Cost Control Strategies for Hubei General Highway Greening Project

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Abstract In order to respond to the national policy of focusing on the service of building a new development pattern and promoting high-quality development, and to reduce the cost of greening projects while ensuring the effect of highway landscape, a process and cost control points of highway greening design, construction, and maintenance are summarized through a review of the literature. Additionally, this paper examines the attributes of highway greening and proposes cost control strategies that are aligned with these attributes. It is proposed that the implementation of cost control strategies for highway greening should commence at the project establishment phase, with the objective of establishing a comprehensive and effective cost management control system. While guaranteeing the greening landscape effect and the duration of the project, it is essential to regulate the crucial nodes in each phase of the design, construction, and maintenance process. Furthermore, it is vital to facilitate close collaboration between all parties involved, thereby reducing costs, conserving resources, and lowering energy consumption. This approach can also lead to enhanced economic and social benefits for highway greening projects.

Highway greening represents a significant aspect of land greening and is an indispensable element of superior transportation development. Since the 18th National Congress of the Communist Party of China, transportation authorities at all levels have accorded considerable significance to the practice of highway greening. In order to implement the concept of resource conservation in green highway construction, some scholars have conducted research on the subject of highway greening. Wang Hui et al.[1] utilized a variety of grades in Shanxi Province as their research subjects, and subsequently proposed specific planting widths for roadside seedlings and canopy density following the formation of forests. Zhou Yong[2] utilized the Lechang–Guangzhou Expressway as a case study to illustrate the implementation of resource conservation in highway landscape greening design. Dong Zhichao[3] utilized a highway project as a case study to illustrate the quality management challenges associated with the construction and technical specifications of three pivotal processes: seedling transplantation, shrub planting, and turf laying, as they pertain to highway greening projects. Song Yuchen[4] highlighted the necessity of implementing measures to control greening costs, which should include strengthening the preliminary design research, soil management, and the seedling price comparison system. Xia Wenli[5] presented an overview of the challenges encountered in the median divider, both sides of the road, and the slope greening of the highway project. In addition, she proposed a series of maintenance and management measures, including water management, soil improvement, pruning, pest control, replanting, weeding, and cold prevention. Li Haijiang[6] undertook an analysis of the current maintenance cost control work of highway greening project, identifying shortcomings in the existing system, such as imperfect cost control system, chaotic material management and waste. In response, he put forward a series of control measures, including improvements to the cost control system, more rigorous material control and management, and the selection of suppliers on a more rational basis. These measures are designed to enhance the effectiveness of the maintenance cost control of highway greening project.

The aforementioned studies are conducted by scholars on the design, construction, and maintenance of highway greening, with a particular focus on expressways. They encompass the contents of three links of highway greening project, existing problems, and relevant solutions. As illustrated in Fig.1, the latest data on the mileage composition of China's national highways (as of the end of 2022) reveals a significant discrepancy between the mileage of low-grade ordinary highways and that of expressways. The former category accounts for a substantial 96.7% of the total mileage, underscoring the prevalence of these less sophisticated roadways within China's transportation infrastructure. This study builds upon previous research by making an investigation of current common highway greening project, summarizes the characteristics and construction process of common highway greening, and further proposes optimization suggestions for cost control.

1 Highway greening charac-teristics

1.1 Single form of highway greening

The configuration of the highway, specifically the dimensions of the road space and cross-section, determines the type of highway greening. This is classified into two categories: central isolation belt greening and roadside greenbelt. In addition to the separation of the up and down lanes and the role of the guardrail, the central isolation belt greening also has the effect of reducing glare on the lane at night by blocking light exposure. The central isolation belt is planted with shallow-rooted vegetation, predominantly evergreen, pruning-resistant, and adaptable native shrubs. These are planted in a dense formation to create hedges that provide the desired isolation and sheltering effect[7]. The roadside greenbelt fulfills a number of functions, including stabilizing the slope, providing sound insulation and dust removal, offering shading and cooling, and enhancing the aesthetic quality of the highway environment. The stabilization of the slope's soil is achieved through the development of plant roots, thereby enhancing the slope's anti-erosion capabilities. In order to conserve land resources, the expropriation of land adjacent to the roadway should be limited

in scope, and the green belt vegetation should predominantly comprise single-row trees and ground cover. Consequently, regardless of whether it is the central isolation belt greening or the roadside greenbelt, the planting form is straightforward and uniform.

