Green highway evaluation based on Big Data GIS and BIM technology

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Received: 11 March 2021 / Accepted: 1 May 2021 / Published online: 29 May 2021 © Saudi Society for Geosciences 2021

Abstract

The construction of a green road that has no negative impacts and can develop in harmony with the natural environment and ecological construction has become the inevitable development direction of our national road construction. For some construction projects with relatively high difficulty, relatively high technical requirements, and relatively complex engineering framework, the use of BIM technology can improve the management ability and management level of the construction of the project, thereby improving the development of quality engineering construction. GIS technology can accurately locate the natural environment and geographic information surrounding the construction project. So as to make the BIM model more complete. Therefore, in the process of highway project construction, GIS data and BIM model are used to combine, so that the two can cooperate with each other to achieve the degree of complementary advantages. The two can effectively communicate and exchange data, so that the model data can be combined more accurately when modeling. Under the guidance of the concept of sustainable development, the design, construction and maintenance of green highways are carried out, so as to provide a theoretical basis and scientific basis for the evaluation of green highways.

Keywords Big data GIS · BIM technology · Green highway · Evaluation research

Introduction

As the saying goes, if you want to get rich before you build roads, with the rapid development of our country’s economic construction, our country’s roads are also very smooth and developed, especially highway construction. Now our country’s highways can be said to extend in all directions. The construction of national highways, provincial highways, and expressways has enabled our country to achieve rapid development. While the highway brings convenience to people’s traffic, it also inevitably brings some negative effects to the natural environment and ecological construction (Gardenas 2000). Therefore, the construction of a green road that has no negative impacts and can develop in harmony with the natural environment and ecological construction has become the inevitable development direction of our national road construction (Norby and Luo 2004). During the construction of highway facilities with the goal of green highways and quality projects, the construction of information technology based on transportation is gradually applied and widely developed. Our country’s relevant authorities have also issued a number of policies in recent years to encourage the use and promotion of BIM technology. In this case, BIM technology has been greatly developed (Köster et al. 2018). For some construction projects with relatively high difficulty, relatively high technical requirements, and relatively complex engineering framework, the use of BIM technology can improve the management ability and management level of the construction of the project, thereby improving the development of quality engineering construction (Abaimov et al. 2000). The BIM technology model is based on WebGL technology. The use of BIM technology in various management platforms has been applied in the design, implementation, and operation of traffic construction projects. The organic integration of GIS technology and BIM technology can enable the construction project to take into account both the macro- and microlevels and enable the transportation construction project to make significant progress in realizing information construction (Laganière et al. 2012).
Application of GIS and BIM technology based on big data in the process of green highway construction

GIS technology

Geographic information system technology is what we usually call GIS technology. Geographical information system refers to the information technology and information system in a certain specific space. Geographic information system refers to an information technology system that collects, organizes, summarizes, and analyzes the relevant geographic data on the surface of our earth through some software and hardware information technologies (Kuzmichev et al. 2005). Through hardware facilities such as remote sensors, cameras, and computers, software systems such as photography and image processing are applied to the hardware facilities to obtain GIS data. Now in the development of various industries such as smart cities and smart transportation advocated in our country, GIS technology has been widely used. And as the scope of my country’s Wisdom+ becomes wider and wider, the role of GIS technology will become greater and greater (O’Neill et al. 2003).

BIM lightweight technology

BIM lightweight technology

Among the BIM models, the model has various high-quality features such as visibility, information, and integration. Due to the existence of these characteristics and advantages, the BIM model is widely used in the construction of engineering projects. But at the same time, in the application process, various software facilities and software system settings are needed to realize it together (Gaüzère et al. 2018). The system of BIM software is different, which will lead to different data requirements. BIM lightweight technology generally refers to the data analysis of the BIM model, the geometric data in the model is analyzed, and these data are optimized at the same time, so that the data information of the BIM model is reduced, and this data information converted into WEB data format (Parazoo et al. 2018). Then watch the BIM model on the computer through the browser. Because the browser is also limited by computer memory, etc., when the browser views the model, the browser data should be adjusted appropriately. The main purpose is to convert the BIM model to a certain extent and load it lightly (Maier and Kress 2000). Only in this way can the model be better viewed by the browser. In the process of viewing from the BIM model to the browser, several conversions are required to achieve this. The application situation in the conversion process directly affects the lightweight effect. Therefore, the BIM model is transformed and further developed and applied by loading, so that the model can adapt to more management system platforms. It can effectively improve the use efficiency of the BIM model, and it can also solve the problem that the model is affected by related software.

