Evaluate of vegetation value for reconstruction and extension project of expressway

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Abstract. A large number of artificial or natural vegetation grow on the both sides of expressway, which play an important role in automobile gas purification and environmental protection. With the development of transportation, more and more reconstruction and extension projects spread up all over the country. However, those valuable biological resources are usually handled by rough means, which cause a waste of resources and damage of environment. Based on this, this paper intends to carry out roadside vegetation protection research in combination with the actual reconstruction and extension project of expressway. Evaluations of the roadside vegetation value are discussed and proposed. Results could provide reference for the roadside vegetation protection for reconstruction and extension project of expressway.

1. Introduction
With the rapid development of China’s economy, highway construction has become a hot spot in China's infrastructure construction and also one of the key development strategies of China's transportation development for a long time. However, with the increase of transportation volume, design of four-lane cannot meet current development needs. So the reconstruction and expansion project of expressway is imperative. Expressway construction caused environmental damage ineluctability, especially the destruction of primary vegetation. in view of the reconstruction and expansion project of expressway, the original roadbed had caused a certain damage on the primary vegetation. Surface fragmentation, poor ecosystem stability, soil erosion and other problems were happened frequently[1-2]. In the early stage of expressway construction, original vegetation grown in the original slope surface was completely felled and destroyed. A large number of road trees and landscape trees were planted along the new expressway. A lot of them were very valuable biological resources[3-4]. At the same time, some treasured, endangered and endemic plants might be planted near by the road. They were treated rudely in the reconstruction and expansion, resulting in a waste of resources. In addition, there was a lack of attention for some plants that were not protected species but were important for upgrading road landscape[5].

First research on vegetation protection in expressway construction in China was The standard of standardization and beautification of highway that published in 1983. Measures that really paid attention to the protection of ecological environment along highway were mentioned in The design of highway environmental protection in 2010[6]. Wang’s study had summarized the protection measures
of plant resources in highway construction in China. He had proposed different protection plans for road planning, survey design, construction and operation, respectively[7]. Li had studied the effect of Huangtong highway on the ecology of the reserve when crossing Taian Nature Reserve. They had obtained protection measures of vegetation in road area during highway construction and operation[8]. The most typical example of road vegetation protection was Heda Expressway. Through the intervention of the design and construction stage, engineers had achieved conservation of original vegetation, which provided valuable reference for other engineering builders[9]. However, most of the methods or measures related to road vegetation protection were aimed at new roads. There was still a lack of systematic and completely road vegetation protection technology for reconstruction and extension projects of expressway. Based on this, this paper intends to investigate road vegetation protection research combining with the actual reconstruction and extension project of expressway. An evaluation system of road vegetation protection is used to classify different plant conservation values. Results are expected to provide reference for road vegetation protection in expressway reconstruction and extension project.

2. Study area
Beijing-Shanghai Expressway (from Laiwu to Linyi) is about 232.4 km long and locates in the south-central part of Shandong Province. Its geographical coordinates are 117°12’ E, 36°21’ N to 118°20’ N 34°23’ N. The southern plain along the expressway is mainly farmland; the northern mountain area is mainly orchard. Soil thickness gradually decreases from south to north. Soil types are cinnamon soil, brown soil and windy sandy soil. The average annual temperature is 13.5°C, and the average annual rainfall is about 600mm, which is a temperate monsoon climate. The main vegetation types are temperate deciduous broad-leaved forest. The main plant species along the expressway are poplar, willow, thapa, juniper, yellow wattle, jujube, pine, cedar, voilemost, herba, zoysia, etc. Road vegetation includes plants growing on both sides of expressway, the central reserve of expressway and the interchange area of expressway. Plants in the study area have grown well for 20 years.

3. Method of vegetation protection evaluation in expressway
At present, there is no systematic evaluation method for vegetation protection value in expressway. Based on the influence of reconstruction and extension projects on road vegetation, equation (1) was used to calculate road vegetation protection value in expressway. When calculated road vegetation protection value, environmental value was considered in priority, followed by vegetation value, then engineering application value.

$$V = \sum wI(k)$$  \hspace{1cm} (1)

Where, $V$ is road vegetation protection value, $w$ is weight, $I(k)$ is the value level under the factor of $k$.

