usage of AHP, the structure of a decision problem is not always hierarchical or the dependence between elements in the hierarchy may exist. Consequently, Saaty (2001) expanded the AHP model to a more comprehensive one called the Analytic Network Process (ANP). The ANP modeling process includes two stages: construct a network diagram and determine the priorities of the elements. First, the structure of a decision problem is delineated as a network diagram to consider all the interactions among the components. In a network diagram, nodes show the components (goals, criteria, sub-criteria, or alternatives, and arcs indicate the interaction between them. The direction of arcs represents dependence or influence and a looped arc indicates that inner dependence exists. Figure C-2 is an example of a network diagram.

Then, the established network is translated into a super matrix that represents the dependence between the components. Using pairwise comparison the priority vectors can be derived which are the elements of a component (node). The supermatrix is now used to calculate the overall priorities of the elements, and thus the cumulative influence of each element on the others is obtained. If a decision problem contains only three components (goal, criteria, and alternatives), a possible network diagram can be drawn as a linear hierarchy (Figure 7) with inner and outer dependencies and no feedback (Saaty and Takizawa 1986). Figure C-3 shows the outer dependence among goal-criteria and criteria-alternatives. It also represents that inner dependence exists in criteria and alternatives. The supermatrix used for this linear hierarchy is shown in Equation C-1 (Safaie 2019).

$$W = \begin{matrix} \text{Goal (G)} \\ \text{Criteria (C)} \\ \text{Arternative (A)} \end{matrix} \begin{bmatrix} 0 & 0 & 0 \\ W_1 & W_3 & 0 \\ 0 & W_2 & W_4 \end{bmatrix} \qquad \text{(C-1)}$$

where W_1 is a vector that indicates the level of influence of the goal on the criteria, W_2 represents the impact level of the criteria on each of the alternatives. W_3 and W_4 show the inner dependence of criteria and alternatives.

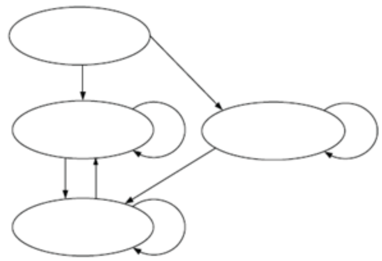

Figure C-2. A network diagram example.

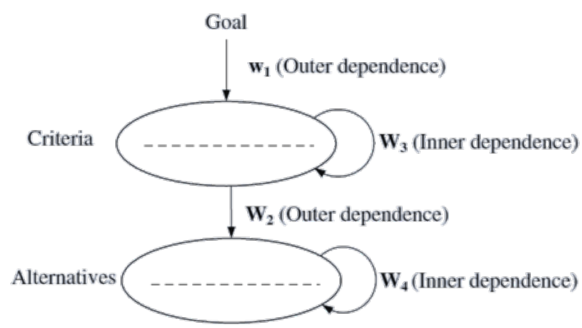

Figure C-3. Network diagram for representation of a three-component decision problem.