# Unravelling Consumer Choices: A Comparative Analysis of Decision-Making Models

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**ABSTRACT**
*This case provides an illustration of the application of various consumer decision-making models to select from a number of alternatives, represented here by physics-related smartphone apps. It covers the weighted additive difference, conjunctive, disjunctive, lexicographical, and elimination by aspects methodologies, representing popular consumer decision-making models in managerial area. It also covers the simple additive weighting (SAW) approach from multi-attribute decision-making area. In addition, it highlights the rank inconsistency phenomenon, which is often considered unavoidable with most decision-making models. Here, this paper applies the unified commensurate multiple (UCM) approach, which successfully addresses this problem of rank inconsistency and leads to more consistent rankings, whereby removal of the lowest-ranked alternative does not affect the overall rankings of the abovementioned smartphone apps.*

**KEYWORDS:** *multiple criteria decision-making, rank inconsistency, unified commensurate multiple (UCM) model.*

**JEL CLASSIFICATION:** *C02, C63*

## 1. INTRODUCTION

This case focuses on consumer decision making models. A young college professor has a reputation for innovative teaching and research. She challenges her senior seminar students to come up with innovative smartphone apps for physics. The students are told that if they create something good, perhaps it could be sold, and the funds split among the students. However, due to university restrictions, she must select only one or possibly two apps. Here, the university's Center for Entrepreneurship could help her choose the best app(s) from a marketing standpoint.

Learning objectives from this case might include reinforcement of price and cost/benefit concepts, application of consumer behaviour decision models, interpretation of the results of these decision models, expanding knowledge on multiple criteria decision-making methodologies, and understanding the implications of their results. Although the most likely use of this case is in an undergraduate consumer behaviour class, it could also be used in other management or economics classes that cover decision making models.

Chun et al. (2013) focused on the consumer aspects of smartphone apps by considering consumers' satisfaction with smartphone app use. Specifically, the study elaborates on various factors affecting consumers' satisfaction with smartphone app use, including needs fulfilment, performance improvement, easy to use, easy to understand, security/privacy, and influence of the peer. Chun et al. (2013) found that most respondents were satisfied with the

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use of smartphone apps, and that their satisfaction level was affected by factors such as needs fulfilment, performance improvement, ease of use, security/privacy, and influence of the peer.

Chun et al. (2013) research returned 165 usable surveys and a factorial analysis on the measurement items was conducted to group them into four factors, namely usefulness, easy to use, security/privacy, and social conforming. We have adopted the four factors from Chun et al. (2013) and have also adapted their measurement items. The same is presented in Table 1.

The results of a standardised canonical discriminant analysis could be used to assign decisional weights to each factor. For example, 'Usefulness' is 0.6, while 'Easy to Use' is 0.7. This could result from a lot of smartphone app downloads simply for fun, even though the app itself may not be used much. Also, 'Security/Privacy' is a 0.4 while 'Social Conforming" is only 0.5. This may be surprising, but perhaps there are as many nonconformists out there as conformists.

**Table 1. Decision factors and measurements**

| Factors | Measurement Items |
|---|---|
| Usefulness | An app that will enable you to accomplish your needs |
| | An app that will increase productivity on the job |
| | An app that will improve your job performance |
| | An app that will get the work done |
| Easy to Use | An app that is easy to operate |
| | An app with clear and understandable interaction |
| Security/Privacy | I am concerned about the security issues of phone |
| | I am concerned that my personal information may be downloaded while I am |
| | I always observe the privacy rules set in the smart phone operating system |
| Social Conforming | Your peers (would) own/use the same apps |
| | Your peers use (would use) the same carrier |
| | Your peers (would) choose the same smart phones |

*Source*: adapted from Chun et al. (2013), p. 30.

The paper is structured as follows: Section 2 explores the phenomenon of rank inconsistency through analytic theories in the management field. In Section 3, we investigate the cause of rank reversal and propose a method to prevent it, drawing on theories from the multiple criteria decision-making domain. A numerical example is revisited using the proposed approach to verify its effectiveness and practicality in preserving ranks. The paper concludes in Section 4.

## 2. LINKAGES TO MANAGERIAL THEORIES

According to Thakkar (2021), the multiple criteria decision-making process involves three broad steps: 1) based on existing theory and practice, one should identify the relevant criteria and alternatives, 2) one should assign numerical values to these criteria, reflecting their relative importance, and also to the alternatives, based on their impacts on the relevant criteria, and 3) one should use a formal mathematical procedure to analyse the numerical values from step two and arrive at a ranking of the different alternatives.

The apps to be rated (out of a possible 10 points), in this case, and the results are shown in Table 2. App A: This app shows the amount of radiation a person has been exposed to, based on factors such as age, occupation, where he/she lives, etc. The results were correlated to health risks that might occur based on similar exposure throughout their life and things that they could consider alleviating these risks.

