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# Professional Baseball Team Starting Pitcher Selection Using AHP and TOPSIS Methods

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**Abstract:** Selecting starting pitchers is a strategic issue with a significant effect on the performance of a professional team. Choosing optimal starting pitchers from many alternatives is a multi-criteria decision-making (MCDM) problem. This study develops an evaluation model, based on the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), to help managers and coaches of a professional baseball team make the optimal selection for starting pitchers. The AHP was used to analyze the structure of starting-pitcher selection and determines weights of the criteria, whereas the TOPSIS method makes the final ranking. Empirical analysis illustrates model utilization for selecting starting pitchers. The results of this study demonstrate the effectiveness and feasibility of the proposed model.
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**Keywords:** Starting pitcher selection; Multi criteria decision-making; AHP; TOPSIS

## 1. Introduction

Empirical analysis shows that pitching skills have a significant effect on team performance, and decrease the batting average of the opposing team (C. C. Chen, and T. T. Chen, 2009; Gould and Winter, 2009; Singell, 1993). Baseball pitchers are typically divided into two types: “starter” and “relief” pitchers (Chen, Lin, Lee, Chen, and Tseng, 2010). The starter, also referred to as the starting pitcher, is the pitcher who delivers the first pitch to the first batter in a game. Team managers generally prefer the starting pitcher to pitch as many innings as possible in a game. Most regular starting pitchers regularly pitch for at least five innings. If unable to do so, there is a high probability that they will, in the future, be relegated to the bullpen. Throughout the long history of baseball, starting pitchers have been considered much more important than relief pitchers and pitch many more innings over the course of a season. Normally, teams select their best pitchers as starting pitchers (C. C. Chen and T. T. Chen, 2009; Chen et al., 2010; Sparks, and Abrahamson, 2005).

Baseball is unique among other sports in Taiwan, in that it is considered to be a “symbol of the Taiwanese spirit and Taiwan’s national sport” (Morris, 2004). Baseball has been ferociously popular for over half a century. The Chinese Professional Baseball League (CPBL) was the first professional sports league established in the country and has steadily increased its popularity. The CPBL has grown to include four teams, each playing 120 games in the regular season (March through early October) – that is, five games a week, not including the pre-season and post-season playoffs (Chen et al., 2010). Before the 2011 season, each team had three starting pitchers playing three games a week. In professional baseball the starting pitcher usually rests three or four days between games. This means that every team in the CPBL must have four or five starting pitchers on its roster. These pitchers, and the sequence in which they pitch, is called the rotation. In modern baseball (for example, the USA’s Major League Baseball association or the Nippon Professional Baseball association in Japan) a five-man rotation is most common. To select the best starting pitcher rotation, the team manager and pitching coaches must judge the abilities of all their own pitchers, and then organize the group of starting pitchers based on this judgment.

Selecting professional starting pitchers involves complicated decision-making, including many quantitative attributes. It can be regarded as a kind of Multi-Attribute or Multi-Criteria Decision Making (MADM/MCDM) problem. This study develops a method to help team managers and pitching coaches select starting pitchers for Taiwan’s domestic professional baseball teams. It uses the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) which is a major decision-making technique commonly used within the Asia-Pacific region (Shih, Shyur, and Lee, 2007), and the Analysis Hierarchy Process (AHP) which allows decision-makers to transform subjective judgments into objective measures. The advantages of the AHP method include relative ease of use and understanding, and effective handling of both qualitative and quantitative data. It draws on the principles of decomposition, pair-wise comparisons, and priority vector generation and synthesis (Guo, Chiang, and Pai, 2007). Because of its mathematical simplicity and flexibility, the AHP has been a favorite tool for decisions in engineering, food, business, ecology, health, government and sport (Sipahi, and Timor, 2010; Zilla, 1988). This study applies the AHP and the TOPSIS approaches to arrange starting pitcher rotation for Taiwan's professional baseball teams. This is accomplished according to relative closeness coefficients based on the criteria deemed most critical for being a competent starting pitcher and winning the game. This analysis will provide useful information for professional baseball team managers and pitching coaches and help them to arrange the rotation of their own team's starting pitchers.

The rest of this paper is organized as follows. Section 2 gives the methodology for evaluation. Section 3 focuses on empirical analysis to find a group of starting pitchers in the CPBL. Finally, Section 4 draws some conclusions and makes remarks for future study.

## 2. Material and Methods

The proposed evaluation procedure consists of several steps. The following subsections describe each step in detail.

### 2.1. AHP method

Saaty introduced the analytic hierarchy process (AHP) in 1971 (Guo, Chiang, and Pai, 2007; Shih, 2008; Sipahi, and Timor, 2010; Zilla, 1988) and is one of the most extensively-used Multiple Criteria/Attributes Decision Making (MCDM/MADM) methods. This study applies AHP to determine the weight of each criterion for performance measurement. The procedure typically involves several steps, from defining the unstructured problem and stating the objectives before determining the relative weights of the decision elements, to obtaining an overall rating for the alternatives (Guo, Chiang, and Pai, 2007). This study uses several steps to determine criterion weights.

