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Analysis of Social Cost in the Whole Life Cycle of High-speed Railway

Minjie Yang, Wenjue Su, Yutong Pu, Mengqin Li

School of Engineering, Southwest Petroleum University, Nanchong 637000, China

Abstract

In order to identify the adverse impact of High-speed railway on social development and determine the social cost of High-speed railway, based on the theory of social impact assessment, combined with the connotation of the whole life cycle of the railway project, the impact path method is used to evaluate the social impact of High-speed railway, and the social cost is used as the assessment indicator. This paper focuses on the analysis of administrative costs, safety production accident costs, business losses, traffic accident costs, operating noise costs and other costs, and puts forward quantitative ideas. The results of this paper hope to promote the cost measurement research of High-speed railway and improve the effectiveness of High-speed railway project decision-making.

Keywords

High-speed Railway; Social Impact; Social Cost; The Whole Life Cycle.

1. Introduction

In recent years, High-speed railway has developed rapidly in China. With the implementation of the "four vertical and four horizontal" and "eight vertical and eight horizontal" planning strategies, the world's most developed High-speed rail network has built[1]. High-speed railways promote exchanges and cooperation between regions and become the core force of national economic development. However, while High-speed railway promotes economic development, social problems such as environmental pollution, land acquisition and demolition, and traffic accidents have become increasingly prominent due to its rapid development. For example, High-speed rail lines passing through noise-sensitive areas (such as residential areas, schools, hospitals, office buildings, etc.) will affect people's health and reduce work efficiency; railway traffic accidents cause huge losses to people's lives and properties; the delay of the train will lead to the loss of the passenger's time value……Therefore, the social problems brought by High-speed railways have gradually been paid attention to in recent years, and many scholars have carried out social impact assessment (SIA) of High-speed railways. For example, Xuan Xiaomei[2]pointed out that the noise generated by the High-speed railway system has attracted great attention from residents along the line, and may become a key factor restricting the development of High-speed railways. Di Jing[3] discussed the social impact of the transportation system from four aspects: traffic accidents, noise pollution, air pollution and climate change. Jin Jing[4] pointed out that High-speed railway may bring social problems such as social chaos, cultural and belief conflict, and government corruption.

Although the research on the social impact of High-speed railway is increasing, the quantitative assessment of its social impact is still relatively lacking, which also leads to little consideration of High-speed railway in the early stages of project initiation, bidding and design. In the project budget estimates, bidding control prices, and bidding quotations, the method of monetization evaluation is rarely used to convert social impacts into social costs and incorporate them into the total project cost. Relevant studies have shown that the ratio of social cost to construction cost of different engineering projects varies greatly[5]. In some municipal projects, the social

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cost can be up to 4 times the construction cost[6]. Therefore, based on the theory of social impact assessment and combined with the whole life cycle of the project, this paper comprehensively identifies the social impact of High-speed railways, and discusses the quantification method of social costs, so as to improve the understanding of project participants on the social problems brought by High-speed railways, further improve the research on cost measurement of High-speed railway, which will help the scientific decision-making of the project.

2. The Whole Life Cycle Theory of High-speed Railway

2.1. The Whole Life Cycle Connotation

The concept of the whole life cycle originally refers to the whole process of an organism from birth to death, and then gradually extended to the whole process of an activity from the beginning to the end[2], and in the process of development, a variety of life cycle theories have been derived. For example, the PMI (Project Management Institute) life cycle theory divides the project cycle into four stages: feasibility study, project planning, project implementation, and project operation; ISO (International Standards Organization) life cycle theory divides the project cycle into construction stage, implementation stage and abolition stage. The CIOB (Chartered Institute Of Building) life cycle theory divides the project cycle into six stages: feasibility study, planning and design, project preparation, construction, commissioning and completion, and putting into use; The project cycle is determined as four stages: project initiation, design, implementation and project completion.

