# An Integrated ANP Modle for Decision-making of Urban Regeneration Projects

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**Abstract.** An integrated model based on ANP method was developed in this paper to optimize the decision-making process of urban regeneration projects. In this model, a nonlinear programming and DEMATEL methods were adopted to improve the processes of traditional ANP, a Zero-one Programming method was used to find out the optimal combination with the constraints of the total budget. Nine alternative urban regeneration projects in downtown Chongqing were adopted to test the developed model. It was proved that the improved model was feasible and effective to solve the problem of optimizing the decision-making process of urban regeneration projects.

## Introduction

Recent years, a shift from economic competitiveness and physical environment objectives of urban regeneration to social-cultural and social-sustainable to prevent negative impact of urban regeneration projects has been observed in many countries [1~3]. The goals of urban regeneration are getting more and more plural, including protecting the diversity of the local economy and population structure, social justice, more stakeholders have being involved in the decision-making group, combining the competitiveness with the local cultural legacies [4]. Thus it is widely accepted that sustainability, competitiveness and culture have been considered as triple bottom line precedes over other concern.

In this context, optimizing the decision-making of urban regeneration projects needs multi-criteria decision analysis (MCDA). Several MCDA methods were successfully applied to urban regeneration purposes assessing their impacts on the built and natural environment and the institutional and socio-economical context. But there is still room for improvement, such as, the factors should be independent in an AHP model [5] which is not consistent with real situation; and NSFDSS [6] can’t provide a structure to analysis the interrelations of the criteria/factors in the model.

The purpose of this study is to present an integrated approach that can cope with the evaluating and optimal selecting of the urban regeneration projects. Therefore, the main contribution of this paper is to enhance the capacity of the ANP method with DEMATEL method, and combine with Zero-One Programming to address the decision-making problem of urban regeneration project within the three criteria of sustainability, competitiveness and culture. The remainder of this paper is organized into three sections. Section 2 addresses the model development steps. In section 3 empirical case studies are employed to demonstrate the developed model. The last section concludes the research.

## Methodology

The Analytic Network Process (ANP) which is a generalization of AHP method has been choose and combined with other methods to evaluate the urban regeneration project [7]. An integrated method which combines ANP, DEMATEL and Zero-one Programming is provided to set priorities among multi-criteria and trade-off among alternatives, and use the investment more efficiently. This method consists of the following five fundamental steps.

**Step 1: Select the evaluative sub-criteria and factors and develop an ANP model.** After the literature review and the interview of experts, an ANP network hierarchy model including sub-criteria and factors using the three criteria of sustainability, competitiveness and culture is developed.

**Step 2: Derive pair-wise comparison marices and the weights.** A nonlinear programming is used to calculate the weights and consistency instead of the classic Eigenvector method [8]. Let $A=(a_{ij})_{n\times n}$ be an $n\times n$ pair-wise comparison matrix by using a scale of 1 to 9. The single sorting weights are $w_k, k=1,2,\cdots,n$. Theoretically, if experts' judgments are consistent, $a_{ij}=w_i/w_j$. A nonlinear programming is used to calculate the sorting weights and check the consistency as (1),

$$\min CIF(n)=\sum_{i=1}^{n}\left|\sum_{j=1}^{n}(a_{ij}w_j)-nw_i\right|/n$$
$$s.t.\sum_{j}^{n}w_j=1$$
$$w_j>0,\ j=1,2,\cdots,n \qquad (1)$$

where, *CIF*(*n*) is the Consistency Index Function, $a_{ij}$ is the elements of matrix *A*, *n* is the rank of *A*, $w_k, k=1,2,\cdots,n$ are the weights , which are the optimizing variables.

**Step 3: Use the DEMATEL method to establish total influence matrices.** The Battelle Memorial Institute investigated the concept of the DEMATEL technique through its Geneva Research Centre [9]. By using it, direction and intensity of direct of each factor and criterion for urban regeneration projects can be analysied with the pairwise scores (normally with 0~3 4 levels)which are judged by experts.