Step 1: Establish pair-wise comparison matrix

Decision-makers or experts compare decision elements pair-wise and assign relative scales to each of the paired elements in the matrices using a questionnaire. Saaty recommended using a nine-point scale to express preferences. The options vary from equally, moderately, strongly, very strongly, to extremely preferred (with pair-wise weights from 1 to 9 respectively) (Guo, Chiang, and Pai, 2007; Sipahi, and Timor, 2010; Zilla, 1988). After each element has been compared, a paired comparison matrix is established. For example, there are n objects, denoted by $O_1, O_2, O_3, \ldots, O_n$, compared in pairs according to their relative weights, denoted by $w_1, w_2, w_3, \ldots, w_n$, respectively. These pair-wise comparisons can be represented in the following matrix (Guo, Chiang, and Pai, 2007; Sipahi, and Timor, 2010; Zilla, 1988).

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Step 2: Estimate the relative weights of the decision elements

After forming a comparison matrix, the priority (the relative weights of the decision elements) of the element can be compared by computing the eigenvalues and eigenvectors with the following formulas:

$$E = \frac{\left(\prod_j^n a_{ij}\right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n a_{ij}\right)^{1/n}} \quad i, j = 1, 2, \ldots, n, \quad (2)$$

$$A \cdot E = \lambda_{\max} \cdot E, \quad (3)$$

where $E$ is the eigenvector and $\lambda_{\max}$ is the largest eigenvalue of $E$.

The entry of the eigenvector represents the relative weight of different decision elements.

Step 3: Test for the consistency of the judgment matrix

The consistency of judgments ensures transitivity of decision-makers' preference during a series of pair-wise comparisons. Thus, decision quality from the weight determination process is strongly related to consistency. Transitivity of preference implies that if $P_1$ is preferred to $P_2$, and $P_2$ is preferred to $P_3$, then $P_1$ is preferred to $P_3$. This consistency property can derive from the consistency index ($CI$) and consistency ratio ($CR$), as follows (Guo, Chiang, and Pai, 2007; Sipahi, and Timor, 2010; Zilla, 1988):

$$CI = \frac{\lambda_{\max} - n}{n-1}, \quad (4)$$

$$CR = \frac{CI}{RI}, \quad (5)$$

where $n$ is the number of items being compared in the matrix, and $RI$ is a random index, which is the average consistency index of randomly generated pair-wise comparison matrices of similar size (Table 1). The threshold $CR$ value is 0.10 (Guo, Chiang, and Pai, 2007; Sipahi, and Timor, 2010; Zilla, 1988). If calculated $CR$ values exceed the threshold, this indicates an inconsistent judgment. Decision-makers must then revise the original values in the pair-wise comparison matrix.

Table 1. Random index (RI)

| Order of matrix | RI |
|---|---|
| 1 | 0.00 |
| 2 | 0.00 |
| 3 | 0.58 |
| 4 | 0.90 |
| 5 | 1.12 |
| 6 | 1.24 |
| 7 | 1.32 |
| 8 | 1.41 |
| 9 | 1.45 |
| 10 | 1.49 |

**2.2.TOPSIS method**

The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) is based on the concept of distance measures. Hwang and Yoon initially presented this approach (Olson, 2004; Shih, Shyur, and Lee, 2007). The ideal solution (also called the positive ideal solution) is one that maximizes the benefit criteria or attributes and minimizes the cost criteria (or attributes). By contrast, a negative ideal solution (also called the anti-ideal solution) maximizes the cost criteria or attributes and minimizes the benefit criteria or attributes (Olson, 2004; Torlaka, Sevklib, Sanala, and Zaim, 2011).

Suppose a MCDM/MADM problem has $m$ alternatives ( $A_1, A_2, ..., A_m$ ), and $n$ decision criteria/attributes ($C_1, C_2, ..., C_n$). Each alternative is evaluated with respect to the $n$ criteria or attributes. All values or ratings assigned to the alternatives with respect to each criterion form a decision matrix denoted by $X = (x_{ij})_{m\times n}$. Let $W = (w_1, w_2, ..., w_n)$ be the relative weight vector about the criteria, satisfying $\sum_{j=1}^{n} w_j = 1$. The following series of steps expresses the TOPSIS method:

Step 1: Normalize the decision matrix $X = (x_{ij})_{m\times n}$ by calculating $r_{ij}$ which represents the normalized criteria/attribute value/rating.

$$r_{ij} = x_{ij} / \sum_j X_{ij}, \quad \forall i, j$$

where $i = 1, 2, ..., m$ and $j = 1, 2, ..., n$. (6)

Step 2: Calculate the weighted normalized decision matrix $V = (v_{ij})_{m\times n}$.

$$v_{ij} = r_{ij} \cdot w_j,$$

where $i = 1, 2, ..., m$ and $j = 1, 2, ..., n$, (7)

where $w_j$ is the relative weight of the j$^{th}$ criterion or attribute, and $\sum_{j=1}^{n} w_j = 1$.