According to the whole life cycle theory mentioned above, the whole life cycle theory of engineering project is based on the engineering construction procedure, which can express the core meaning of the project. Referring to the project life cycle theory and combining the characteristics of High-speed railways, this paper divides the High-speed railway project life cycle into three stages, namely the planning period, the construction period and the operation period, as shown in Figure 1.

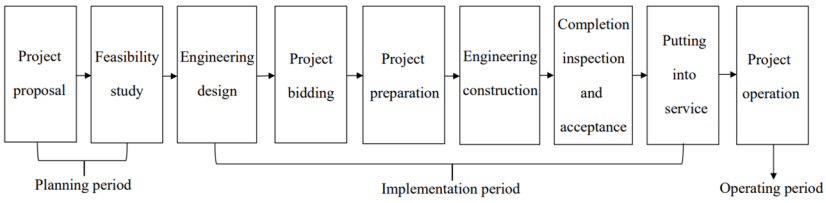

Figure 1. Division of stages in the whole life cycle of High-speed railway construction projects

2.2. The Whole Life Cycle Cost

The traditional project cost generally refers to the direct cost of the construction stage, mainly including labor, materials, machinery, etc., while the whole life cycle cost covers more extensive content. The classic whole life cycle cost includes project design, construction, inspection, maintenance and project failure cost[7], which can be further divided into direct cosst and indirect costs. Direct costs are the cost that directly forms the engineering entity, including the cost of materials, equipment, manpower, etc., and the costs are directly borne by the owner. Indirect costs are economic losses caused by environmental or social impacts related to engineering activities, which are divided into environmental costs and social costs. Such costs are not directly borne by the owner, but shared by the affected people[8]. Therefore, the project whole life cycle cost can be expressed by equation (1):

$$LCC = C_D + C_E + C_S \tag{1}$$

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C_D is the direct cost, C_E is the environmental cost, C_S is the social cost.

In 1989, Norway published "The Application of Life Cycle Cost Analysis in High-speed Railway System"[9], and put forward the life cycle cost analysis mode of High-speed railway system for the first time, Which determined the cost items of the whole life cycle of the High-speed railway system as: initial fixed cost, operation and maintenance cost, accident delay cost and hazard loss cost. Yang Yu[9] proposed a cost analysis framework for High-speed railways, including infrastructure cost, operating cost, environmental external cost, user cost and accident loss cost. Ma Chongyan[10] divided the comprehensive cost of High-speed railway into operation cost, capital cost and external cost. External cost mainly includes traffic accident cost and environmental cost. In recent years, although the academic community has gradually begun to emphasize that the indirect cost of the High-speed railway system, in addition to the direct cost, should be taken into account in the total project cost, the whole life cycle cost of the High-speed railway is still not fully covered, and there is a lack of a unified cost division standard. For example, in the early decision-making process of the project, due to factors such as engineering concepts and program selection, there may be conflicts with local ethnic habits, religious beliefs, social customs, etc., resulting in social public opinion, and in severe cases, parades and demonstrations may even occur. Administrative departments such as courts, courts and other administrative departments incur administrative costs to deal with such incidents; construction noise and operational noise will affect people's physical and mental health, reduce work efficiency, and damage the income of the affected people...