**Step 4: Establish supermatrix, and calculate weighted and limit supermatrix.** To obtain the priorities of the alternatives in a evaluation system with interdependece and feedback, we enter the priorities obtained in step 2 and the total influence matrices in the appropriate columns of an unweighted supermatrix. Let $C_k$, $k$=1, 2, …, $N$ with $nk$ elements $e_{k1},e_{k2},\cdots,e_{kn_k}$ be the components of the evaluation system. The weighted supermatrix is raised to the power of 2*k* + 1, where *k* is an arbitrarily large number, and get the limit supermatrix. The priority weights of alternatives $(w_1,w_2,\cdots,w_n)^T$ can be found in the column of alternatives in the limit supermatrix.

**Step 5: Apply zero-one programming for project selection.** The priorities obtained through ANP are then combined with a Zero-one Programming model to handle the interactions between evaluation results and the constraints on investments. Considering the individual budget $(b_i)$ of each project ($P_i$) and total budget ($F$), Let $x_i$ be the decision variable and let

$$x_i=\begin{cases}1, & if\ project\ p_i\ is\ selected\\ 0, & otherwise\end{cases}.$$

The Zero-one Programming of optimal project selection is as follows

$$\max W=\sum_{i=1}^{n}w_ix_i$$
$$\begin{cases}\sum_{i=1}^{n}p_ix_i\le F\\ x_i=0\ or\ 1\end{cases} \qquad (2)$$

## Empirical Case study

The case we used in this paper is from downtown Chongqing, China. After years of urban regeneration processes, some places in the downtown where the CBD is located contains the most expensive business buildings, busiest shopping malls, and is the most densely populated district in Chongqing. But there are still a lot of areas which have been in declining for years and expecting to be regenerated. There are nine alternative projects (Table 1) and the total budget on urban regeneration is 10 billion.

Table 1 Basic information of the nine alternatives

| Alternatives | Regeneration target | Expected cost $I_i$ million | Expected annual profit $p_i$ million | Expected annual profit-cost ratio （%） |
|---|---|---|---|---|
| $P_1$ | Redevelop Public and commercial building | 2500 | 300 | 1 |
| $P_2$ | Rehabilitate Traditional buildings | 400 | 12 | 3 |
| $P_3$ | Redevelop Public and commercial buildings | 2200 | 230 | 10.5 |
| $P_4$ | Rehabilitate Resident buildings | 600 | 20 | 3.3 |
| $P_5$ | Redevelop Commercial buildings | 3300 | 500 | 15.2 |
| $P_6$ | Redevelop public and commercial buildings | 1000 | 110 | 11 |
| $P_7$ | Redevelop commercial buildings | 2800 | 350 | 12.5 |
| $P_8$ | Redevelop for transportation hub | 2500 | 150 | 6 |
| $P_9$ | Rehabilitate residential and commercial buildings | 400 | 30 | 7.5 |

Sixteen experts were asked to help to develop the ANP model and evaluate the priority of each project in this research. We develop an evaluative ANP model which contains three major criteria, 13 sub-criteria (four of them belong to sustainability, six of them based on the diamond model belong to competitiveness, and three of them belong to culture) and 36 factors, as shown in Figure1.