Step 3: Determine the ideal ( $A^*$ ) and negative ideal ( $A^-$ ) solutions:

$$A^* = \{v_1^*, v_2^*, ..., v_n^*\} \text{ where } v_j^* = \max_i (v_{ij}), \quad (8)$$

$$A^- = \{v_1^-, v_2^-, ..., v_n^-\} \text{ where } v_j^- = \min_i (v_{ij}). \quad (9)$$

Step 4: Calculate the Euclidean distances of each alternative from the positive ideal solution and the negative ideal solution, respectively:

$$d_i^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_j^*)^2} \quad i = 1, 2, ..., m, \quad (10)$$

$$d_i^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_j^-)^2} \quad i = 1, 2, ..., m. \quad (11)$$

Step 5: Calculate the relative closeness of each alternative to the ideal solution. The relative closeness of the alternative $A_i$ with respect to $A^*$ is defined as $CC_i$

$$CC_i = d_i^- / (d_i^* + d_i^-) \quad i = 1, 2, ..., m. \quad (12)$$

Step 6: Rank the alternatives according to the relative closeness to the ideal solution. The bigger the $CC_i$, the better the alternative $A_i$. The best alternative is the one with the greatest relative closeness to the ideal solution.

### 2.3. Data

Data employed in this study originated with the official CPBL website (http://www.cpbl.com.tw), which has collected and posted records of every CPBL baseball game in 2010. Researchers selected pitchers from each team for alternatives, referred to in the official CPBL website in 2011. If an individual alternative is a rookie or first-time player in the CPBL, this data is available on Taiwan's minor league website or overseas baseball league website. Every alternative pitcher is listed on the team roster. Only those statistics familiar to all fans contribute to the AHP and TOPSIS calculation. Statistics for empirical analysis include the number of innings pitched per game, earned run average (ERA), strikeouts per nine innings pitched (K/9), and walks plus hits per inning pitched (WHIP) (C. C. Chen, and T. T. Chen, 2009; Chen et al., 2010; Lewis, 2003; Sparks, and Abrahamson, 2005), all of which this study includes. This study calculates the IPG, ERA, K/9 and WHIP for all starting pitchers as follows: IPG=Innings Pitched/games; ERA=9 × (Earned Run Allowed/Innings Pitched); K/9 = 9 × (Strikeouts/Innings Pitched); WHIP = (Walks + Hits)/Innings Pitched.

## 3. Empirical analysis for starting pitcher rotation in the CPBL

This section discusses the procedure for selecting starting pitchers for teams in the CPBL.

### 3.1.Alternatives for starting pitchers for CPBL teams

A brief description of all pitchers for all four teams is below. Tables 2 through 5 list pitchers' names for each team in the CPBL.

Table 2 Alternative pitchers' pitching information, decision matrix and normalized decision matrix for the Uni-Lions

| | | Pitching information and Decision matrix | | | | Normalized decision matrix | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name | IPG | ERA | WHIP | K/9 | IPG | ERA | WHIP | K/9 |
| L1 | Pan, W.L. | 6.20 | 3.19 | 1.13 | 4.75 | .134 | .050 | .053 | .060 |
| L2 | Reichert, D. | 6.20 | 3.95 | 1.23 | 7.05 | .134 | .061 | .057 | .089 |
| L3 | Wang, J. M. | 5.20 | 3.83 | 1.43 | 6.16 | .112 | .060 | .067 | .077 |
| L4 | Pan, J. R. | 2.20 | 6.48 | 1.77 | 4.15 | .047 | .101 | .083 | .052 |
| L5 | Sanchez, J. | 6.20 | 2.82 | 1.09 | 5.50 | .134 | .044 | .051 | .069 |
| L6 | Xu, Y. W. | 3.00 | 4.11 | 1.31 | 5.91 | .065 | .064 | .061 | .074 |
| L7 | Mai, J. Y. | 2.20 | 7.33 | 2.02 | 4.13 | .047 | .114 | .094 | .052 |
| L8 | Lin, C. F. | 1.10 | 2.56 | 1.38 | 5.74 | .024 | .040 | .064 | .072 |
| L9 | Lin, Y. P. | 1.20 | 3.67 | 1.51 | 5.12 | .026 | .057 | .071 | .064 |
| L10 | Kao, C. S. | 1.10 | 3.35 | 1.47 | 5.36 | .024 | .052 | .069 | .067 |
| L11 | Chang, C. C. | 1.10 | 4.61 | 1.18 | 5.29 | .024 | .072 | .055 | .067 |
| L12 | Chen, Y. C. | 2.20 | 4.50 | 1.44 | 2.70 | .047 | .070 | .067 | .034 |
| L13 | Li, W. H. | 1.20 | 6.23 | 1.74 | 6.58 | .026 | .097 | .081 | .083 |
| L14 | Halama, J. | 4.20 | 4.39 | 1.32 | 4.56 | .091 | .068 | .062 | .057 |
| L15 | Tsai, J. H. | 3.10 | 3.24 | 1.40 | 6.49 | .067 | .050 | .065 | .082 |