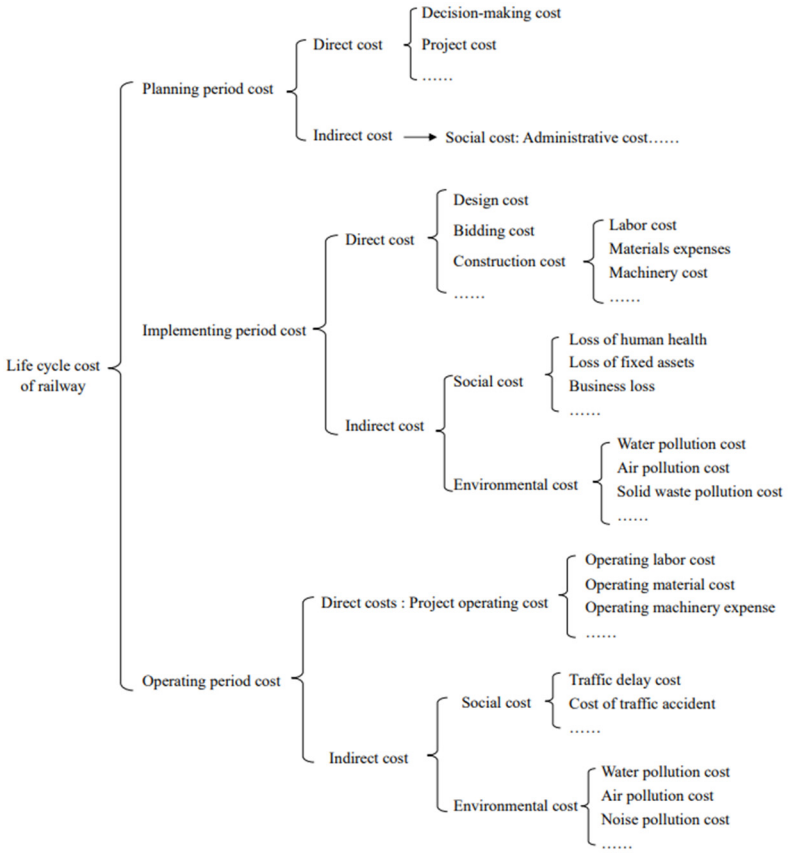

Figure 2. The whole life cycle cost of High-speed railway

Based on the division of High-speed railway construction stages shown in Figure 1, this paper determines the whole life cycle cost, as shown in Figure 2. Among them, direct costs can

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generally be obtained through project cost data, direct operating expenses, etc. Indirect costs are often ignored in High-speed railway project cost analysis because they are mostly intangible and difficult to measure in monetary terms. Indirect costs can generally be divided into environmental costs and social costs. Environmental costs are the monetization of environmental issues such as noise pollution, air pollution, ecological damage, and climate change caused by the construction and operation of High-speed railway projects. There are many mature estimation methods[11]. The social cost is the monetization of the impact of the High-speed railway project on the surrounding social environment, such as traffic delays, depreciation of fixed assets, business losses, etc. At present, the quantitative assessment of its social impact is still lacking, and the social cost is rarely included in the total project. Social impact analysis and social cost assessment of High-speed railway construction projects are still in their infancy.

3. Quantitative Analysis of Social Cost in the Whole Life Cycle of High-speed Railway

3.1. Identification of Social Impact

Social Life Cycle Assessment (S-LCA) can be used to assess the potential positive and negative socio-economic impacts of a product throughout its life cycle from raw material acquisition and processing, manufacturing, use, maintenance, recycling, etc[12]. The social impact category was proposed by the Society of Environmental Toxicology and Chemistry (SETAC) in 1993[13]. In 2004, the Life Cycle Initiative Research Organization of the United Nations Environment Programme (UNEP) proposed that it is necessary to incorporate social assessment into the research of LCA, and in 2009, the Guidelines for Social Assessment of Product Lifecycle was issued[14]. The "Guide" proposes 5 major stakeholders closely related to the product life cycle, involving 31 social impact indicators such as health and safety, community participation, employment, and cultural heritage protection.