System architecture

In the system framework associated with the lightweight BIM model, there are mainly two parts to constitute: one is the C/S client side, and the other is the B/S browser side (Osawa et al. 2010). Each of these two parts has its own advantages and disadvantages. It can be used for many types of management platforms. In the C/S architecture, because the architecture system needs to be installed on the client side, the model and system program must be installed in the computer. The systems that need to be placed are the client system and the background management system. The main purpose of putting in the client system is to display it in the function interface (Abbott and Jones 2015). The main purpose of putting it in the background manager is to realize data sharing and data maintenance. In the C/S architecture, because the BIM system model has more operation interfaces, data security is easier to guarantee.

![Fig. 1: Basic structure of B/S system](image-url)
And under the effect of a layer of interaction, the speed of the model can become very fast. The same problem is that the framework has relatively few adaptability, and it must be implanted in the location of the project. And after the system is installed, when the model or data changes, it is more difficult to adjust and the cost is higher. The B/S architecture refers to the abbreviation of browser and server. See Fig. 1 for details.

The BIM system does not need to be specially installed and implanted in the platform, and it can be viewed in the WEB browser of the Internet. Therefore, the BIM model is usually used as the main method in the real society. The B/S architecture is mainly through the interaction between the user and the background and the background manager, after logical analysis and various operations on the BIM model, viewing and browsing through the WEB terminal (Gentsch et al. 2018).

The feature of this architecture is that users do not need to perform special installation and only need to use a web browser to operate, and because the data and programs of the BIM system are in the background manager, when the data changes or the program is updated, it can be completed by upgrading the server, and the operation is relatively simple (Pleshkov 2002). The same problem is that if certain customization requirements arise, special development is required, and the model will be limited and affected by speeds such as network speed. When the data or the program changes, the browsing interface needs to be refreshed before it can be displayed.

**Combination of GIS data and BIM model**

The BIM model enables the entire process of construction projects to realize information transmission,
information sharing, and information collaboration. Therefore, the BIM model is widely used in transportation construction projects. At the same time, the area spanned by highway construction is relatively large. It has a very close relationship with the geographic location information of different regions (Makhnykina et al. 2020). Therefore, the disadvantage of the BIM system is that it cannot accurately grasp the geographic information and geographic positioning in the road construction. If the BIM technology is used alone, it will make the project construction process encounter many difficulties and uncertainties. GIS technology can accurately locate the natural environment and geographic information surrounding the construction project, so as to make the BIM model more complete (Komulainen et al. 1999). Therefore, in the process of highway project construction, GIS data and BIM model are used to combine, so that the two can cooperate with each other to achieve the degree of complementary advantages. The two can effectively communicate and exchange data, so that the model data can be combined more accurately when modeling.

### The concept of green highway

Green roads refer to roads with sustainable development concepts established on the basis of protecting the ecological environment and natural resources (Shugalei 2005). In simple terms, green roads refer to those that have long-term development potential and can save

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**Table 1** Index system in planning and design stage

| Indicator type       | First level indicator                           | Secondary indicators                                      | Indicator attributes |
|----------------------|-------------------------------------------------|----------------------------------------------------------|----------------------|
| **Pressure layer**   | **Rational design**                             | Rationalization of highway curves                        | Qualitative          |
|                      |                                                 | Rationalization of pavement quality                      | Qualitative          |
|                      |                                                 | Rationalization of various indicators                    | Qualitative          |
|                      |                                                 | Rationalization of related facilities                    | Qualitative          |
| **State layer**      | **Social environment**                          | Land use                                                  | Qualitative          |
|                      |                                                 | Impact of infrastructure                                 | Qualitative          |
|                      |                                                 | Security design situation                                | Qualitative          |
|                      |                                                 | Demolition and resettlement situation                    | Qualitative          |
|                      | The problems caused by the ecological environment | The impact of organisms and surrounding environment       | Qualitative          |
|                      |                                                 | The impact of natural resources such as water           | Qualitative          |
| **Response layer**   | **Environmental pollution design**              | Air pollution prevention and control                       | Qualitative          |
|                      |                                                 | Water pollution prevention and control                    | Qualitative          |
|                      | **Ecological protection design**                | The area occupied by green space                         | Fixed oxygen          |
|                      |                                                 | Animal condition per unit area                           | Quantitative          |