Each team in the CPBL (Uni Lions, Lamigo Monkeys, Brother Elephants and Sinon Bulls) selects twelve to fifteen alternative pitchers. Most regular starting pitchers regularly pitch for at least five innings per game. Four pitchers pitched more than five innings per game (Tables 2-5). The Brother Elephants had two pitchers who pitched five innings per game.

### 3.2. AHP for weights of evaluation criteria

A professional baseball team manager and three coaches, two Taiwanese baseball team coaches, and two experts contributed their professional experience to determine the relative importance of the four individual performance measures: innings pitched per game, earned run average, strikeouts per nine innings pitched, and walks plus hits per inning pitched.

Table 3 Alternative pitchers' pitching information, decision matrix normalized decision matrix for the Lamigo Monkeys

| | | Pitching information and Decision matrix | | | | Normalized decision matrix | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name | IPG | ERA | WHIP | K/9 | IPG | ERA | WHIP | K/9 |
| M1 | Ray, K. | 6.20 | 2.32 | 1.25 | 7.10 | .156 | .042 | .056 | .080 |
| M2 | Wang, F. S. | 3.10 | 2.60 | 1.32 | 5.57 | .078 | .047 | .060 | .063 |
| M3 | Huang, Q. Z. | 5.00 | 3.50 | 1.21 | 3.40 | .126 | .063 | .055 | .038 |
| M4 | Hammond, S | 6.20 | 3.07 | 1.07 | 6.59 | .156 | .055 | .049 | .074 |
| M5 | Burnside, A. | 5.00 | 5.34 | 1.66 | 6.30 | .126 | .096 | .075 | .071 |
| M6 | Lin, C. M. | 1.20 | 2.57 | 1.48 | 4.71 | .030 | .046 | .067 | .053 |
| M7 | Zeng, Z. H. | 1.10 | 2.67 | 1.08 | 5.34 | .028 | .048 | .049 | .060 |
| M8 | Chen, J. D. | 1.10 | 3.93 | 1.91 | 10.81 | .028 | .071 | .087 | .122 |
| M9 | Guo, J. H. | 1.20 | 4.59 | 1.69 | 3.38 | .030 | .082 | .077 | .038 |
| M10 | Zeng, B. L. | 2.00 | 6.28 | 1.49 | 2.51 | .050 | .113 | .068 | .028 |
| M11 | Keng, P. H. | 1.00 | 3.26 | 1.57 | 4.98 | .025 | .059 | .071 | .056 |
| M12 | Hsu, M. J. | 1.10 | 1.30 | 1.21 | 10.09 | .028 | .023 | .055 | .114 |
| M13 | Li, J. G. | 1.20 | 2.20 | 1.19 | 5.63 | .030 | .040 | .054 | .064 |
| M14 | Lin, C. W. | 4.20 | 3.95 | 1.65 | 6.56 | .106 | .071 | .075 | .074 |
| M15 | Hsiao, Y. C. | 0.20 | 8.10 | 2.27 | 5.45 | .005 | .145 | .103 | .062 |

The AHP method determined the weights of the evaluation criteria. The questionnaire method obtained judgments from managers, coaches and experts. A sample question is: 'Which performance measures should receive more emphasis in determining starting pitcher criteria, and how much more?' A nine-point scale permitted pair-wise comparisons. Eight questionnaires were returned. Each one passed a consistency test.