Regarding the social impact of High-speed railways, in 2001, the former Ministry of Railways formulated the "Social Evaluation Measures for High-speed Railway Construction Projects", which requires the social evaluation of High-speed railways from macro and micro levels[15]. In recent years, although the research on the social impact of High-speed railway has been increasing, most of them mainly involve the positive effect of the social impact of High-speed railway. For example, Bai Yunfeng[16] analyzed the social impact of High-speed rail on the region from the aspects of regional accessibility, industrial structure optimization effect, employment effect, urbanization effect, and environmental protection effect. Zhang Feilian[17] analyzed the social impact of High-speed railway from four aspects: social environment, natural resources, social economy and transportation network conditions. Actually, while promoting social development, High-speed railway projects will also have negative social impacts, such as traffic accidents, traffic delays, and public opinion, which will cause losses to the lives and properties of the affected people. Although the academic community is gradually carrying out research on the negative effects of High-speed railway social impact, there are still few social impact analyses involving the whole life cycle of High-speed railway projects, and social impact factors are mainly concentrated in one or several aspects. For example, Xuan Xiaomei[2] quantitatively analyzed the noise impact during the operation of the High-speed railway system. Di Jing[3] quantitatively analyzed the social impact of the transportation system in the operation process from five aspects: traffic accidents, noise pollution, air pollution and climate change. Wang Yafei[19] analyzed the social impact of High-speed rail from traffic accidents, noise and harmful gases, and compared it with other modes of transportation.

This paper refers to the impact path method based on quantitative indicators in social impact assessment to identify the social impact of High-speed railways in the whole life cycle. The

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impact path method is an evaluation method that selects quantitative data from a social impact list to measure social impact based on impact paths or causal chains[20]. Among them, the impact source is the direct impact of the project, and the change of the impact source on stakeholders or areas of concern can be used as a midpoint indicator to promote the identification and quantification of endpoint indicators. The endpoint indicators can directly reflect the magnitude of social impact. This paper uses social cost indicators to quantify social impacts. According to the main research steps of the impact path method, as shown in Figure 3, the social impact of the whole life cycle of High-speed railways is identified, as shown in Figure 4.

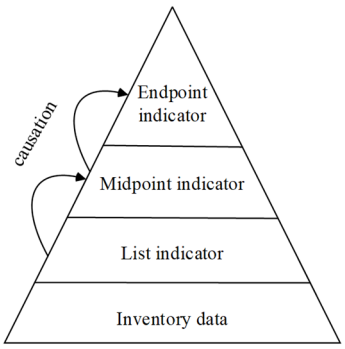

Figure 3. The main research steps of the influence path method [21]