1.2 Barren planting soil

The deficiencies of soil for highway greening planting can be classified into three primary categories: structural instability, low nutrient concentration, and a soil temperature that is significantly influenced by external factors[8]. The construction process for roadways entails the removal of topsoil and subsequent construction of the roadbed, subgrade, and pavement in that order. Once the primary construction of the route is complete, the next step is to backfill with green planting soil. The construction of the highway main body has an adverse impact on the structural integrity of the original soil, thereby affecting the original functioning of the local soil layer and the natural environment. The soil nutrients that affect plant growth are pH, organic matter, nitrogen, phosphorus, and potassium[9]. The majority of planted soil utilized in highway project is the clear surface earthwork or the general earthwork in the borrow area. This soil has a low nutrient content and does not meet the nutritional requirements for the healthy growth of seedlings. The greening of highways with simple collocation does not result in the formation of an ecological system that is as perfect as that observed in parks. Furthermore, this method of greening is not conducive to the decomposition of nutrients in the soil. Hubei exhibits four distinct seasons, with considerable temperature fluctuations between summer and winter. The highway greening soil is influenced not only by the climate but also by the road surface. During the summer months, road temperatures are typically elevated, and soil surfaces adjacent to highways are subjected to prolonged periods of sunlight.

Fig.1 Composition of national highway mileage by the end of 2022

This can result in the direct damage of roots of seedlings and plants due to the extremely high surface temperatures. Additionally, soil water evaporation can contribute to the emergence of drought, dryness, and other related phenomena, which can directly impact the strength of the plant. The reduction in temperature caused by the influx of cold air during the winter months increases the risk of frostbite for seedlings planted on road surfaces.

1.3 Long planting mileage

The scale of highway projects differs from that of urban roads due to the inherent characteristics of highway green plantings, which are typically long in mileage and narrow in section, in contrast to urban roads, which are typically short in mileage and wide in section. A wide and short urban road green belt can be utilized in the form of natural planting. A variety of seedlings are available, with a relatively limited number of specimens of a given species. The specifications can be tailored to suit the required dimensions, and the procurement of seedlings is a relatively straightforward process. The practice of highway greening predominantly employs the planting of street trees in a single, equidistant row. The green varieties of trees are typically single. In order to achieve a uniform and rhythmic linear highway landscape effect, it is necessary to implement a unified set of specifications for street trees. These specifications must ensure that the branch points are consistent, that the trees are of a full shape, and that the demand for seedlings of the same specifications is high. This increases the difficulty of implementing the supply source of seedlings and transporting seedlings. In the event of an inappropriate planting period, and inclement weather (excessive dryness and flooding), the maintenance of the seedlings with limited varieties and considerable quantity becomes challenging. The probability of replacing seedlings is elevated, and the cost is greater.

1.4 High maintenance difficulty

The maintenance of highway greening primarily encompasses the practices of watering, pruning, soil improvement, disease and pest control, replanting, weeding, and winter protection, etc. In comparison to conventional landscaping, highways present unique challenges due to the limited availability of maintenance resources. These include the scarcity of water sources, the harsh natural environment along the highway, and the accelerated loss of water from vegetation due to the combined effects of wind and sun. Consequently, the frequency of watering must be increased to compensate for these factors. The highway greening watering

method is either sprinkler or tractor watering. However, due to a number of factors, including the limited number of sprinklers and the amount of water transported, the relatively high cost of transporting water, and the relatively small proportion of the greening maintenance funds, it is difficult to meet the vegetation's demand for water[10]. The dearth of maintenance professionals has resulted in a greening maintenance team that is both overloaded and understaffed. This has led to a situation in which operators and technicians are demotivated, which in turn has resulted in a lack of efficiency and a significant reduction in the level of greening. As a result, the development of highway greening maintenance has been challenging.

2 Highway greening construction process

2.1 Initial design phase

The initial design phase represents a pivotal juncture in the process of implementing highway greening projects, wherein critical decisions are made that shape the project's overall trajectory. At this stage, the designer will determine the varieties, specifications, forms, planting spacing, and engineering quantity of seedlings in a timely and appropriate manner, ensuring adherence to the principles of ecology, economy, and aesthetics, as well as the ecological habits of seedlings. The variety, specifications, and quantity of seedlings directly influence the financial implications of greening.