The remaining apps were App B: Exposure checks for radiation technologists, App C: Physics experiments, App D: Quantum physics particle finder, App E: Physics equation finder, and App F: 3-D molecules and atoms.

**Table 2. Factors with weights and Apps rated in a decision matrix**

| Factors/Apps | Weight | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Usefulness | 0.6 | 6 | 7 | 8 | 6 | 4 | 6 |
| Easy to Use | 0.7 | 8 | 8 | 9 | 4 | 8 | 3 |
| Security/Privacy | 0.4 | 7 | 7 | 7 | 6 | 6 | 7 |
| Social Conforming | 0.5 | 7 | 5 | 4 | 8 | 4 | 5 |

*Source*: Author's own work

Here, we have applied some popular decision-making models. However, the instructor may introduce other models depending on their coverage in the required textbook and on the students' level of knowledge. We have used weighted additive difference, conjunctive, disjunctive, lexicographical, and elimination by aspects and have also discussed low/high effort and cognitive/affective decision-making in our answer.

### 2.1 Weighted additive difference

In this model, the ratings are multiplied by the weights and then summed. In other words, A's score would be computed as follows:

$$0.6 * 6 + 0.7 * 8 + 0.4 * 7 + 0.5 * 7 = 15.5$$

The results from this model are as follows, and App C is the clear winner. (Table 3)

**Table 3. Results from the Weighted Additive Difference method**

| Factors/Apps | Weight | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Usefulness | 0.6 | 6 | 7 | 8 | 6 | 4 | 6 |
| Easy to Use | 0.7 | 8 | 8 | 9 | 4 | 8 | 3 |
| Security/Privacy | 0.4 | 7 | 7 | 7 | 6 | 6 | 7 |
| Social Conforming | 0.5 | 7 | 5 | 4 | 8 | 4 | 5 |
| **Score** | | 15.5 | 15.1 | 15.9 | 12.8 | 12.4 | 11.0 |

*Source*: Author's own work

### 2.2 Conjunctive

In the conjunctive model, a cutline score is established. Each factor is assessed individually, and any applications that score below this threshold are eliminated. Given that the original scale is 10 points, a cut-off of above 5 (50%) serves as a reasonable starting point.

When assessing usefulness, we eliminate App E. for easy to use, we lose App D and App F. No applications are discarded for security/privacy. However, in evaluating social conforming, we remove Apps B, C, E, and F. This leaves App A as our final choice. This can be represented in Table 4.

**Table 4. Results from the Conjunctive method**

| Factors/Apps | Weight | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Usefulness | 0.6 | 6 | 7 | 8 | 6 | | 6 |
| Easy to Use | 0.7 | 8 | 8 | 9 | | 8 | |
| Security/Privacy | 0.4 | 7 | 7 | 7 | 6 | 6 | 7 |
| Social Conforming | 0.5 | 7 | | | 8 | | |

*Source*: Author's own work

### 2.3 Disjunctive

In the disjunctive method, we prioritise the factors based on their importance. We consider the top two factors and eliminate all but the highest-ranking application. If there's a tie, we proceed to the third factor, and so on. The top two factors in this case are "ease of use" and "usefulness." After the first round of evaluation, we identify a winner: App C. (See Table 5).

**Table 5. Results from the Disjunctive method**

| Factors/Apps | Weight | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Usefulness | 0.6 | 6 | 7 | 8 | 6 | 4 | 6 |
| Easy to Use | 0.7 | 8 | 8 | 9 | 4 | 8 | 3 |
| **Sum** | | 14 | 15 | 17 | 10 | 12 | 9 |

*Source*: Author's own work

### 2.4 Lexicographical

This decision model focuses on the factors of importance as well. In this case, we look for the best of the most important factors and eliminate all the others. 'Easy to Use' is the most important factor. App C is the only app to rate at 9. App C wins again.

### 2.5 Elimination by aspects

Once again, we look at the factors in order of importance. We also establish a cutline value. If we use 5 as the cutline again and reorder the factors in terms of importance, we will get the results shown in the table below. With this model, we are now back to "App A" as the only choice. (Table 6)

**Table 6. Results from the Elimination by Aspects method**

| Factors/Apps | Weight | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Easy to Use | 0.7 | 8 | 8 | 9 | | 8 | |
| Usefulness | 0.6 | 6 | 7 | 8 | 6 | | 6 |
| Security/Privacy | 0.4 | 7 | 7 | 7 | 6 | 6 | 7 |
| Social Conforming | 0.5 | 7 | | | 8 | | |

*Source*: Author's own work

Discussion/Follow-up: While App C is the choice in three of the five models discussed, App A is the choice in two of these models. Here, App C still comes up in the weighted additive model, but App A is a very close competitor. If you were able to market two apps, the decision would be easier. The other apps never appear as the best choice, and, indeed, some of them do not fare well in any test.