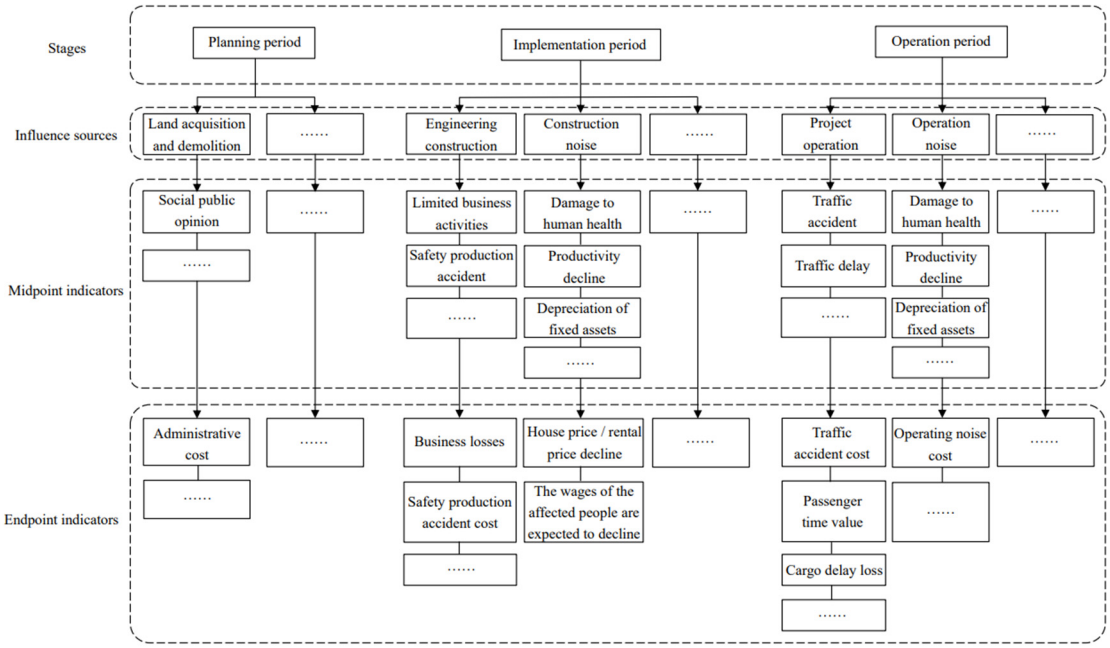

Figure 4. Analysis of the social impact path in the whole life cycle of High-speed railway construction projects

3.2. Quantitative Analysis of Social Cost

The social cost of an engineering project is the external cost of engineering activities, which is the measurable cost of one or more adverse impacts on the affected population borne by the public rather than the project participants (owners or contractors) [22]. Although social cost is rarely considered in the budget and bidding of High-speed railway projects at present, social cost is usually regarded as an indirect cost in the LCC model, and it is a non-negligible part of the total cost analysis of High-speed railway projects.

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3.2.1. Social Costs during Project Planning

administrative costs. In the early planning process of High-speed railway, due to factors such as scheme design, land acquisition and demolition, it may conflict with religious beliefs, social customs, and ethnic habits along the line, resulting in the occurrence of social public opinion and administrative costs. For the quantification of administrative costs, the proportion of accident administrative costs in previous studies can be used for simple estimation. For example, Tang [23] counted the case data of 223 construction projects in Hong Kong, and considered that the administrative cost of the accident was about 57% of the sum of the medical expenses and the loss of the victim's income. The administrative costs considered here include the traffic accidents and safety production accidents mentioned later, which are the costs for police dispatching, hospital first aid, court assistance, and firefighting services.

3.2.2. Social Costs during Project Implementation

1. Safety production accident costs. Relevant research shows that the cost of project production accidents is about 0.25%~3% of the total construction cost, and its size is affected by the number of construction workers, the number of subcontractors, project scale, project management complexity, security investment, etc[23]. Safety production accident costs mainly include medical expenses, labor value loss and mental loss. Property losses, on-site cleaning costs, accident investigation and litigation costs, safety accident fines, economic losses due to production stoppages and production reductions, and corporate reputation losses are all borne by the project contractor, and therefore are not included in the social cost [24].

(1) Medical costs. Including treatment fees, hospitalization fees, rehabilitation fees for the disabled, etc. Medical costs are related to factors such as disability grade, medical price level, and the number of disabled persons. Medical cost data can be collected through hospital charges, insurance payments, and casualty surveys.

(2) Loss of labor value. The bodily injury caused by the accident may lead to a decrease in labor capacity after resumption of work, a reduction in wage income, and the death or permanent disability may lose the ability to accumulate wealth. According to statistics, the value of labor lost by persons with permanent disabilities due to severe injuries accounts for 45% of the value of their full labor capacity[1]. The loss of labor value is related to factors such as wage income, age structure, disability level, etc. The loss value can be calculated by the Human Capital method[24].

(3) Mental loss. Mental loss refers to the loss of quality of life caused by “pain and grief” to victims and their relatives and friends[25], which can be estimated by using social experience values (such as court ruling experience)[24]. According to the court's judgment experience on the cost of mental damage in related cases, setting the proportional coefficient of the cost of mental damage to the total accident cost[26], the quality of life lost by the victim can be assessed. The mental loss here includes not only the mental loss of casualties and relatives caused by safety production accidents, but also the mental loss of casualties and relatives in the High-speed railway traffic accident mentioned later.