Table 4 Alternative pitchers' pitching information, decision matrix normalized decision matrix for the Brother Elephants

| | | Pitching information and Decision matrix | | | | Normalized decision matrix | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name | IPG | ERA | WHIP | K/9 | IPG | ERA | WHIP | K/9 |
| E1 | Roman, O. | 6.10 | 3.03 | 1.19 | 6.62 | .136 | .050 | .054 | .076 |
| E2 | Yeh, T. J. | 5.10 | 3.86 | 1.73 | 5.96 | .114 | .064 | .079 | .069 |
| E3 | Tseng, S. W. | 3.00 | 5.31 | 1.44 | 2.23 | .067 | .088 | .066 | .026 |
| E4 | Lee, J. M. | 4.00 | 3.77 | 1.31 | 3.39 | .089 | .062 | .060 | .039 |
| E5 | Cullen, R. | 1.20 | 1.95 | 0.93 | 8.99 | .036 | .032 | .043 | .104 |
| E6 | Huang, J. M. | 2.00 | 3.75 | 1.44 | 3.90 | .045 | .062 | .066 | .045 |
| E7 | Lin, E. Y. | 3.20 | 6.52 | 2.29 | 15.43 | .071 | .108 | .105 | .178 |
| E8 | Ye, Y. J. | 1.20 | 4.38 | 1.26 | 4.38 | .027 | .072 | .058 | .051 |
| E9 | Guan, D. Y. | 3.20 | 1.92 | 1.17 | 6.67 | .074 | .032 | .054 | .077 |
| E10 | Cheng, C. H. | 4.10 | 4.16 | 1.43 | 4.16 | .092 | .069 | .066 | .048 |
| E11 | Luo, G. H. | 3.00 | 3.09 | 1.27 | 2.98 | .067 | .051 | .058 | .034 |
| E12 | Lee, F. H. | 1.00 | 2.59 | 1.34 | 4.03 | .022 | .043 | .061 | .046 |
| E13 | Barzilla, P. J. | 4.10 | 6.58 | 1.62 | 5.19 | .092 | .109 | .074 | .060 |
| E14 | Kuo, C. W. | 2.00 | 4.47 | 1.95 | 5.08 | .045 | .074 | .089 | .059 |
| E15 | Chen, W. J. | 1.10 | 5.14 | 1.43 | 7.71 | .025 | .085 | .066 | .089 |

In the first step, Eq. (1) constructs the pair-wise comparison. In the second step, Eq. (2) and Eq. (3) calculate the eigenvector and eigenvalue. In the third step, Eq. (4) and Eq. (5) calculate the CR value and CI value. The final step verifies whether the CR value passes the consistency test. If the CR value is less than 0.1, the questionnaire passes. Otherwise, decision-makers will need to revise the original values in the pair-wise comparison matrix until all questionnaires pass the consistency test. The weights for each performance measure follow these steps:

Table 5 Alternative pitchers' pitching information, decision matrix normalized decision matrix and for the Sinon Bulls

| | | Pitching information and Decision matrix | | | | Normalized decision matrix | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name | IPG | ERA | WHIP | K/9 | IPG | ERA | WHIP | K/9 |
| B1 | Lin, Y. C. | 5.10 | 2.69 | 1.20 | 6.55 | .139 | .071 | .073 | .095 |
| B2 | Yang, C. F. | 5.00 | 2.33 | 1.14 | 5.35 | .136 | .062 | .069 | .078 |
| B3 | Lin, C. W. | 4.20 | 3.23 | 1.27 | 7.00 | .114 | .085 | .077 | .102 |
| B4 | Yu, W. B. | 1.60 | 4.82 | 1.92 | 3.96 | .044 | .127 | .116 | .058 |
| B5 | Luo, J. L. | 5.00 | 1.90 | 1.29 | 5.60 | .136 | .050 | .078 | .082 |
| B6 | Shen, F. J. | 1.20 | 1.34 | 1.13 | 6.16 | .033 | .035 | .068 | .090 |
| B7 | Tsai, M. J. | 1.10 | 2.82 | 1.25 | 7.30 | .030 | .075 | .076 | .106 |
| B8 | Chang, G. H. | 3.10 | 3.44 | 1.21 | 6.73 | .084 | .091 | .073 | .098 |
| B9 | Shen, Y. J. | 1.20 | 2.87 | 1.40 | 8.70 | .033 | .076 | .085 | .127 |
| B10 | Chen, H. Y. | 3.00 | 2.96 | 1.25 | 3.34 | .082 | .078 | .076 | .049 |
| B11 | Lin, K. C. | 5.10 | 4.02 | 1.46 | 4.14 | .139 | .106 | .088 | .060 |
| B12 | Wu, J. S. | 1.10 | 5.40 | 1.98 | 3.88 | .030 | .143 | .120 | .056 |

Step 1: Construct a pair-wise comparison matrix

Using all the questionnaire results, calculate the geometric mean for all pair-wise comparisons for each manager, coach or expert. Table 6 shows the results.

Table 6 Comparison matrix

| | IPG | ERA | K/9 | WHIP |
|---|---|---|---|---|
| IPG | 1.00 | 1.72 | 0.90 | 1.23 |
| ERA | 0.58 | 1.00 | 0.33 | 0.45 |
| K/9 | 1.12 | 3.00 | 1.00 | 0.66 |
| WHIP | 0.82 | 2.23 | 1.51 | 1.00 |

Step 2: Calculate the eigenvector and eigenvalue.