2.2 Construction phase

The construction phase represents the implementation phase of the highway greening project, wherein the project's objectives are actualized. In the initial phase of construction, the construction team must ascertain the source of plant seedlings, the designated site for transportation from the construction site to the planting site, and the method of transporting the seedlings. They must also assess the soil quality of the planting site to guarantee that it is essentially consistent with that of the planting site. Furthermore, they must determine the precise planting location of the seedlings in accordance with the actual situation of the site pipe network and coordinate the construction timeline. This will ensure that the optimal planting time is selected, thereby maximizing the survival rate[11]. The planting process should be conducted in accordance with the established guidelines for tree hole preparation, fertilizer application, support structure installation, root irrigation, and timely documentation and acceptance.
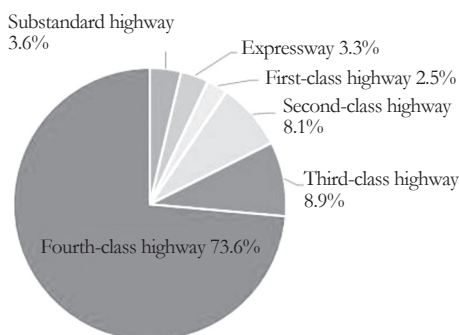
2.3 Late maintenance phase

The maintenance phase represents a crucial phase in the lifecycle of a landscaping project, serving as a vital safeguard. Greening projects emphasize three points of planting and seven points of maintenance. The maintenance of highway greening is a daily, fundamental, and long-term undertaking. It encompasses the implementation of greening maintenance technology and management strategies[10]. Greening maintenance encompasses a number of disciplines, including environmental ecology, botany, soil and water conservation, soil geology, highway engineering, and landscape architecture. It is evident that the professional competence of greening maintenance technicians is of the utmost importance. They must possess a comprehensive understanding of the growth characteristics of an array of seedlings, possess the ability to scientifically determine the optimal watering frequency and quantity, demonstrate an acute ability to identify the diseases and pests affecting seedlings, and implement prompt treatment programs. Additionally, they must possess the ability to perform pruning in a manner that ensures the healthy growth of seedlings.

3 Highway greening cost control principle

3.1 Economy principle

The principal objective of cost control is to reduce expenditure, whereas the primary aim of highway greening is to enhance the aesthetic appeal of the environment, provide a visually appealing setting, and address the growing demand for a superior quality of life. In regard to street trees, seedlings with a thick trunk diameter, a unified branch point, and a full tree shape will be preferable, though this will entail a higher price. The greening project must consider the long-term implications of its actions, including the financial implications of purchasing seedlings. It is not feasible to select seedlings with smaller trunk diameters or of varying quality in order to reduce costs. Instead, a cost-benefit analysis must be conducted to determine the most optimal plan, balancing the aesthetic value of the trees with the financial costs.

3.2 Principle of comprehensiveness

The term "comprehensiveness" is used to describe the comprehensive integration and coordination of the various stakeholders, resources, and machinery involved in the four processes of design, construction, maintenance, and management of highway greening projects. Due to the limited availability of pricing information for seedlings, it is often necessary to request quotations. During the initial design phase, it is crucial to ascertain the cost of seedlings, as the accuracy of this information directly influences the overall budget. The cost of construction is contingent upon a number of factors, including the management of human resources, the organization and planning of project progress, the supervision of material procurement, and the implementation of change management strategies. The implementation of a reasonable deployment of personnel, a close organization of the schedule, strict compliance with the requirements of auditing and signing off on materials, and the streamlining of unreasonable changes can collectively result in cost savings. The maintenance phase should be conducted in conjunction with the growth patterns of the seedlings, incorporating pruning and topdressing as necessary. Additionally, the frequency of watering should be adjusted based on the prevailing weather conditions. It is essential that the entire process management system strives to achieve the greatest possible cohesion among all parties involved in order to facilitate the seamless completion of the project. Accordingly, in the context of cost management, it is essential to gain a comprehensive understanding of the critical points of cost control and enhance the responsiveness of project cost monitoring.