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**Index system of planning and design stage**

![Index system of planning and design stage](image)

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energy, improve the environment, and prevent pollution to the greatest extent within the scope of the road. At the same time, people who have walked on the road can have a feeling of comfort, safety, and beauty. The high-way can be harmoniously integrated with natural resources (Bhupinderpal-Singh et al. 2003). The concept of green highway mainly includes five aspects. One is the concept of sustainable development. In other words, it cannot only meet the needs of people today, but will not pose any threat to our children and grandchildren and can continue to develop for a long time. The second is that in the design, construction, construction, and

| Indicator type          | First level indicator                      | Secondary indicators                                      | Indicator attributes |
|-------------------------|--------------------------------------------|-----------------------------------------------------------|---------------------|
| Pressure layer          | According to the construction plan         | Rationalization of temporary land use during construction  | Qualitative         |
|                         |                                            | Rationalization of mechanical equipment in construction    | Qualitative         |
|                         |                                            | Rationalization of construction technology                | Qualitative         |
| For workers             |                                            | Environmental protection awareness of operators            | Qualitative         |
|                         |                                            | Garbage disposal status of operators                       | Qualitative         |
|                         |                                            | The impact of operators on the surrounding biological environment | Qualitative |
| State layer             | the effect on the environment              | Impact on land environment                                | Qualitative         |
|                         |                                            | Impact on soil erosion per unit area                       | Quantitative        |
|                         |                                            | Impact on vegetation per unit area                         | Qualitative         |
| Use of resources        |                                            | Improve the use of various resources                      | Quantitative        |
|                         |                                            | Saving raw materials                                      | Quantitative        |
|                         |                                            | Reuse of various resources                                | Quantitative        |
|                         |                                            | Use of local materials                                    | Quantitative        |
| Response layer          | Prevention and treatment of environmental pollution | Control of noise                                          | Qualitative         |
|                         |                                            | Disposal of construction waste                            | Quantitative        |
|                         |                                            | Treatment of water pollution                              | Fixed body          |
| Protection of the ecological environment | Restoration of surrounding vegetation | Quantitative                                               |
|                         |                                            | Protection of surrounding species                          | Qualitative         |
|                         |                                            | Protection of surrounding ancient trees and cultural relics | Qualitative         |

Fig. 5 Construction index system

Index system of construction stage
use of the highway, the concept of green must be emphasized and environmental pollution and waste of resources must be avoided. The third is in the entire process of design, construction, and use of the highway to achieve the purpose of saving energy and protecting the environment. The fourth is to make people feel safe, comfortable, and beautiful when passing on the highway (Sulzman et al. 2005). Fifth, the construction of green roads enables the road and the surrounding environment to be organically and harmoniously integrated and to achieve the common integration of people, nature, and roads.