4. Selection and construction of vegetation protection value system

4.1. Principles of road vegetation protection value

4.1.1. Principles of economic viability. In carrying on the road vegetation protection, resources protection and cost input should be considered at the same time. For example, when the seedlings are transplanted, vegetation value should not be lesser than the cost of transplanting.

4.1.2. Principles of value priority. In the process of road vegetation protection, ecological and landscape value are quite different within different plant species. It is important to evaluate road vegetation under the ecological law and the natural landscape. Usually, plants with high ecological benefits and good landscape value are preferentially protected.
4.1.3. **Principles of convenient construction.** Transplanting methods should be adopted under the premise of considering the convenient construction. For some large seedlings, nearby transplant approach should be adopted; for area transplantation, in situ protection should be implemented.

4.1.4. **Principles of remark focus.** In the process of road vegetation protection of expressway, some sections have the similar vegetation condition. When evaluate the vegetation protection of these sections, value of vegetation growing in concentrated areas is higher than those in dispersed areas. For the reconstruction and extension projects, the protection of road vegetation is limited by the construction organization. Thus, it’s necessary to protect the road vegetation according to its protection value in expressway.

4.2. **Index selection and classification**

Through summarizing and summarizing the previous research results, analytic hierarchy process was used to obtain the index system of vegetation protection value (Table 1) under fully considering the influence of reconstruction and extension project on road vegetation protection value of expressway. Next, eight indexes of the index layer were graded, and the higher the protection grade, the greater value of the protection grade.

**Table 1. Index system of vegetation protection value of reconstruction and extension project of expressway.**

| Target layer | System layer | Index layer (I) |
|--------------|--------------|-----------------|
| Evaluate of vegetation value for reconstruction and extension project of expressway | Diversity index | Rarity (I₁) |
| | | Typicality (I₂) |
| | Natural index | Importance (I₃) |
| | | Fragility (I₄) |
| | | Interference (I₅) |
| | Social index | Complex value (I₆) |
| | | Project influence (I₇) |
| | | Re-utilization need (I₈) |

4.2.1. **Diversity index.** The rarity of road vegetation referred to the rarity degree of a certain vegetation in the vegetation zone, which was usually determined by the ratio of its existing area to the area covered by the same vegetation zone. The smaller the ratio, the more valuable it is. The typicality of road vegetation was divided according to the area distribution level. When the species were unique and infrequent, they usually had a higher protection value in that area. Classifications of diversity index were shown in Table 2.

**Table 2. Descriptions of diversity index classification.**

| Level | Diversity index | Typicality (I₂) |
|-------|-----------------|----------------|
| 5     | Small distributed, rare in road-region | road-region endemic species |
| 4     | Small distributed, common in road-region | region endemic species |
| 3     | general distributed, common in region | China endemic species |
| 2     | widely distributed, common in region | native species |
| 1     | widely distributed, common in the country | alien invasive species |
4.2.2. **Natural index.** Natural index was the evaluation of characteristics and value of plants. It consisted of three indices: importance, fragility and interference. The importance of road vegetation referred to the importance of vegetation in the maintenance of ecosystem stability in this area. Because of road vegetation were mostly artificially planted, the importance mainly referred to the ecological service function such as slope protection, soil and water conservation and air purification. The vulnerability of road vegetation meant the degree of disturbance and destruction of a certain vegetation type, which could also be expressed as the community stability of one vegetation type in the road area ecology. Vegetation’s growing environment in road area was usually man-made, so the habitat condition of the community largely determined its vulnerability. The interference of road vegetation was understood as the extent of human access, which could be evaluated by the degree of utility value of human use and the extent of access. Classifications of natural index were shown in Table 3.