Calculate the eigenvector and eigenvalue using Eq. (2) and Eq. (3), respectively.

$$E = \begin{bmatrix} IPG \\ ERA \\ K/9 \\ WHIP \end{bmatrix} = \begin{bmatrix} 0.278 \\ 0.129 \\ 0.289 \\ 0.304 \end{bmatrix}, \quad \lambda_{\max} = 4.091 .$$

The eigenvector shows the weights of the different criteria. Results show that the WHIP, with a weight of 0.304, is the major factor in determining starting pitcher rotation in the CPBL; second is the IPG; third is the K/9; ERA is the fourth.

Step 3: Calculate the CR value and CI value.

Calculate CR value and CI value with Eq. (4) and Eq. (5), respectively,

$$CI = \frac{4.091-4}{4-1} = 0.0303,$$

$$CR = \frac{0.0303}{0.90} = 0.0336 .$$

Since CR value is less than 0.1, the comparison matrix is deemed consistent.

### 3.3. TOPSIS for alternative pitchers

Hwang and Yoon originally proposed the order preference technique to solve MCDM problems in 1981. This technique is based on similarity to the ideal solution (TOPSIS) in which the chosen alternative should not only be the shortest distance from the positive ideal reference point (PIRP), but also the longest distance from the negative ideal reference point (NIRP), (Aydogan, 2011; Olson, 2004; Shih, Shyur, and Lee, 2007; Shih, 2008). This study measures the performance of each team's starting pitchers with respect to each criterion. Tables 2 through 5 show each team's decision matrix of selection criteria.

Table 7 Weighted normalized decision matrix, positive and negative ideal solutions and distance for each alternative, as well as the closeness coefficient and Rankings for the Uni-Lions

| | Weighted normalized decision matrix | | | | PIS, NIS, closeness coefficient and Rank | | | |
|---|---|---|---|---|---|---|---|---|
| No. | IPG | ERA | WHIP | K/9 | $d^*$ | $d^-$ | $CC_i$ | Rank |
| L1 | .0371 | .0064 | .0152 | .0182 | .0066 | .0350 | .8404 | 3 |
| L2 | .0371 | .0079 | .0166 | .0247 | .0034 | .0364 | .9144 | 1 |
| L3 | .0312 | .0077 | .0192 | .0215 | .0086 | .0294 | .7746 | 4 |
| L4 | .0132 | .0130 | .0239 | .0145 | .0287 | .0091 | .2412 | 14 |
| L5 | .0371 | .0057 | .0146 | .0192 | .0055 | .0356 | .8672 | 2 |
| L6 | .0180 | .0083 | .0177 | .0207 | .0201 | .0197 | .4959 | 6 |
| L7 | .0132 | .0147 | .0273 | .0144 | .0305 | .0083 | .2134 | 15 |
| L8 | .0066 | .0051 | .0186 | .0201 | .0312 | .0167 | .3492 | 8 |
| L9 | .0072 | .0074 | .0204 | .0179 | .0313 | .0132 | .2960 | 12 |
| L10 | .0066 | .0067 | .0198 | .0187 | .0316 | .0143 | .3121 | 10 |
| L11 | .0066 | .0093 | .0159 | .0185 | .0315 | .0155 | .3301 | 9 |
| L12 | .0132 | .0090 | .0194 | .0094 | .0291 | .0117 | .2872 | 13 |
| L13 | .0072 | .0125 | .0235 | .0230 | .0321 | .0143 | .3075 | 11 |
| L14 | .0252 | .0088 | .0178 | .0159 | .0156 | .0226 | .5920 | 5 |
| L15 | .0186 | .0065 | .0189 | .0227 | .0192 | .0214 | .4214 | 7 |
| PIS | .0371 | .0051 | .0146 | .0247 | | | | |
| NIS | .0066 | .0147 | .0273 | .0094 | | | | |

Note. PIS (Positive ideal solution), NIS (Negative ideal solution)

Equation (6) finds the normalized decision matrix, depending on whether the objective of the selection criterion is minimization or maximization. Tables 2 through 5 show the normalized decision matrices for each team. Each criterion is categorized as either maximization or minimization. The IPG and K/9 are maximization criteria, and the ERA and WHIP are minimization criteria. The weighted normalized decision matrix is calculated using Eq. (7). Tables 7 through 10 show weighted normalized decision matrices for all selection criteria. Equations (8) and (9) determine positive $(A^*)$ and negative $(A^-)$ ideal solutions. Tables 7 through 10 also show resultant values.

Next, Eq. (10) and (11) calculate the distance of each alternative. These values are contained in Tables 7 through 10. The closeness coefficient $CC_i$ is determined using Eq. (12). The closeness coefficient value for all starting pitchers and their ranking in each team are also contained in these tables.