**Table 3** Operation and maintenance stage indicator system

| Indicator type                        | First level indicator                                      | Secondary indicators                                                                 | Indicator attributes |
|--------------------------------------|------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------|
| Pressure layer                       | Daily use of highways                                      | Situation of various types of vehicles passing                                       | Quantitative         |
|                                      |                                                            | Damage to the highway by large and medium trucks                                     | Quantitative         |
|                                      |                                                            | Safety of vehicle traffic                                                             | Qualitative          |
| Usage of service area in highway     |                                                            | Sewage treatment in the service area                                                 | Quantitative         |
|                                      |                                                            | Water saving in the service area                                                      | Qualitative          |
|                                      |                                                            | The impact of service area personnel on the surrounding environment                 | Qualitative          |
| State layer                          | Pollution to the surrounding environment                   | Air pollution                                                                         | Quantitative         |
|                                      |                                                            | Noise pollution                                                                       | Quantitative         |
| Impact on the surrounding environment|                                                            | Soil erosion in surrounding unit area                                                | Qualitative          |
|                                      |                                                            | Coordination of the road and surrounding scenery                                     | Qualitative          |
|                                      |                                                            | The surrounding animals are affected                                                 | Qualitative          |
| Response layer                       | Prevention and treatment of environmental pollution        | Prevention and control of dust in the road                                            | Qualitative          |
|                                      |                                                            | Installation of sound barriers on highway                                            | Quantitative         |
| Protection of the ecological environment|                                 | The passage of animals per unit area                                                 | Quantitative         |
|                                      |                                                            | Compensation for damaged ecology                                                     | Quantitative         |
| Installation of traffic safety facilities|                                | Details of the installation of traffic safety facilities                              | Quantitative         |

**Index system of operation and maintenance stage**

Fig. 6 Operation and maintenance stage indicator system
Construction of the evaluation system of green highways

Framework model of sustainable development indicator system

The framework model of the sustainable development indicator system mainly has the following three models. Through the research and analysis of these three models, it is believed that under the state of exerting pressure on the surrounding environment, the quality of the environment is improved and the state of the environment is improved to get better (Makhnykina et al. 2016). The state and society have made various aspects of society respond by issuing environmental protection policies and policies for coordinated economic and environmental development. This approach is consistent with the development of green highways.

PSR (pressure-state-response) framework model

The pressure-state-response model is also the PSR model. It is a model framework commonly used in society. He was a model framework for sustainable development proposed in the West in 1989. In this model framework, sustainable development is used as a basic viewpoint and dominant idea (Abaimov et al. 2004). This model is properly expressed by analyzing the various impacts of people’s activities on the surrounding environment and the relationships between man and nature. Pressure means that people’s production and business activities will put a certain pressure on the surrounding environment (Zobitz et al. 2008). State refers to a state between the environment and natural resources and people’s activities in order to achieve sustainable development when environmental pressure increases (Tang et al. 2020). Response refers to a series of measures taken by people to improve and protect the environment based on the current situation of environmental pollution and environmental damage guided by the idea of sustainable development. The specific model is shown in the figure below (Fig. 2):

| Grade standard | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|----------------|---------|---------|---------|---------|---------|
| Score range    | 90-100  | 80-89   | 70-79   | 60-69   | 0-59    |
| Type of pressure| Very light pressure | Less pressure | General pressure | Heavier pressure | Extreme stress |
| State type     | Minimal impact | Minor impact | General impact | More serious impact | Very severe impact |
| Response type  | Great response | Larger response | General response | Smaller response | Minimal response |