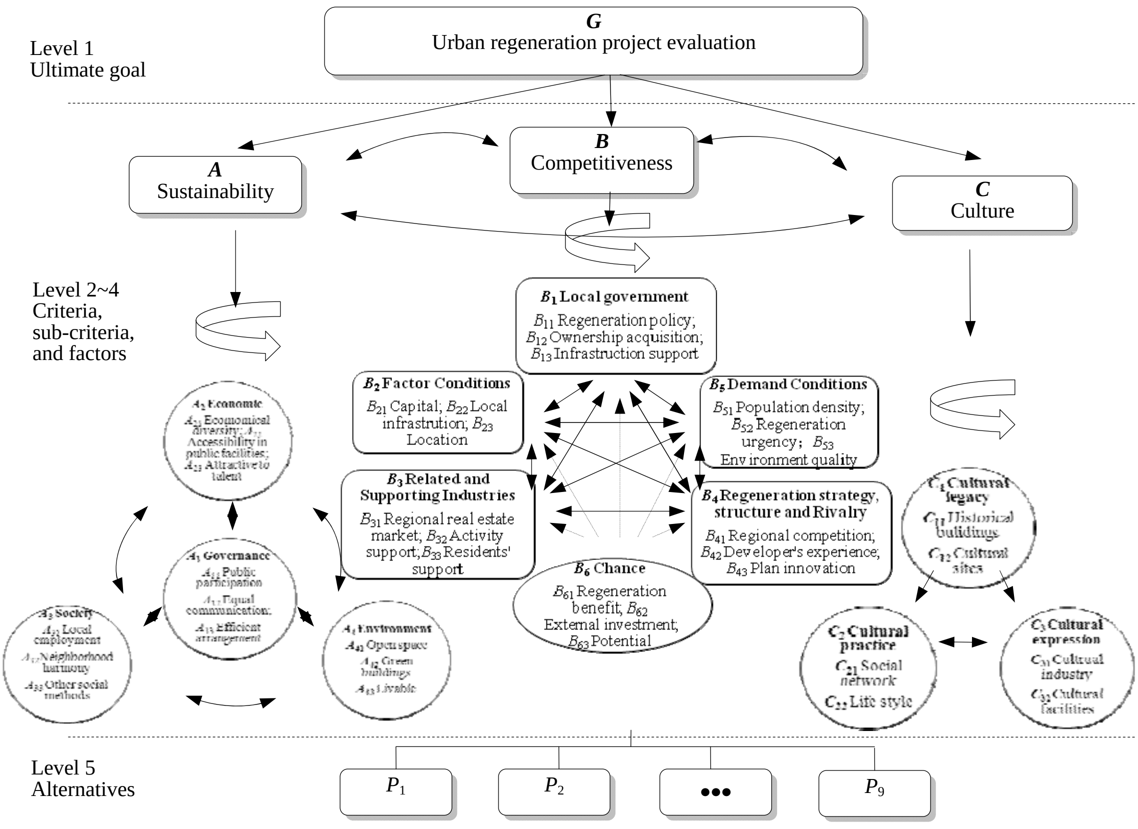


Fig. 1 Urban regeneration evaluative ANP model

Supermatrix ($W$) of this ANP model contains 9 parts ($W_{21}$, $W_{32}$, $W_{43}$, $W_{54}$, $W_{11}$, $W_{22}$, $W_{33}$, $W_{44}$, $W_{55}$), $W_{21}$, $W_{32}$, $W_{43}$, $W_{54}$ are weights decided from pair-wise comparison marices and $W_{11}$, $W_{22}$, $W_{33}$, $W_{44}$, $W_{55}$ are total influence matrices where $W_{11}$ is 1 and $W_{55}$ is the identity matrix according to Figure 1.

After the next four steps, we get the results of Zero-one programming (Table 2).

Table 2 Results of Zero-one programming

| alternatives | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| weights | 0.094 | 0.120 | 0.091 | 0.115 | 0.077 | 0.092 | 0.093 | 0.144 | 0.174 |
| results | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 |

## Conclusions

In this paper we propose an integrated method of ANP, DEMATEL and Zero-one Programming to optimize the decision-making process of urban regeneration projects. A new nonlinear programming method which can measure the inconsistency of the pair-wise comparisons in the same time of calculating the priorities is applied in the pair-wise comparison stage of ANP. With the applying of DEMATEL method, the analysis of interdependencies of criteria/factors becomes more comprehensive. By applying the proposed method to evaluate and choose the optimal project package, the seven projects which have more commitment on sustainability and public interest are chosen.

To achieve sustainability, competitiveness and culture of urban regeneration in practice, the optimal decision-making method we developed should be combined with appropriate local policies which are based on the understanding of local context and how this shapes the relationships between stakeholders [10]. Although the result can be pleasingly positive, continuous corrections and validation of proposed ANP model, as well as, the wider application of this approach to larger group of urban regeneration projects are goals for further study.

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