Table 3. Descriptions of natural index classification.

| Level | Importance ($I_3$) | Fragility ($I_4$) | Interference ($I_5$) |
|-------|-------------------|------------------|----------------------|
| 5     | stable community, high ecological service function | good habitat condition, high anti-interference ability | far away from routes and villages, high use value |
| 4     | general ecological service function and recovery ability | good habitat condition, general anti-interference ability | far away from routes and villages, general use value |
| 3     | general ecological service function and low recovery ability | general habitat condition and anti-interference ability | nearby routes and villages, high use value |
| 2     | low ecological service function and recovery ability | general habitat condition, bad anti-interference ability | nearby routes and villages, general use value |
| 1     | no ecological service function | bad habitat condition and anti-interference ability | nearby routes and villages, no use value |

4.2.3. **Social index.** Social index was the evaluation of economic value of vegetation and the influence of the reconstruction and extension project on road vegetation. It also consisted of three indices: complex value, project influence and re-utilization need. A vegetation community was composed of different plant species, among which some belonged to rapid growth, some had relatively slow growth, some had economic value and some had landscape value. They should be treated differently and quantitatively. However, in the process of engineering construction, because of the convenience of construction and the need of cost, construction organization only considered the engineering demands rather than road vegetation protection. Different locations of vegetation communities led to different impact on engineering construction. In general, vegetation located on both sides of expressway, the central reserve of expressway and the interchange area of expressway had low impact on construction organization. If engineers did nothing to them, they could be protected in situ. Other plants in other locations had a greater impact on construction organization. They could be protected by transplanting. When it came to the end of construction, they could be applied into the rehabilitating vegetation of new expressway. Thus avoided waste of resources and reduced the cost of project. Therefore, it was necessary to evaluate the re-utilization need to realize full embodiment of road vegetation value in reconstruction and extension project of expressway. Classifications of social index were shown in Table 4.
Table 4. Descriptions of social index classification.

| Level | Complex value ($I_6$) | Project influence ($I_7$) | Re-utilization need ($I_8$) |
|-------|------------------------|--------------------------|----------------------------|
| 5     | plants grow well, some plants have high landscape and economic value | plants locate beyond the boundary of project | high reused value, easy to transplant |
| 4     | plants grow well, some plants have general landscape and economic value | plants locate between the boundary of expressway and isolated gate | general reused value, easy to transplant |
| 3     | plant growth is poor, some plants have high landscape and economic value | plants locate in the central reserve of expressway and the interchange area of expressway | high reused value, hard to transplant |
| 2     | plant growth is poor, some plants have general landscape and economic value | plants locate in the construction detour | general reused value, hard to transplant |
| 1     | poor plant growth and lack of high landscape and economic value | plants locate in the expressway side ditch | low reused value, hard to transplant |

4.3. Index weight
Analytic hierarchy process was used to calculate index weight. Weights of different index were shown in Table 5.

Table 5. Weights of different index. (CR=0.001<0.1).

| Index          | Weight ($w$) | Index          | Weight ($w$) |
|----------------|--------------|----------------|--------------|
| Rarity ($I_1$) | 0.2023       | Interference ($I_3$) | 0.0292       |
| Typicality ($I_2$) | 0.0896    | Complex value ($I_6$) | 0.0598       |
| Importance ($I_3$) | 0.0640     | Project influence ($I_7$) | 0.3619       |
| Fragility ($I_4$) | 0.0425     | Re-utilization need ($I_8$) | 0.1507       |

Therefore, $V$ could be calculated by equation (2).

$$V=0.2023 \times I_1+0.0896 \times I_2+0.064 \times I_3+0.0425 \times I_4+0.0292 \times I_5+0.0598 \times I_6+0.3619 \times I_7+0.1507 \times I_8$$

Where, $1 \leq V \leq 5$

4.4. Classification of road vegetation protection value
Based on the survey of vegetation along the project, there had a lot of trees grown on both sides of road. Subgrade slope was mainly herb, shrub and few trees. Vegetation in the interchange area of expressway was well maintained and managed. For a certain tree species, planting position and age could have big impacts on plant growth. Thus, it might have different levels of road vegetation protection value. Classifications of road vegetation protection value were shown in Table 6.
Table 6. Classification of road vegetation protection value.

