A Mathematical Programming Approach for Product Selection with Multiple Criteria

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Abstract. Product selection is very important for customer who looks for functionalities of the product. To get the best product with the available budget, multiple criteria should be considered simultaneously while making decision. In this paper, we propose a multi-objective decision model for selecting the most suitable product for the customers. The model is tested by using a real case of power unit selection in studio recording, and the results are presented.

1. Introduction
The decision making of choosing a right product for the customer can be difficult due to multiple factors involved in the decision process. For examples, the variety of product, the decision making criteria, the available budget, the product requirement, and etc. Some of these factors are often conflict to each other. For example, a feature-rich product is usually more expensive.

In general, the decision making process is commonly divided into seven steps. It starts with identifying the decision, gathering the relevant information, and identifying the alternatives. The next steps are evaluating the evidence and then choosing among alternatives. Finally, the corresponding action is taken, and the result of the decision is reviewed.

Decision making tools can be used to simplify the decision making process and to help decision makers for making better decision. Decision making tools are widely used in many areas. Among them, the decision tree is probably the most commonly used method in decision analysis. It can be used to help decision makers identify the most valuable choice to the goal. The decision tree uses a flowchart-like structure to track for the possible decisions and their consequences. Each option is "tested" to evaluate its expected value (or utility) and the option with the highest expected value is selected. The analytic hierarchy process (AHP) and the analytic network process (ANP) are widely used for multi-criteria decision making [1] in different areas such as strategic planning [2], material or equipment selection [3,4], aircraft type selection [5], nuclear power plant selection [6], and etc. They provide a comprehensive framework for structuring the decision problem in a hierarchical structure (in AHP) or in a complex interrelationships among decision levels and attributes (in ANP) by using pairwise comparisons that represent the dominance of one element over another. A numerical weight is derived for each element to allow calculation of the final numerical priority for each of the decision alternatives. Multi-objective programming is another widely used tool in multiple criteria decision making for identifying optimal solutions to decision problems which involve more than one objective. Applications of multi-objective programming include product design [7], product line design and supplier selection [8], material selection [9], and etc.
2. Problem statement

In this paper, we consider a product selection problem where customers are faced with making decision to choose the right product among many alternatives. Multiple criteria are considered in this problem including price and product requirements. In particular, we consider a power unit selection problem in studio recording for this study. There are fifteen products or alternatives to choose from depending on customer’s application or needs. The objective (or goal) is to maximize customer’s satisfaction or preferences based on his/her available budget subject to customer’s product requirements (product features). Table 1 shows the features of each product and the short description of each feature is provided in Table 2.

| Product/Feature | Price | Amp | Outlets | Surge Protection | Noise Filtering | Over-voltage Protection | Voltage Regulation | Power Boost | Power Sequencing | UPS | Isolation | Indicator | USB Charger | Software Control |
|----------------|-------|-----|---------|------------------|-----------------|------------------------|-------------------|-------------|------------------|-----|-----------|-----------|-------------|------------------|
| M-15X E        | 3,780 |10  | 11      | Standard        | RFT+EMI         | -                      | -                 | -           | -                | Yes | -         | -         | -           | -                |
| PL-15C E       | 11,000|10  | 11      | SMP             | LFT             | EVS                   | -                 | -           | -                | Yes | Yes       | -         | -           | -                |
| PL-PRO DMC E   | 14,000|10  | 11      | SMP             | LFT             | EVS                   | -                 | -           | -                | Yes | Yes       | -         | -           | -                |
| PL-PRO DMC III| 22,500|10  | 11      | SMP             | LFT             | EVS                   | -                 | Yes         | Yes              | Yes | Yes       | -         | -           | -                |
| CN-3600 SE     | 14,000|10  | 9       | SMP             | LFT             | EVS                   | -                 | Yes         | Yes              | Yes | Yes       | -         | -           | -                |
| P-23000 IT E   | 22,500|10  | 9       | SMP             | LFT             | EVS                   | -                 | Yes         | Yes              | Yes | Yes       | -         | -           | -                |
| P-14000 AR E   | 44,100|6   | 11      | SMP             | LFT             | EVS                   | True RMS          | -           | -                | Yes | Yes       | Yes       | -           | -                |
| P-9000 AR E    | 126,000|30 | 31      | SMP             | LFT             | EVS                   | True RMS          | -           | -                | Yes | Yes       | Yes       | -           | -                |
| F1500-UPS E    | 54,000|7   | 10      | SMP             | LFT             | EVS                   | AVR               | Yes         | Yes              | Yes | Yes       | Yes       | -           | -                |
| IT-REF 16IE1   | 146,200|16 | 12      | SMP             | LFT+HP          | EVS                   | -                 | Yes         | Yes              | Yes | Yes       | Yes       | -           | -                |
| ELITE-16FTE1   | 43,000|16  | 12      | SMP             | LFT             | EVS                   | -                 | Yes         | Yes              | Yes | Yes       | -         | -           | -                |
| ELITE-10E1     | 28,373|10  | 8       | SMP             | LFT             | EVS                   | -                 | -           | -                | Yes | -         | -         | -           | -                |
| AC-210A E      | 6,300 |10  | 2       | SMP             | LFT             | EVS                   | -                 | -           | -                | Yes | -         | -         | -           | -                |

Table 2: Description of the product features

| No. | Features       | Description                                      |
|-----|----------------|--------------------------------------------------|
| 1   | Price          | The price of the product                         |
| 2   | Amp            | The current rating of the product                |
| 3   | Outlets        | The number of outlets                            |
| 4   | Surge protection| The type of surge protection                      |
| 5   | Noise filtering| The type(s) of noise filtering technology         |
| 6   | Over-voltage protection| The type of over-voltage protection |
| 7   | Voltage regulation | The type of voltage regulation technology        |
| 8   | Power boost    | Whether the product provides power boost feature |
| 9   | Power sequencing| Whether the product provides power sequencing feature |
| 10  | UPS            | Whether the product provides energy storage (UPS) |
| 11  | Isolation      | Whether the product provides isolation circuits for different equipment |
| 12  | Indicator      | Whether the product provides system monitoring indicator |
| 13  | USB charger    | Whether the product provides built-in USB charger |
| 14  | Software control| Whether the product can be controlled by software |

3. Mathematical model

To solve the product selection problem, we define set, index, decision variable and parameters as follows.

