A Study on the Procedure of Decision-Making for Entrance Architecture of Modern MRT Station in Taiwan

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Abstract

The purpose of this study is to establish a set of consistent guidelines for deciding entrance architecture of modern MRT (Mass Rapid Transit) stations in Taiwan, so that the details of construction, passenger circulation, and operation and maintenance procedures will be uniform throughout the entire MRT network. There exist the multi-criteria evaluation of subjectivities and externalities for the decision. To fulfill the interaction between subjectivities and externalities, we applied the appropriate ways, which included 1) the method of key-informant interview with decision-makers, professionals, experts and scholars to establish the multi-criteria, 2) the method of questionnaire and mathematical calculation to establish the weighting of each criterion, and finally applied 3) the method of multi-criteria evaluation with qualitative and quantitative data (MEQQD) for decision making. After the procedure of this study, it was found that ‘site response’ was the most dominant criterion and the method of MEQQD could evaluate the alternatives to obtain the objective and appropriated consequence.

Keywords: entrance architecture; MRT station; multi-criteria evaluation; MEQQD

1. Introduction

1.1 The architecture of MRT System

Since the first MRT line- Mucha Line- a medium capacity elevated system started running in Taipei city of Taiwan, 1996, rapid development and regeneration of urban environment and activities along the MRT lines in Taipei are observed. Facing these challenges of the rapid economic growth and urban development, Kaohsiung, Taiwan’s 2nd largest city and its most important commercial harbor, has been proceeding a MRT system including two lines in a total length of 42.7 kilometers and 37 stations together along the routes, and the construction has already been started on October 24, 2001. MRT system will play an important role on urban development and townscape regeneration these years in Taiwan.

The developed architectural form and image of MRT is the visible and emotional connection between stations and their surroundings. The purpose of MRT design should provide an attractive and comfortable environment for people. (KMRT, 1994a; DORTS, 1998a) Meanwhile, it should be as transparent as possible, both architecturally and structurally to reduce the visual impact and to allow passengers to orient themselves.

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materialized lines of force have become an image for the design of transport constructions symbolizing speed and mobility. (Kelly, 1989) The visual effect on passengers comes from the architecture of the stations is officially regarded as a tangible indicator of the value and quality of transport systems. (Fai, 1987) Therefore, how to create a highly technical functional construction of entrance architecture with high passengers density, through security and safety precautions, operational constraints, choice of materials, maintenance problems and strict financial limits is a main issue for MRT designers.

1.2 Multi-criteria of evaluation

The architectural design of station, besides makes primarily to accommodate the demands of the passengers, vehicular system and station operating staff, shall also provide the passengers with a safe, convenient, comfortable and appealing environment, as well as offer a lasting quality of easy maintenance, straightforward servicing, low-cost replacement and extended use. (KMRT, 1994b; DORTS, 1998b) The design goals of the MRT entrances shall be reflected in the architectural concept including modern design that reflects the lifestyle of the greater metropolis and the vision for the future, life-cycle cost effectiveness, sustainable operation, responsiveness to the public’s needs and to neighborhood character, minimal impact on surrounding properties, low maintenance and safety.

There exist specific interactions among the entrance of MRT station, passengers’ circulation, landscape and environment of urban context. Namely, environmental improvement by MRT station planning will increase the accessibility and aesthetics of urban area served by new MRT systems. In the aspect of interactions between MRT station and urban environment impacts, especially the architecture of entrance supplys, which stimulates architectural form, structure and technology, also creates new meaning of future architecture and urban landscape. However, MRT architectural subjectivities such as construction cost, maintennance and life, which are induced by the increasing usage of passengers and vehicles are unsettled, and eventuate in facilities replacing costs and impair effectiveness. To fulfill the interaction between subjectivities and externalities, it is appropriate to determine the alternative of entrance architecture of MRT station by the ways of multi-criteria evaluation.