Index grade standard

![Index grade standard](image-url)
| Stage                              | Grade                              | Level 1            | Level 2            | Level 3            | Level 4            | Level 5            |
|-----------------------------------|------------------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Planning and Design               | Score range                        | 90–100             | 80–89              | 70–79              | 60–69              | 0–59               |
| Stress situation                  | Very light pressure                | Less pressure      | General pressure   | Heavier pressure   | Extreme stress     |
| Reasonable situation along the road| Very reasonable along the highway  | Reasonable along the highway | Unreasonable along the highway | Very unreasonable along the highway |
| Road design rationalization situation| The road design is very reasonable | Road design is more reasonable | Unreasonable road design | The road design is very unreasonable |
| Rationalization of design standards| The design standards are reasonable | Design standards are reasonable | Unreasonable design standards | The design standards are very unreasonable |
| Rationalization of related supporting equipment | Related supporting equipment is very reasonable | Related supporting equipment is more reasonable | Related supporting equipment is reasonable | Related supporting equipment is very unreasonable |
| Construction                      | Selected temporary construction situation | The selection of temporary construction is very reasonable | Selection of temporary construction is more reasonable | Reasonable selection of temporary construction | Unreasonable selection of temporary construction | The selection of temporary construction is very unreasonable |
| Usage of construction equipment   | Construction equipment is very easy to use | Construction equipment is more easy to use | Easy to use construction equipment | Construction equipment is not easy to use | Construction equipment is very difficult to use |
| Environmental awareness of operators | Operators have very good environmental awareness | Operators have good environmental awareness | Operators have a general impact on the biological habitat around the highway | Operators have a greater impact on the biological habitat around the highway |
| The impact of operators on living things around the highway | Operators have minimal impact on the biological habitat around the highway | Operators have little impact on the biological habitat around the highway | Operators have a general impact on the biological habitat around the highway | Operators have a great impact on the biological habitat around the highway |
| Operation and maintenance         | Vehicle traffic safety              | Vehicle traffic is extremely safe | Higher vehicle traffic safety | High vehicle traffic safety | Low vehicle traffic safety | Very low vehicle traffic safety |
| Energy and water conservation in the service area | The energy and water conservation in the service area is very good | Good energy and water conservation in the service area | General energy and water conservation in the service area | Poor energy and water conservation in the service area | The energy and water conservation situation in the service area is very bad |
| The impact of service area personnel on the surrounding environment | Service area personnel have minimal impact on the surrounding environment | Service area personnel have little impact on the surrounding environment | Service area personnel have a general impact on the surrounding environment | Service area personnel have a greater impact on the surrounding environment | Service area personnel have a great impact on the surrounding environment |
| Table 6 | Classification table of status indicators |
|---|---|
| **Stage** | **Grade** | **Score range** | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **Level 5** |
| Stress situation | Minimal pressure | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| Planning and Design | Less pressure | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | General pressure | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Greater pressure | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Great pressure | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| Biological and environmental impact | Minimal biological and environmental impact | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| | Less biological and environmental impact | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | General biological and environmental impact | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Greater biological and environmental impact | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Great biological and environmental impact | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| Impact on environmental protection water resources | Minimal impact on environmental protection and water resources | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| | Less impact on environmental protection and water resources | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | General impact on environmental protection and water resources | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Great impact on environmental protection and water resources | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Great impact on environmental protection and water resources | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| Construction | Minimal impact on the land environment | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| | Less impact on the land environment | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | General impact on land environment | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Great impact on land environment | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Great impact on the land environment | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| Degree of energy reuse | Extremely high degree of energy reuse | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| | High degree of energy reuse | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | Moderate degree of energy reuse | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Low energy reuse | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Very low degree of energy reuse | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| Operation and maintenance | Highly integrated with the surrounding environment | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| | High integration with the surrounding environment | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | Moderate integration with the surrounding environment | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Low integration with the surrounding environment | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Very low integration with the surrounding environment | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| Biological impact | Minimal biological impact | 90 – 100 | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure impact is average | Infrastructure has a huge impact |
| | Less biologically affected | 80 – 89 | General driving safety guarantee | General driving safety guarantee | General driving safety guarantee | Greater driving safety guarantee | Great driving safety guarantee |
| | Biologically affected | 70 – 79 | General biological and environmental impact | General biological and environmental impact | General biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
| | Biologically affected | 60 – 69 | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources | Great impact on environmental protection and water resources |
| | Biologically affected | 0 – 59 | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact | Great biological and environmental impact |
development ideas and concepts. The PS R model of the green highway is shown in the figure below (Fig. 3):

**Establishment of green highway evaluation index system**

Design the PSR framework model of the green highway. In the process, design the pressure layer, the state layer, and the response layer (Maljanen et al. 2001). Through expert argumentation, specific indicators for preventing environmental pollution and protecting the environment are proposed. The details are shown in the table below (Table 1):

The graphic description of the index system in the planning and design stage is shown in Fig. 4.

The land occupied along the highway is preferably barren and deserted land, and try not to occupy arable land and wetland (Tarnocai et al. 2009). In terms of highway protection facilities, these facilities should also reduce the encroachment on surrounding land. Therefore, the calculation formula for the use of land:

\[
\text{Land use ratio} = \frac{\text{Area of cultivated land occupied}}{\text{Total area of highway}} \times 100\% \quad (1)
\]

The possible calculation formula for the demolition and resettlement of the surrounding residents is as follows:

\[
\text{Demolition and resettlement rate} = \frac{\text{Demolition building area}}{\text{Total area of construction project}} \times 100\% \quad (2)
\]

The area occupied by the green area is the ratio of the area of the green area to the area of the road, namely:

\[
\text{Green coverage} = \frac{\text{afforested area}}{\text{Total area of highway}} \times 100\% \quad (3)
\]

Use the green highway PSR framework model to analyze the construction of the green highway, and set various indicators from the perspective of natural ecological environment. The specific indicators are shown in Table 2:

The image description of the index system during the construction phase is shown in Fig. 5.