2. Business losses. During the construction of the High-speed railway project, due to the influence of dust, noise and occupation of the right-of-way, the merchants on both sides of the adjacent High-speed railway line will reduce the convenience of transportation for consumers, resulting in loss of business income. The loss of business income can be quantified by on-the-spot investigation of changes in business income before and after construction[24], and the impact of High-speed railway construction projects on business activities can also be analyzed by comparing taxes in relevant years before, during, and after the project. Since High-speed railway lines are generally far away from urban areas except for stations and are sparsely populated, the impact on business losses of merchants along the line is generally small.

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3.2.3. Social Costs during Project Operation

1. Railway traffic accident cost. Railway traffic accident mainly causes casualties and property losses. Regarding the cost of casualties, referring to the relevant statistics of foreign High-speed railway traffic accidents, as shown in Table 1, it can be found that the average cost of casualties per person kilometer is far less than 0.001 yuan. Therefore, the loss of casualties in the cost of High-speed railway traffic accidents is negligible[10]. Property damage includes damage to High-speed rail vehicle systems, track systems, and traction systems, etc., and can be estimated by the cost of repairing or replacing damaged items.

Table 1. Deaths and injuries in High-speed railway accidents[9]

	accident fatality rate(people/pkm)	accident injury rate(people /pkm)
Inter City Express	1.27×10^{-10}	1.36×10^{-10}
Train à Grande Vitesse	6.31×10^{-11}	0.29×10^{-11}

2. Passenger time cost. According to the current operation of High-speed railways, High-speed railways have a higher punctuality rate than other modes of transportation[9]. Therefore, the cost of traffic delay is not considered in the passenger time cost, and the value of travel time (VTT) is used as the cost indicator. VTT is estimated based on the consumer behavior theory, based on the user's income level and their willingness to pay for choosing a time-saving option (travel mode/destination/route) during travel. A common expression of VTT is the percentage of a user's average hourly wage, which in previous studies has ranged from 25% to 100% [24].

3. Operating noise cost. In 1996, the European Union issued a green paper on future noise strategies [27], which clearly mentioned that “the problem raised by the public for High-speed rail transportation is excessive noise”. Long-term exposure to noise environment is likely to increase the risk of hypertension and cardiovascular disease, and may also affect the human endocrine system and the central nervous system of the brain, resulting in sleep disorders, mental diseases, etc[2]. At present, there are few investigations and studies on the noise cost of High-speed railway operation in China. The European Union has earlier studied on the external cost of transportation and has achieved relatively mature research results. With reference to the research results of the European Union on the noise cost of High-speed railways, a quantitative estimation model of the noise cost of High-speed railways in China can be established. Referring to the average noise cost of High-speed railways in 28 EU countries, Xuan Xiaomei[2]used the unit value transfer method to use the per capita purchasing power parity GDP ratio, population density ratio and CPI ratio as correction factors to establish the noise cost calculation model of High-speed railways in China.

The total social cost of High-speed railway is the sum of the various costs in the above analysis. It can be seen that although various social costs often exist as recessive factors in the project cost analysis, they will have a non-negligible impact on the whole life cycle cost of the railway. . It should be noted that since the social impact brought by High-speed railway involves all aspects of social development, the social cost of High-speed railway listed in this paper is still incomplete, and it is still necessary to further investigate the social impact of specific High-speed railway projects.

4. Conclusion

This paper analyzes the social cost of High-speed railway in the whole life cycle. With reference to the social cost system for the whole life cycle of High-speed railway established in this paper, the social impact of High-speed railway in different life stages can be evaluated and the social

cost can be calculated. The calculation of the social cost of High-speed railway can not only further improve the comprehensive cost of the railway, but also provide a more scientific basis for the decision-making of railway projects. However, regarding the calculation and application of the social cost of High-speed railway, this paper only proposes relevant calculation ideas, and the calculation method and calculation data of the social cost of specific High-speed railway projects still need further discussion.

Acknowledgments

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