Based on the considerations mentioned above, this study from a viewpoint of multi-criteria evaluation applies an approximation method to represent. A deterministic model by applying a qualitative and quantitative programming method is proposed to explore relationships between subjectivities and externalities by taking into account several critical factors. There are three issues discussed in this study, that is, 1) establishment of multi-criteria for decision-making, 2) weighting of each criterion, 3) evaluation mode of decision-making.

2. Methods

This study constructs a static and deterministic procedure about establishment of multi-criteria, weighting of each criterion and alternative of decision-making by considering critical factors including MRT image, construction cost, environment systems and effective maintenance etc. Procedure constructed herein is applied a consistent theoretical and mathematical method, i.e., the method of key-informant interview with experts and scholars to establish the multi-criteria about decision-making; mathematical calculation of the mean about each criterion to establish the weighting; the method of multi-criteria evaluation with qualitative and quantitative data (MEQOD) to decide the appropriated alternative. The methods of this study are summarized as follows:

![Fig.1. The applied methods of this study](image)

2.1 Key-informant interview

The first step of this study was to establish the evaluated multi-criteria, and adopted the method of key-informant interview. The basic targets of key-informant interview were the decision makers, professionals, experts and scholars who possess the professional knowledge or technology and were willing to share their opinions with the researchers. (Goetz and LeCompte, 1984) The basic targets of key-informant interview for this study are shown in table 1.

2.2 The mean of the given scores of criteria

After the first step, we categorized the results of key-informant interview and established the main multi-criteria including the qualitative (the criterion of site response, orientation and intentionality of MRT system, high-tech image and ethereal form, feasibility of maintenance) and quantitative (the criterion of construction cost, length of life) criteria, which are shown in table 2.
The second step of this study was to establish the weighing of each criterion by the method of questionnaire and mathematical mode to calculate the mean of each criterion’s score. The targets of questionnaire were the same as the first step. Each respondent was asked to rank from ‘very high’ (score 10) to ‘very low’ (score 1). According to eq.1, we established the weighting of each criterion by the mathematical method of calculating the mean scores.

\[
Ma = \frac{\sum_{i=1}^{n} (x_i \cdot n_i)}{n}
\]

\(Ma\): the Mean of ‘criterion \(a\)’ weighting.
\(x_i\): the specimen \(i\) of questionnaire.
\(n_i\): the weighting of the specimen \(i\).
\(n\): the total number of questionnaire.

2.3 Multi-criteria evaluation with qualitative and quantitative data (MEQQD)

The method of multiple criteria evaluation is generally applied to evaluate different schemes. According to the consequence of theory review, the multi-criteria of decision-making for entrance architecture of MRT station are composed by critically qualitative and quantitative data. The method of multi-criteria evaluation with qualitative and quantitative data (MEQQD) can evaluate the complicated issues which contain the qualitative and quantitative criteria simultaneously. (Hwang and Yoon, 1981) The procedure of MEQQD is summarized as follows:

1) Categorizing qualitative and quantitative criteria.
   \(O\)=\{The set of all qualitative criteria\}
   \(C\)=\{The set of all quantitative criteria\}

2) Calculation of standardization of criteria score of quantitative criteria.
   \(\tilde{e}_k = (e_k - \bar{e}_k) / (e^*_k - \bar{e}_k)\)
   \(e^*_k\): the best value among all options under the ‘criterion \(k\)’
   \(\bar{e}_k\): the worst value among all options under the ‘criterion \(k\)’

3) Measuring the dominance level of each alternatives.
   a. MEQQD measures the dominance level of

\(e_k\): the criteria score of ‘option \(i\)’ under the ‘criterion \(k\)’
\(\tilde{e}_k\): the standardization value of \(e_k\)
\(\bar{e}_k\): the best value among all options under the ‘criterion \(k\)’
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   \(\bar{e}_k\): the worst value among all options under the ‘criterion \(k\)’