Table 8 Weighted normalized decision matrix, positive and negative ideal solutions and distance for each alternative, closeness coefficient and Rankings for the Lamigo Monkeys

| | Weighted normalized decision matrix | | | | PIS, NIS, closeness coefficient and Rank | | | |
|---|---|---|---|---|---|---|---|---|
| No. | IPG | ERA | WHIP | K/9 | $d^*$ | $d^-$ | $CC_i$ | Rank |
| M1 | .0433 | .0054 | .0163 | .0244 | .0132 | .0486 | .7869 | 1 |
| M2 | .0217 | .0060 | .0173 | .0192 | .0285 | .0290 | .5040 | 5 |
| M3 | .0349 | .0081 | .0159 | .0117 | .0274 | .0379 | .5809 | 4 |
| M4 | .0433 | .0071 | .0141 | .0226 | .0151 | .0483 | .7619 | 2 |
| M5 | .0349 | .0124 | .0218 | .0217 | .0214 | .0374 | .6362 | 3 |
| M6 | .0084 | .0060 | .0194 | .0162 | .0412 | .0194 | .3205 | 10 |
| M7 | .0077 | .0062 | .0142 | .0184 | .0404 | .0231 | .3642 | 9 |
| M8 | .0077 | .0091 | .0250 | .0372 | .0378 | .0311 | .4519 | 8 |
| M9 | .0084 | .0106 | .0222 | .0116 | .0447 | .0135 | .2318 | 14 |
| M10 | .0140 | .0145 | .0195 | .0086 | .0429 | .0167 | .2809 | 13 |
| M11 | .0070 | .0076 | .0206 | .0171 | .0422 | .0177 | .2953 | 12 |
| M12 | .0077 | .0030 | .0159 | .0347 | .0358 | .0341 | .4879 | 6 |
| M13 | .0084 | .0051 | .0156 | .0194 | .0393 | .0235 | .2992 | 11 |
| M14 | .0293 | .0092 | .0216 | .0226 | .0224 | .0337 | .4800 | 7 |
| M15 | .0014 | .0188 | .0298 | .0187 | .0509 | .0101 | .1657 | 15 |
| PIS | .0433 | .0030 | .0141 | .0372 | | | | |
| NIS | .0014 | .0188 | .0298 | .0086 | | | | |

Note. PIS (Positive ideal solution), NIS (Negative ideal solution)

The AHP and TOPSIS approaches identified Reichert, Sanchez, Pan, Wang and Halama as the top five starting pitchers of the Uni-Lions. Ray, Hammond, Burnside, Huang and Wang ranked as the top five starting pitchers in the Lamingo Monkeys. Wang ranked fifth and pitched 3.10 innings per game in the last season. Lin, Roman, Cullen, Yeh and Guan were selected as the top five starting pitchers for the Brother Elephants. Last season, Roman and Yeh pitched more than five innings per game.

Table 9 Weighted normalized decision matrix, positive and negative ideal solutions and distance for each alternative, closeness coefficient and Rankings for the Brother Elephants

| | Weighted normalized decision matrix | | | | PIS, NIS, closeness coefficient and Rank | | | |
|---|---|---|---|---|---|---|---|---|
| No. | IPG | ERA | WHIP | K/9 | $d^*$ | $d^-$ | $CC_i$ | Rank |
| E1 | .0379 | .0065 | .0157 | .0232 | .0312 | .0389 | .5550 | 2 |
| E2 | .0316 | .0082 | .0230 | .0209 | .0357 | .0301 | .4578 | 4 |
| E3 | .0186 | .0113 | .0191 | .0078 | .0511 | .0170 | .2495 | 11 |
| E4 | .0248 | .0080 | .0173 | .0119 | .0446 | .0238 | .3482 | 8 |
| E5 | .0099 | .0042 | .0124 | .0315 | .0359 | .0316 | .4677 | 3 |
| E6 | .0124 | .0080 | .0191 | .0137 | .0484 | .0154 | .2410 | 14 |
| E7 | .0199 | .0139 | .0304 | .0541 | .0273 | .0482 | .6390 | 1 |
| E8 | .0074 | .0093 | .0167 | .0154 | .0497 | .0163 | .2473 | 12 |
| E9 | .0205 | .0041 | .0155 | .0234 | .0354 | .0277 | .4385 | 5 |
| E10 | .0254 | .0089 | .0190 | .0146 | .0422 | .0239 | .3618 | 7 |
| E11 | .0186 | .0066 | .0168 | .0104 | .0480 | .0200 | .2940 | 10 |
| E12 | .0062 | .0055 | .0178 | .0141 | .0513 | .0165 | .2429 | 13 |
| E13 | .0254 | .0140 | .0215 | .0182 | .0403 | .0236 | .3693 | 6 |
| E14 | .0124 | .0095 | .0258 | .0178 | .0466 | .0134 | .2229 | 15 |
| E15 | .0068 | .0110 | .0190 | .0270 | .0423 | .0226 | .3480 | 9 |
| PIS | .0379 | .0041 | .0124 | .0541 | | | | |
| NIS | .0062 | .0140 | .0304 | .0078 | | | | |