## 3. LINKAGES TO MULTIPLE CRITERIA DECISION-MAKING THEORIES

### 3.1 Simple Additive Weighting (SAW) Method

Similarly to the weighted additive difference method previously applied, simple additive weighting (SAW) is one of the most used mathematical tools for multiple criteria decision-making problems involving *n* alternatives and *m* decision attributes (Hwang & Yoon, 1981). In this approach, each alternative is assessed based on the m attributes. The evaluation scores are normalised using the following equation (1) to remove the dimensional units of the attributes.

$$A_{ij} = (a_{ij} - a_j^{min}) \div (a_j^{max} - a_n^{min}), \qquad i = 1, \dots, n; j = 1, \dots, m \qquad (1)$$

The overall assessment value for each alternative is calculated by summing the products of the evaluation scores and the weights of relative importance assigned by the decision maker to each attribute. The higher the overall priority value, the more favourable the alternative.

**Table 7. Decision matrix for the SAW method**

| | Useful | EasyUse | Secu | Social | Useful | EasyUse | Secu | Social | Priority | Composite | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.60 | 0.70 | 0.40 | 0.50 | 0.60 | 0.70 | 0.40 | 0.50 | | | |
| **A** | 6 | 8 | 7 | 7 | 0.5 | 0.83 | 1 | 0.75 | 1.658 | 0.229 | C>A>B>D>F>E |
| **B** | 7 | 8 | 7 | 5 | 0.75 | 0.83 | 1 | 0.25 | 1.558 | 0.215 | |
| **C** | 8 | 9 | 7 | 4 | 1 | 1.00 | 1 | 0 | 1.700 | 0.235 | |
| **D** | 6 | 4 | 6 | 8 | 0.5 | 0.17 | 0 | 1 | 0.917 | 0.127 | |
| **E** | 4 | 8 | 6 | 4 | 0 | 0.83 | 0 | 0 | 0.583 | 0.081 | |
| **F** | 6 | 3 | 7 | 5 | 0.5 | 0.00 | 1 | 0.25 | 0.825 | 0.114 | |
| **A** | 6 | 8 | 7 | 7 | 0 | 0.83 | 1 | 0.75 | 1.358 | 0.242 | C>**B>A**>D>F |
| **B** | 7 | 8 | 7 | 5 | 0.5 | 0.83 | 1 | 0.25 | 1.408 | 0.251 | |
| **C** | 8 | 9 | 7 | 4 | 1 | 1.00 | 1 | 0 | 1.700 | 0.303 | |
| **D** | 6 | 4 | 6 | 8 | 0 | 0.17 | 0 | 1 | 0.617 | 0.110 | |
| **F** | 6 | 3 | 7 | 5 | 0 | 0.00 | 1 | 0.25 | 0.525 | 0.094 | |

*Source*: Author's own work

The SAW method is also susceptible to the rank inconsistency problem when an alternative is added or removed. In Table 7, when alternative E, which has the lowest priority value, is removed from the original set, the ranking between A and B is reversed, resulting in B becoming the second-best alternative. In contrast, the next method, the unified commensurate multiple (UCM) approach, maintains the original rankings in both scenarios.

### 3.2 Unified Commensurate Multiple (UCM) approach

This approach was introduced by Shin and Lee (2012). In this method, a matrix, Aij' is multiplied by L, the least common multiple (LCM) of all column sums of criteria, where

$$L = \sum_{j=1} \sum_{i=1} a_{ij} \qquad (2)$$

Next, the weight vector of criteria ($C_j$ ) is defined as $C_j = [\, c_1 \quad c_2 \quad c_3 \ \text{------------} \ c_j \,]^T$.

Multiplying the criteria weight vector $C_j$ by the revised value matrix $A_{ij}''$ produces the data matrix $X_i$ as shown below in equation (3).

$$X_i = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \cdots \\ x_i \end{bmatrix} = \begin{bmatrix} \frac{a_{11}\ c_1 L}{\sum_{i=1} a_{i1}} + \frac{a_{12}\ c_2 L}{\sum_{i=1} a_{i2}} + \frac{a_{13}\ c_3 L}{\sum_{i=1} a_{i3}} + \dots\dots\dots + \frac{a_{1j}\ c_j L}{\sum_{i=1} a_{ij}} \\ \frac{a_{21}\ c_1 L}{\sum_{i=1} a_{i1}} + \frac{a_{22}\ c_2 L}{\sum_{i=1} a_{i2}} + \frac{a_{23}\ c_3 L}{\sum_{i=1} a_{i3}} + \dots\dots\dots + \frac{a_{2j}\ c_j L}{\sum_{i=1} a_{ij}} \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \frac{a_{i1}\ c_1 L}{\sum_{i=1} a_{i1}} + \frac{a_{i2}\ c_2 L}{\sum_{i=1} a_{i2}} + \frac{a_{i3}\ c_3 L}{\sum_{i=1} a_{i3}} + \dots\dots\dots + \frac{a_{ij}\ c_j L}{\sum_{i=1} a_{ij}} \end{bmatrix} \tag{3}$$