3) Measuring the dominance level of each alternatives.
   a. MEQQD measures the dominance level of
qualitative criteria as \( F \) Function shown below:
\[
a_i = F(e_k, a_k, W_k), \quad k \in O
\]
\[
= \left\{ \sum \left( W_k (e_k - e_k) \right) \right\}^{1/1}
\]
\( a_i \): the measuring level of ‘option i’ better than ‘option j’.
\( W_k \): the weighting of qualitative ‘criterion k’
\( r \): scaling parameter
The function \((e_k - e_k)\) means below:
\[
(e_k - e_k) = \begin{cases} +1, \text{ if } e_k > e_k \\ 0, \text{ if } e_k = e_k \\ -1, \text{ if } e_k < e_k \end{cases}
\]
Where \( e_k \) (or \( e_k \)) can be represented as ranking or degree of satisfaction for calculation. (Feng and Lin, 1988)
b. MEQQD measures the dominance level of quantitative criteria as \( G \) Function shown below:
\[
c_i = G(e_k, a_k, W_k), \quad k \in C
\]
\[
= \left\{ \sum \left( W_k (e_k - e_k) \right) \right\}^{1/1}
\]
c_i : the measuring level of ‘option i’ better than ‘option j’.
The meaning of the other variables is the same as above.
(4) Standardization of dominance level
There are two basic assumptions in MEQQD: one is that the mean of appraisal score of each option is a constant (we assume this constant is 0); the other is that the dominance level of the ‘option i’ and ‘option j’ can be the subtraction of these two appraisal scores.
The mathematical equation of these basic assumptions can be shown below:
\[
(1/1) \sum_j s_j = 0
\]
(Assuming that there are \( J \) options, and \( s_j \) is the appraisal scores of ‘option i’)
\[
m_i = K(s_i, s_j) = s_i - s_j
\]
and defines \( m_i = W_j b_j + W_i d_j \)
\[
(8)
\]
(The calculation equation of \( b_j \) and \( d_j \) refers to eq.8 and eq.9)
Where \( W_j = \sum_{k \neq i} W_k \)
\( W_i = \sum_{k \neq i} W_k \)
And \( W_j + W_i = 1 \)
a. Standardizing the dominance level of qualitative criteria.
\[
b_j = H(a_i) = a_i / \sum_j a_i
\]
b_j : the standardization of the dominance level of the ‘option i’ compare to ‘option j’
b. Standardizing the dominance level of quantitative criteria.
\[
d_j = H(c_i) = c_i / \sum_j c_j
\]
d_j : the standardization of the dominance level of the ‘option i’ compare to ‘option j’
(5) Calculating the appraisal score of each alternative and evaluating.
Because \( m_j = s_j / s_j \) (from eq. 6), so we can establish the mathematical equation shown below:
\[
\sum_j m_j = \sum_j s_j - \sum_j s_j = s_j - s_j
\]
\[
s_i = (1/1) \sum_j m_j + (1/1) \sum_j s_j
\]
Given \((1/1) \sum_j s_j = 0\) from eq.5
\[
s_i = (1/1) \sum_j m_j
\]
The whole procedure of MEQQD from ‘step (1)’ to ‘step (5)’ can be generalized and presented on Fig. 2.

According to these applied methods, we tried to find out the multi-criteria, weighting of each criterion and the appropriated alternatives.

3. Result
According to the result of this study shown above, we tried to execute a case based on the method of MEQQD to find out the most suitable alternative.