| Position           | Species                  | Average height (m) | \(V\) | Position           | Species                  | Average height (m) | \(V\) |
|--------------------|--------------------------|--------------------|-------|--------------------|--------------------------|--------------------|-------|
|                   | **Picea asperata**       | 3~7                | 4.182 | Interchange Area   | **Cedrus deodara**       | 3~9                | 2.555 |
|                   | **Metasequoia glyptostroboides** | 3~7                | 4.092 | of express (in the | **Photinia serrulata**   | 1.2~1.5            | 2.353 |
|                   | **Cedrus deodara**       | 3~9                | 4.003 | disturbance       | **Ligustrum lucidum**    | 3~5                | 2.353 |
|                   | **Magnolia heptapeta**   | 3~6                | 3.801 | boundary of project) | **Pinus thunbergii**     | 2~3                | 2.209 |
|                   | **Swida alba**           | 0.8~1.5            | 3.801 |                   | **Kaizuka Hort**         | 3~6                | 2.182 |
| Interchange Area  | **Hibiscus syriacus**    | 3~5                | 3.741 |                   | **Trewia nudiflora**     | 1.5~2.5            | 2.041 |
| of express (beyond | **Ligustrum lucidum**    | 3~5                | 3.741 |                   | **Pyramidalis Carr**     | 2~6                | 1.940 |
| the boundary of   | **Fraxinus**             | 4~5                | 3.681 |                   | **Prunus cerasifera**    | 2~4                | 1.940 |
| project)          | **Pennsylvaniaica**      | 3~4                | 3.538 |                   |                          |                    |       |
|                   | **Prunus cerasifera**    | 3~4                | 3.538 |                   |                          |                    |       |
|                   | **Kaizuka Hort**         | 3~6                | 3.479 |                   |                          |                    |       |
|                   | **Pyramidalis Carr**     | 3~7                | 3.479 |                   |                          |                    |       |
|                   | **Pinus thunbergii**     | 1.5~5              | 3.479 |                   |                          |                    |       |
|                   | **Prunus cerasifera**    | 1.5~3              | 3.479 |                   |                          |                    |       |
|                   | **Salix matsudana**      | 3~8                | 3.217 |                   |                          |                    |       |
|                   | **Populus gansuensis**   | 3~6                | 3.217 |                   |                          |                    |       |
| Service Area      | **Cedrus deodara**       | 3~6                | 2.485 |                   |                          |                    |       |
|                   | **Hibiscus syriacus**    | 1~3                | 2.043 |                   |                          |                    |       |
|                   | **Pyramidalis Carr**     | 3~5                | 1.673 |                   |                          |                    |       |
|                   | **Salix matsudana**      | 3~5                | 1.196 |                   |                          |                    |       |
| Both sides        | **Populus gansuensis**   | 4~5                | 1.196 |                   |                          |                    |       |
| of road           | **Sophora japonica**     | 3~8                | 1.196 |                   |                          |                    |       |
|                   | **Ulmus pumila**         | 1~2                | 1.196 |                   | **Platycladus orientalis** | 1~1.5            | 2.564 |

Protection value of plant species in different positions was quite different. For the same plant species, protection value was also quite different. In different positions, vegetation in interchange area and service area of expressway had the highest protection value, followed by the central reserve of expressway. Vegetation in both sides of road and in the disturbance boundary of project had the worst protection value. Vegetation in the disturbance boundary of project showed a higher protection value than those out of the disturbance boundary of project. The protection value of trees was generally higher than that of shrubs. Comparing the value of road vegetation protection in different positions, it
was found that spruce and cedar were generally higher than that of other plants. The lower protection value was mostly willow and other isokinetic tree species. Those relatively concentrated growth such as heather and ligustrum were generally showed medium protection value in an area of expressway. In general, in view of road vegetation protection value within the scope of the project, spruce and cedar were recommended priority of conservation, followed by heather, magnolia and ginkgo. Fast-growing tree species in the disturbance boundary of project could disregard. In addition, the reconstruction of the central reserve of expressway was relatively small, so the juniper in this position should also be taken measures such as retaining and maintenance to make in situ retention.

5. Conclusion
Based on the investigation of road vegetation in Beijing-Shanghai Expressway (from Laiwu to Linyi), level of road vegetation protection value were calculated and classified. Results showed that plant species grown in different regions had different protection values. Vegetation in interchange area and service area of expressway had the highest protection value, followed by the central reserve of expressway. Vegetation in both sides of road and in the disturbance boundary of project had the worst protection value. Impact on construction, vegetation value and transplanting cost were the key indices affecting the of vegetation protection value. For the reconstruction and extension project of Beijing-Shanghai Expressway (from Laiwu to Linyi), cedars and spruces should be protected primarily, followed by heather, magnolia and ginkgo. Other items of higher protection value were juniper in the central reserve of expressway.

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