The control of water and soil erosion by green highways is mainly expressed by the amount of water and soil erosion per unit area:

\[
Q = \frac{S}{S \times L} \quad (4)
\]

The protection of surrounding vegetation by green roads is mainly calculated by the loss rate of vegetation per unit area. Calculated as follows:

\[
P = \frac{(S_q - S_h)}{S_q} \quad (5)
\]
The sewage treatment rate is calculated as the ratio of the treated sewage to the total sewage. The calculation formula is as follows:

\[
\text{Sewage treatment rate} = \frac{\text{The amount of sewage meeting the discharge standard after treatment}}{\text{Total amount of sewage}} \times 100\%
\]  

(6)

Restoration of surrounding vegetation:

\[
\text{Slope vegetation recovery rate} = \frac{\text{Area of vegetation restoration within the scope of slope control}}{\text{Total vegetation restoration area within the scope of slope control}} \times 100\%
\]  

(7)

Use the green highway PSR framework model to analyze the maintenance of the green highway, and set the pressure layer, the state layer, and the corresponding layer three indicators; the specific indicators are shown in Table 3:

The image description of the index system in the operation and maintenance phase is shown in Fig. 6.

The purpose of installing sound barriers on highways is to reduce the noise impact of vehicles passing on the highway on the surrounding environment (Trefilova et al. 2009). The calculation formula of the sound barrier setting rate is as follows:

\[
\text{Setting rate of sound barrier} = \frac{\text{The sound screen length has been set}}{\text{The length of sound barrier should be set}} \times 100\%
\]  

(8)

The road construction will affect the surrounding vegetation and organisms, which will be compensated after the completion of the project, so the calculation formula for the ecological compensation rate is as follows:

\[
\text{Ecological compensation rate} = \frac{\text{Ecological restoration}}{\text{Ecological loss}} \times 100\%
\]  

(9)

Traffic safety facilities include traffic signs and protective facilities. Accidents can be reduced, so the calculation formula for the amount of safety facilities is:

\[
\text{Arrangement rate of safety facilities} = \frac{\text{Safety quantity arranged}}{\text{The quantity of safety facilities should be arranged}} \times 100\%
\]  

(10)

Quantification of green highway evaluation indicators

The evaluation index of green highway is set to four types and five grades (Table 4). Because some types cannot be accurately defined by numerical values, only general descriptions can be made (Kudeyarov and Kurganova 2005). The specific standards and corresponding scores are shown in the following table:

The image description of the index level standard is shown in Fig. 7.

It can be seen in detail from Table 5 that the green company has graded and refined the scores in the initial design, intermediate construction, and final maintenance, as shown in Table 5 (Tables 6, 7, 8, and 9)

Empirical analysis of green highway evaluation

Establishment of comment collection for a green highway renovation project

The road greenness evaluation set refers to the evaluation of possible results through a variety of factors, where V represents the possible results, and the research results are divided into 5 levels, as shown in the following table:

The image descriptions of pressure, status and response index levels are shown in Fig. 8.

The greeness of the highway is divided into 5 grades. The specific evaluation standards and conditions are shown in the following table:

The image description of the green level standard is shown in Fig. 9.

Determination of the evaluation index weight of a green highway renovation project

Through the weight calculation method and method, the following weight values are obtained, as shown in Table 10:
The image description of the indicator weights is shown in Fig. 10.

Analysis of fuzzy comprehensive evaluation results of a green highway renovation project

The analysis of the comprehensive evaluation results of the fuzzy transformation of green highways shows that in the process of design, construction, and maintenance of green highways, energy-saving and environmentally friendly products are used, noise and waste treatment are reduced, and water resources are reasonably protected (Bond-Lambert and Thompson 2010). The road landscape and the surrounding scenery can be well integrated.