3.1 Establishment of the multi-criteria
According to the results of key-informant interview, we categorized the targets’ opinions and established the main multi-criteria for evaluating the entrance architecture of MRT station. According to the procedure of section 2-2, the results of questionnaire are shown in table 3. For checking the \textit{Internal Consistency Reliability} of this questionnaire, we calculated the \textit{Cronbach a} value of each criterion.
\[
\alpha = \frac{n}{n-1} \left( 1 - \sum_j \frac{s_j^2}{\bar{S}^2} \right)
\]
\( \alpha \): the value of consistency reliability
\( n \): the amount of criteria
\( \bar{S} \): the variance of each criterion score
\( \bar{S} \): the variance of all criteria scores
According to eq.13, we calculated the value of Cronbach \( \alpha = 0.8540 \) (0.7 \( \leq \text{Cronbach } \alpha \)), and the reliability of this survey is ranked ‘very high’. (Guieford, 1965; Nunnally, 1978).
Because this study was by the method of key-informant interview with three categories including decision-makers, professionals, experts and scholars who possess the professional MRT knowledge or technology to establish the multi-criteria, the validity was high. Meanwhile, we established the two-way table to examine the content validity using the method of MEQQD. The criteria were able to meet the objectives and the content validity was acceptable. This result is shown in table 4.

### Table 3. The results of questionnaire

| Evaluation | Criterion                     | Mean | Max. Value | Min. Value | Standard deviation | Cronbach α Value | Cronbach α Value except this criterion |
|------------|-------------------------------|------|------------|------------|--------------------|-----------------|----------------------------------------|
| Qualitative| Site Response                 | 9    | 10         | 7          | 0.8165             | 0.7996          |                                        |
| Qualitative| Orientation and intentionality of MRT system | 8.333 | 10         | 6          | 1.0541             | 0.8326          |                                        |
| Qualitative| High-tech image and ethereal form | 7.722 | 10         | 6          | 0.9313             | 0.8401          |                                        |
| Qualitative| Feasibility of maintenance    | 7.056 | 8          | 6          | 0.7800             | 0.8457          |                                        |
| Quantitative| Construction cost             | 8.111 | 10         | 7          | 0.8089             | 0.8398          |                                        |
| Quantitative| Length of life                | 7.444 | 9          | 6          | 0.8958             | 0.8172          |                                        |

### Table 4. The two-way table of content validity

| Objective                     | Environment Impact | Expression of MRT system | Control of Cost | Sustainable Operation |
|-------------------------------|--------------------|--------------------------|-----------------|----------------------|
| Site Response                 | ✅                 |                          | ✅              |                      |
| Orientation and intentionality of MRT system | ✅               | ✅                       | ✅              |                      |
| High-tech image and ethereal form | ✅               | ✅                       | ✅              |                      |
| Feasibility of maintenance    | ✅                 | ✅                       | ✅              |                      |
| Construction cost             | ✅                 | ✅                       | ✅              |                      |
| Length of life                | ✅                 | ✅                       | ✅              |                      |

### 3.2 Weighting of each criterion

According to eq.1, the priorities of the criteria with respect to our goal are as follows: site response (0.189), orientation and intentionality of MRT system (0.175), construction cost (0.170), high-tech image and ethereal form (0.162), length of life (0.156) and feasibility of maintenance (0.148) as shown in table 5.

### Table 5. The weighting of the multi-criteria

| Ranking | Criterion                        | Weighting |
|---------|----------------------------------|-----------|
| 1       | Site Response                    | 0.189     |
| 2       | Orientation and intentionality of MRT system | 0.175   |
| 3       | Construction cost                | 0.170     |
| 4       | High-tech image and ethereal form | 0.162     |
| 5       | Length of life                   | 0.156     |
| 6       | Feasibility of maintenance       | 0.148     |

### 3.3 Case study-A decision-making of alternatives

1. Establishment of evaluation

In the first step, we rearranged the qualitative and quantitative criteria for evaluating the alternatives according to the results of table 3 and table 5 for this case study. The result is shown in table 6.
Table 6. The index of the multi-criteria on evaluation

| Index               | Criterion                                    | Weighting |
|---------------------|----------------------------------------------|-----------|
| Quantitative        | Construction cost (k=1)                      | 0.170     |
|                     | Length of life (k=2)                         | 0.156     |
| Qualitative         | Site Response (k=3)                          | 0.189     |
|                     | Orientation and intentionality of MRT system (k=4) | 0.175     |
|                     | High-tech image and ethereal form (k=5)      | 0.162     |
|                     | Feasibility of maintenance (k=6)             | 0.148     |