3.3 Dynamic principle

The market environment is in a state of constant change, which creates a dynamic cost control environment. For example, the price of seedlings rose unexpectedly, the shape of seedlings did not meet the design requirements, drought and flood caused a large number of deaths of newly transplanted seedlings, and so forth. These issues will result in changes to the project. In response to these changes, all departments should cooperate with each other to solve these problems and implement projects in accordance with quality and quantity. It can be observed that the implementation of a highway greening project is a continuous and dynamic process, extending from the initial stage of project initiation to the final stage of completion. This dynamic process is accompanied by a correspondingly dynamic cost profile. Any alterations to the plan must be justified in terms of cost[12], and the plan itself should be developed within a reasonable cost range.

4 Cost control strategy

4.1 Management cost control

Management cost control can be divided into two measures: concretization and responsibility. As the process of each department of highway greening project is summarized and sorted out, it becomes evident that the departments involved in greening projects are management, design, construction, and supervision. Furthermore, cost control is identified as a factor of concern for all departments. Each department can save cost by implementing the specific work to the exact person, and cost control requires the joint efforts and cooperation of all departments of the project. Each department is responsible for its work in cost control, achieving effective management of cost control through the cooperation between the departments[13]. Specific and responsible management control can result in rational coordination of resources, which can avoid rework, and is conducive to the recycling of resources, thereby reducing project costs.

4.2 Design cost control

The direct transportation function of highway is greater than its landscape beautification function. Barren growth soil of green belt and automobile exhaust pollution of the environment along the line are not suitable for fine landscaping. Hence, plants with strong adaptability and easy survival are usually selected for planting. Because the unit price of seedlings with different trunk diameters is relatively large, the size of the trunk diameter should be selected according to the life cycle of the seedlings. For example, camphor tree and koelreuteria exhibit faster growth, and the seedlings with a trunk diameter of 8−10 cm can be selected, while ginkgo and sweet-scented osmanthus exhibit slower growth, and the seedlings with a trunk diameter of 10−12 cm can be selected. In addition to the specifications of the seedlings that will determine the cost, the number of seedlings and planting spacing of highway greening also determine the number of seedlings, and the planting spacing is mainly determined by the canopy diameter of seedlings. For example, the trees such as camphor tree and koelreuteria with unfolding canopy can be planted at an appropriate large spacing of 6−8 m, while ginkgo and metasequoia with small canopy can be planted at a small spacing of 4−6 m. Therefore, the control points of highway greening in the design process are determined by the varieties, specifications and planting spacing of seedlings.

4.3 Construction cost control

The cost control in the construction phase is mainly based on the price comparison of seedling source, reasonable schedule and

segmented construction. In order to determine the optimal planting time for seedlings, it is essential to consider their growth habits. When deploying seedlings, it is crucial to select a suitable transport route and mode to ensure timely delivery and prevent delays in planting. This will also help to avoid the potential issue of laborers being unable to work effectively due to a lack of seedlings. The planting process should be conducted in accordance with the established guidelines for tree hole preparation, fertilizer application, support structure installation, and root irrigation. Additionally, nutrition is supplemented according to the specific growth of seedlings, to increase the survival rate of seedlings. After the completion of the project, the project manager should be familiar with the acceptance standards, and apply for acceptance in time after passing the self-inspection. The sooner the acceptance is passed, the sooner the warranty period is entered, thus reducing the maintenance cost.

4.4 Maintenance cost control

Highway greening landscape maintenance requires long-term investment costs. In order to improve the maintenance management input and output benefits[14], it is necessary to choose professional maintenance personnel to develop maintenance work schedule for regular watering, pruning, fertilizer application, timely management of diseases and pests to ensure the survival rate of green plants and reduce the cost of later reconfiguration of plants. It is necessary to implement the material receiving system, material categorization and placement, and do a good job of maintenance material receiving and using records, thus avoiding material waste[15]. Therefore, the cost control of the maintenance phase should be controlled from three aspects: the quality of maintenance personnel, technical

costs, and material costs.

5 Conclusions

The cost control of highway greening project is a comprehensive and dynamic process which involves every link of the project. Cost is regarded as a prerequisite from the early design to the later maintenance, and cost can determine the choice of design scheme and construction method. Therefore, a scientific and perfect cost management control system should be established from the beginning of the project. While guaranteeing the greening landscape effect and the duration of the project, it is essential to regulate the crucial nodes in each phase of the design, construction, and maintenance process. Furthermore, it is vital to facilitate close collaboration between all parties involved, thereby reducing costs, conserving resources, and lowering energy consumption. This approach can also lead to enhanced economic and social benefits for highway greening projects.

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