Note. PIS (Positive ideal solution), NIS (Negative ideal solution)

The other three pitched fewer than 3.20 innings. Y. C. Lin, C. W. Lin, J. L. Luo, C. F. Yang and K. C. Lin emerged as the top five starting pitchers for the Sinon Bulls. Last season, with the exception of C.W. Lin who pitched 4.20 innings per game, they all pitched more than five innings per game.

Table 10 Weighted normalized decision matrix, positive and negative ideal solutions and distance for each alternative, closeness coefficient and Rankings for the Sinon Bulls

| | Weighted normalized decision matrix | | | | PIS, NIS, closeness coefficient and Rank | | | |
|---|---|---|---|---|---|---|---|---|
| No. | IPG | ERA | WHIP | K/9 | $d^*$ | $d^-$ | $CC_i$ | Rank |
| B1 | .039 | .009 | .021 | .029 | .0107 | .0373 | .7777 | 1 |
| B2 | .038 | .008 | .020 | .024 | .0152 | .0358 | .7013 | 4 |
| B3 | .032 | .011 | .022 | .031 | .0123 | .0320 | .7223 | 2 |
| B4 | .012 | .016 | .034 | .018 | .0384 | .0052 | .1184 | 11 |
| B5 | .038 | .006 | .023 | .025 | .0142 | .0355 | .7151 | 3 |
| B6 | .009 | .005 | .020 | .027 | .0316 | .0239 | .4302 | 8 |
| B7 | .008 | .010 | .022 | .032 | .0314 | .0234 | .4270 | 9 |
| B8 | .023 | .012 | .021 | .030 | .0189 | .0261 | .5794 | 6 |
| B9 | .009 | .010 | .025 | .038 | .0304 | .0272 | .4726 | 7 |
| B10 | .023 | .010 | .022 | .015 | .0292 | .0210 | .4183 | 10 |
| B11 | .039 | .014 | .026 | .018 | .0229 | .0322 | .5843 | 5 |
| B12 | .008 | .018 | .035 | .017 | .0423 | .0024 | .0535 | 12 |
| PIS | .0386 | .0046 | .0198 | .0385 | | | | |
| NIS | .0083 | .0184 | .0347 | .0148 | | | | |

Note. PIS (Positive ideal solution), NIS (Negative ideal solution)

The study results of starting pitcher selection for each team in the CPBL were quite consistent with those on the official CPBL website. The list of starting pitchers for the 2011 season, selected by the managers and coaches of the Uni-Lions and Lamingo Monkeys, was the same as the results of this study. For the Sinon Bulls, four starting pitchers were the same, but one was different. For the Brother Elephants, three starting pitchers that this study recommended also corresponded with the team roster.

## 4. Conclusion and remarks

Choosing starting pitchers is difficult for professional baseball team managers and coaches and can be defined as a kind of MADM/MCDM problem. This study first applies AHP to calculate criterion weights to determine who will be the strongest starting pitcher. TOPSIS then calculates the performance of each starting pitcher candidate with respect to each criterion. Finally, AHP and TOPSIS calculate the ranks of all CPBL starting pitchers for each team. In the preseason, managers and coaches must organize the roster of starting pitchers. Good pitchers can dominate the game and decrease the batting average of the opposing team, having a significantly positive effect on the performance of their own team. The 2011 season of the CPBL is currently in progress. At the moment, the Lamigo Monkeys and Uni-Lions are ranked first and second. Interestingly, in contrast to the starting pitcher rosters for the Brother Elephants and Sinon Bulls, the starting pitcher rosters for the Uni-Lions and Lamingo Monkeys are consistent with the results obtained in this study. The method proposed in this study thus appears useful.

Starting pitchers are a valuable asset to a professional baseball team. It is hard to train a good starter, and not every candidate is necessarily suitable for the job. Most team managers and coaches select starting pitchers based on their professional judgment. If managers and coaches make an incorrect decision and release a potentially good starting pitcher this would be a loss to the team. This study proposes a method that can confirm the suggestions of managers and coaches, providing additional information to assist in the decision making process. The authors suggest two avenues for future research. First, future studies should identify more criteria for starting pitcher selection, such as batting average against (AVG) or rate of ground-outs divided by air-outs (GO/AO). Second, they should employ AHP and TOPSIS methodology to analyze the statistics for relief pitchers, catchers, infielders and outfielders, and ultimately to help coaches or managers make the best decisions based on scientific analysis.

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