(2) Evaluation by the method of MEQQD
Here, there were 3 options developed by the design architect for evaluating. We applied the method of MEQQD to find out the most favored alternative according to the evaluation of multi-criteria.

a. Evaluation of quantitative data

Table 7. The quantitative data of the alternatives

| Option            | Option 1                  | Option 2                  | Option 3                  |
|-------------------|---------------------------|---------------------------|---------------------------|
| Quantitative      | 6.5M NTD.                 | 7.5M NTD.                 | 6.0M NTD.                 |
| Construction cost | 6.5M NTD.                 | 7.5M NTD.                 | 6.0M NTD.                 |
| Length of operation life | 30 yrs                   | 35 yrs                   | 35 yrs                   |

(a) According to eq.2, we calculated \( \hat{\epsilon}_2 \), (k=1)

The best value of criterion ‘construction cost’ is the lowest one. According to Table 7, the lowest construction cost is 6.0M NTD., option 3.

So, \( \hat{\epsilon}_2 = (6.5 - 7.5) / (6.0 - 7.5) = 0.667 \)

\( \hat{\epsilon}_3 = 0 \)

\( \hat{\epsilon}_1 = 1 \)

Similarly, according to eq.2, we calculated \( \hat{\epsilon}_2' \). The best value of criterion ‘length of operation life’ is the longest life. According to Table 7, the longest life is 35 years, option 1 and option 2.

So, \( \hat{\epsilon}_2' = (30 - 30) / (35 - 30) = 0 \)

\( \hat{\epsilon}_3' = 1 \)

(b) Measure the dominance level
According to eq.4, we established a mathematical equation to calculate the value of \( c_{ij} \).

Because the establishment of weighting was by the results of questionnaire and Cronbach α value is greater than 0.7, the reliability of each criterion’s weighting is very high. According to the theory of Voogd (1983), we can assume \( r = 1 \) in case of the high reliability of the given criteria.

\( c_{i2} = (0.170) \times (0.667 - 0) + (0.156) \times (0 - 1) = -0.043 \)

\( c_{i3} = -0.213 \)

\( c_{i1} = -0.170 \)

Similarly, \( c_{21} = 0.043, c_{23} = 0.213, c_{22} = 0.170 \)

(c) Standardizing the dominance level
According to eq.9, we established a mathematical equation to calculate the value of \( d_{ij} \).

\[ \sum \mid d_{ij} \mid = \mid (-0.043) \mid + \mid (-0.0213) \mid + \mid (-0.170) \mid + 0.043 + 0.0213 \mid + 0.170 \mid = 0.851 \]

\( d_{i2} = (-0.043) / 0.851 = -0.050 \)

\( d_{i3} = (-0.213) / 0.851 = -0.250 \)

\( d_{i1} = (-0.170) / 0.851 = -0.200 \)

Similarly, \( d_{21} = 0.050, d_{23} = 0.250, d_{22} = 0.200 \)

b. Evaluation of qualitative data

(a) Establishment of the appraisal scores
For evaluation of these options about the qualitative criteria, we established a decision committee composed 8 experts and scholars. Each member had scored 1 (the lowest) to 10 (the highest) for each quantitative criterion. After calculating the mean of each criterion, we built a list to show the appraisal scores and to measure the dominance level.