3.1. Set

\[ P = \text{Set of product} \]
\( C = \) Set of criteria
\( F = \) Set of features

3.2. Index
\( i = \) Index of product
\( j = \) Index of criteria
\( k = \) Index of features

3.3. Variable
\( x_i = \begin{cases} 
0, & \text{if product } i \text{ is not selected} \\
1, & \text{if product } i \text{ is selected}
\end{cases} \)

3.4. Parameter
\( b = \) available budget
\( w_j = \) weight associated with criteria \( j \)
\( c_{ij} = \) score of product \( i \) associated with criteria \( j \)
\( p_i = \) price of product \( i \)
\( r_k = \) requirement of feature \( k \)
\( s_{ik} = \) specification of product \( i \) associated with feature \( k \)

3.5. Mathematical model
The following mathematical model is proposed.

\[
\max \sum_{i \in P} \sum_{j \in C} w_j c_{ij} x_i \quad (1)
\]
\[
\sum_{i \in P} p_i x_i \leq b \quad (2)
\]
\[
\sum_{i \in P} x_i \leq 1 \quad (3)
\]
\[
s_{ik} x_i \geq r_k x_i, \quad \forall i \in P, k \in F \quad (4)
\]
\[
x_i \in \{0,1\}, \quad \forall i \in P \quad (5)
\]

Equation (1) is the objective function where the customer satisfaction is maximized for the selected product based on the weight of each criterion. Equation (2) ensures that the total price is within the available budget. Equation (3) enforces that at most one product can be selected. Equation (4) ensures that the selected product has met the customer’s requirements. Note that the decision variable \( x_i \) on both sides of the inequality is mandatory to ensure that the inequality is feasible for the unqualified product \( x_i = 0 \). Equation (5) defines that the decision variable \( x_i \) is binary for each product \( i \).

4. Experiments and results
In this section, we present experiment for testing the proposed model and the results. Five customers are asked to answer a given set of questions to obtain his/her product requirements and preferences of the product. Four criteria, i.e., price, equipment protection, noise, and
voltage regulation are considered in this experiment. The features of the products are collected from the product manuals. The score of each product which associated with each criterion is provided by the experts of the field.

Table 3 shows the results gathered from the customer surveys as well as the solutions from the proposed model. The recommendations from the expert according to each customer’s requirement are also provided for comparison.

Table 3: Results from customer surveys and product recommendations

| Question                                                                 | Result from customers | Recommendation from proposed model | Recommendation from expert |
|-------------------------------------------------------------------------|-----------------------|------------------------------------|---------------------------|
| 1. What is your budget?                                                 | <= 50,000             | ELITE-16 PFE I                     | PL-PRODMCE                 |
| 2. What is your equipment current rating?                               | <= 10                 | P-6900 AR E                        | P-6900 AR E                |
| 3. What is your maximum number of equipment                             | <= 9                  | F1500-UPS E                        | F1500-UPS E                |
| 4. What level of equipment protection is required? (i.e. surge and over-voltage protections) | medium                | F1500-UPS E                        | F1500-UPS E                |
| 5. What level of sound quality (protection from noise) do you prefer?   | very high             | F1500-UPS E                        | F1500-UPS E                |
| 6. How often do you require for power boost?                            | medium                | F1500-UPS E                        | F1500-UPS E                |
| 7. Do you need power sequencing?                                        | No                    | -                                  | PL-PRODMCE                 |
| 8. Do you need energy storage? (UPS)                                    | Not required          | -                                  | PL-PRODMCE                 |
| 9. How important is power isolation to your equipment?                  | very low              | -                                  | PL-PRODMCE                 |
| 10. Do you care about the status of the power system?                   | No                    | -                                  | PL-PRODMCE                 |
| 11. Do you need built-in USB charger?                                   | No                    | -                                  | PL-PRODMCE                 |
| 12. Do you need software control for the power unit?                    | No                    | -                                  | PL-PRODMCE                 |

From Table 3, we can see that the suggested products from the model agree with the suggestions from the expert in Case 2 and Case 3. In Case 1 however, the model selects a more expensive product which has better features compared to the one suggested by the expert. While the more expensive alternative is still within the customer’s budget, this product has a power boot feature which is rated very high in the customer survey. In contrast, the expert suggests a more economical alternative based on his experience that the ‘PL-PRODMCE E’ is sufficient enough for most users in this level. In Case 4, the model cannot suggest any alternative since there is no product that could meet the customer’s requirements. On the other hand, the expert suggests a combination of three products to the customer which in turn provide solution to the customer. In Case 5, the model suggests a less expensive alternative to the customer compared to the suggestions from the expert (see prices in Table 1). The explanation is that there are no significant differences of the features based on the criteria provided by the customer. In contrast, the suggestions from the expert are based on his personal preferences.

5. Conclusion

In this paper, we proposed a mathematical programming model to solve the product selection problem where multiple criteria are considered in the objective function. The model is tested by using a real case in studio recording for selecting a suitable power unit. We compared the results from the model with the recommendations from the expert. The results are well applicable but with limitation for recommendation with combination of the products.

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