Finally, equation (4) provides the normalised composite weights of alternatives.

$$X_i' = \begin{bmatrix} \frac{x_1}{\sum_{i=1} x_i} & \frac{x_2}{\sum_{i=1} x_i} & \frac{x_3}{\sum_{i=1} x_i} \dots\dots\dots \frac{x_i}{\sum_{i=1} x_i} \end{bmatrix}^T \tag{4}$$

Due to the converted matrix of the unified commensurate unit, the rank inconsistency phenomenon in multiple-attribute decision making problems can be avoided without the need to adjust the weights of criteria or wondering about structural or functional dependency and independence.

**Table 8. Revised Decision matrix for the SAW method**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 6 | 8 | 7 | 7 | 7920 | 9768 | 8547 | 10360 | 20188.4 | 0.188 | C>A>B>D>E>F |
| **B** | 7 | 8 | 7 | 5 | 9240 | 9768 | 8547 | 7400 | 19500.4 | 0.181 | |
| **C** | 8 | 9 | 7 | 4 | 10560 | 10989 | 8547 | 5920 | 20407.1 | 0.190 | |
| **D** | 6 | 4 | 6 | 8 | 7920 | 4884 | 7326 | 11840 | 17021.2 | 0.158 | |
| **E** | 4 | 8 | 6 | 4 | 5280 | 9768 | 7326 | 5920 | 15896.0 | 0.148 | |
| **F** | 6 | 3 | 7 | 5 | 7920 | 3663 | 8547 | 7400 | 14434.9 | 0.134 | |
| **A** | 6 | 8 | 7 | 7 | 7920 | 9768 | 8547 | 10360 | 20188.4 | 0.188 | C>A>B>D>E |
| **B** | 7 | 8 | 7 | 5 | 9240 | 9768 | 8547 | 7400 | 19500.4 | 0.181 | |
| **C** | 8 | 9 | 7 | 4 | 10560 | 10989 | 8547 | 5920 | 20407.1 | 0.190 | |
| **D** | 6 | 4 | 6 | 8 | 7920 | 4884 | 7326 | 11840 | 17021.2 | 0.158 | |
| **E** | 4 | 8 | 6 | 4 | 5280 | 9768 | 7326 | 5920 | 15896.0 | 0.148 | |

*Source*: Author's own work

Table 8 illustrates that the original rankings in the decision matrix are C>A>B>D>E>F. Notably, when we remove the alternative F, which had the lowest rank, all other rankings remain intact. We still have A at 0.188 and B at 0.181, with A is continuing to be preferred over B.

As is known, normalisation is essential in multiple criteria decision-making theories to address the dimensional disparities between criteria or alternatives. The UCM method presented in this paper identifies that rank reversal occurs as a result of the normalisation process, rather than the removal of an alternative.

## 4. CONCLUSIONS

The rank reversal (or rank inconsistency) phenomenon is evident in both popular managerial models and many well-known multi-attribute decision-making methods. Numerous studies suggest that rank inconsistency is an unavoidable issue when any decision-making method is employed. Some research indicates that this problem is particularly pronounced when decision makers work with criteria measured in different units.

Analytic hierarchy process (AHP), developed by Saaty and Sagir (2009), is a widely used decision-making tool. In an early critique, Belton and Gear (1983) demonstrated that rank inconsistency occurs when an exact copy of an alternative is added.

To mitigate the rank inconsistency phenomenon in decision matrices, various mathematical approaches (Bazilai et al., 1994; Dyer & Wendell, 1985; Kendall, 1962; Schoner et al., 1993) have been proposed for synthesising composite priority vectors across different criteria.

Despite this, there is a growing consensus that no normalisation method can fully address rank inconsistency issues. This paper, however, employs an alternative method known as the unified commensurate multiple (UCM) approach (Shin & Lee, 2012) to prevent the rank inconsistency phenomenon in decision matrices where such changes should not occur.

It is crucial for an effective decision-making method to avoid ranking inconsistencies when alternatives are added and removed. Although the UCM method (Shin & Lee, 2012) does not encounter these problems, further research in decision analysis is essential to ensure the development of a reliable ranking that can be trusted.

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