Table 8. The scores of qualitative criteria of the alternatives

| Option            | Option 1                  | Option 2                  | Option 3                  |
|-------------------|---------------------------|---------------------------|---------------------------|
| Quantitative      | 8.375                     | 8.675                     | 8.125                     |
| Site Response     | 8.375                     | 8.675                     | 8.125                     |
| Orientation and intentionality | 7.75                   | 8.125                     | 7.5                      |
| Image and form    | 8.125                     | 8.5                       | 8.0                       |
| Feasibility of maintenance | 8.5                    | 7.875                     | 8.25                      |

(b) measure the dominance level
According to eq.3, we assumed \( r = 1 \). We established a mathematical equation to calculate the value of \( a_{ij} \).

\[ a_{i2} = (0.189) \times (8.375 - 8.125) + (0.175) \times (7.75 - 8.125) + (0.162) \times (8.125 - 8.5) + (0.148) \times (8.5 - 7.875) = -0.081 \]

\( a_{i1} = 0.148 \)

\( a_{i2} = 0.229 \)

Similarly, \( a_{i3} = 0.081, a_{i1} = -0.148, a_{i2} = -0.229 \)

(c) Standardizing the dominance level
According to eq.8, we established a mathematical equation to calculate the value of \( b_{ij} \).
c. Calculating the appraisal score of each alternative and evaluating.

According to eq.9, we established a mathematical equation to calculate the value of \(m_{ij}\).

\[
\Sigma a_{ij} = |(-0.081) + 0.148 + 0.229 + 0.081 + (-0.0213) + (-0.170)| = 0.917
\]

\[b_1 = (-0.081)/0.917 = -0.088\]

\[b_2 = (0.148)/0.917 = 0.162\]

\[b_3 = (0.229)/0.917 = 0.250\]

Similarly, \(b_2 = 0.088, b_3 = -0.162, b_3 = -0.250\).

\[\]

d. Evaluating the options.

According to eq.10, eq.11, and eq.12, we established a mathematical equation to calculate the value of \(s_j\) and evaluated the options.

\[s_1 = (0.170 + 0.156) \times (-0.500) + (0.189 + 0.175 + 0.162 + 0.148) \times (-0.088) = -0.0759\]

\[m_{12} = 0.0273\]

\[m_{23} = 0.2949\]

Similarly, \(m_{21} = 0.0759, m_{13} = -0.0273, m_{22} = -0.2949\)

And \(m_{11} = 0, m_{22} = 0, m_{33} = 0\)

4. Conclusion

The design of entrance architecture of MRT station is one of the more challenging and rewarding fields of practice. The opportunity to enhance the public realm and to balance engineering with more practical considerations results in a building type of particular relevance and visual complexity. (Edwards, 1997) As a typology, it employs a distinctive architectural language and image with multi-criteria. This study presented a novel approach to evaluate alternative entrance architecture of MRT station. We found that the methodology employed quietly appropriated in establishing consensus among those involved in the conception and implementation of such schemes. According to the results of this study, we can apply this procedure to establish a procedure of decision-making. The findings obtained in this study are as follows:

1. By applying the method of key-informant with decision-makers, professional, experts and scholars, we can attain objective multi-criteria for entrance architecture of MRT station.

2. From the investigation and weighting of each criterion, it was found that ‘site response’ is the most dominant criterion in Taiwan. It means that the architectural form of MRT station entrance should be diverse based on the characteristics of station site.

3. Because of the characteristic of each criterion, the application of the multi-criteria evaluation method can evaluate the alternatives and obtain the objective and appropriated consequence.

4. This study could be an objective reference for establishing a procedure of decision-making about the architecture of MRT station entrance.

Based on the results of this study, we also found that there were some schemes for future study. These suggestions obtained after this study are as follows:

1. The usefulness of this study is however limited by the fact that the questionnaires were administered to particular experts and scholars rather than the residents who are the direct beneficiaries of MRT systems.

2. The evaluation of qualitative criteria is based on the standardization of criteria score rather actual data, that causes a difference as comparing between the data. According to the method of MEQGD, the calculation result of standardization of the data qualitative cannot really reflect the qualitative difference between the alternatives; hence we suggest this approach for future study.

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