Comparative analysis of evaluation results before and after a certain green highway reconstruction

Comparative analysis of evaluation results in the planning and design stage

Through comparison and analysis, it can be seen that the pressure is relatively small in the planning and design stage, and it is bright green at this time (Kumpu et al. 2018). In the engineering transformation stage, it is generally green.

Comparative analysis of evaluation results during construction stage

It is generally bright green during the construction phase. In the process of the renovation project, it gradually changed from bright green to green.

Comparative analysis of evaluation results in the operation and maintenance phase

In the maintenance phase, the degree of bright green is relatively high. In the transformation process, the degree of green is obviously greater than that of bright green (Widén 2002).

Countermeasures and suggestions for green highway construction

Environmental protection measures in the early decision-making stage of green highways

Environmental protection in the early decision-making stage of green highways should pay attention to the sensitivity of the surrounding environment and divide

Pressure, state and response index grade standard

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Table 9 Green level standard

| Grade | V1 | V2 | V3 | V4 | V5 |
|-------|----|----|----|----|----|
| Greenness Points | 90-100 | 80-89 | 70-79 | 60-69 | 0-59 |
| Rating | Level 1 Dark green | Level 2 Dark green | Level 3 Green | Level 4 Bright green | Level 5 Light green |

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Fig. 8 Pressure, status, and response index level standards
different regions into several sensitive areas (Eliasson et al. 2005). For areas with high sensitivity, the sensitivity is reduced by reducing noise and pollution, so as to provide the protective factors required for environmental investigations for the construction of green roads.

**Green highway environmental protection design**

The environmental protection of green roads requires the establishment of comfortable, safe, and beautiful green roads under the general direction of sustainable development (Morishita et al. 2010). At the same time, energy-saving and environmentally friendly materials are used to construct roads.

**Table 10** Index weight

| Indicator type       | First level indicator | First-level indicator weight | Secondary indicators | Secondary indicator weight | Comprehensive weight |
|----------------------|-----------------------|------------------------------|----------------------|---------------------------|---------------------|
| Pressure layer       | Design rationality    | 0.455                        | Reasonability of Highway Route Selection | 0.257                    | 0.257               |
|                      |                       |                              | Long-life pavement design | 0.184                    | 0.184               |
|                      |                       |                              | Design index rationality | 0.408                    | 0.408               |
|                      |                       |                              | Rationality of supporting facilities along the line | 0.153                    | 0.153               |
|                      | Social environmental impact | 0.455                        | Ten places to use | 0.258                    | 0.119               |
|                      | Infrastructure impact |                              | 0.236                        | 0.108                     |
|                      | Degree of travel and security | 0.182                        | 0.182                     |
|                      | Demolition and resettlement rate | 0.326                        | 0.149                     |
|                      | Biological environmental impact | 0.545                        | The impact of organisms and their habitats | 0.438                    | 0.239               |
|                      | Water resources, natural water flow suit | 0.564                        | 0.308                     |
|                      | Environmental pollution prevention | 0.587                        | Acoustic pollution prevention design | 0.412                    | 0.242               |
|                      | Water pollution prevention design | 0.588                        | 0.346                     |
|                      | Ecological Protection | 0.415                        | Green coverage | 0.617                    | 0.256               |
|                      | Animal passage corridor per kilometer | 0.385                        | 0.158                     |

In terms of road protection, attention should be paid to reducing noise and waste water pollution in terms of aspects makes the highway environment and the surrounding environment well integrated.

**Environmental protection measures during construction of green highway**

During the construction process, temporary land should be used for various building materials in the highway. Try to avoid occupying basic farmland and at the same time in lots of earthwork (Gao et al. 2018). During the rainy season, attention should be paid to drainage to avoid the phenomenon of rainwater accumulation.

**Environmental protection measures during the operation and maintenance period of green highways**

During highway maintenance, attention should be paid to the use of noise barriers to reduce the pollution caused by traffic noise to the surrounding environment (Yanagihara et al. 2000). At the same time, the road surface should be cleaned and cleaned regularly to ensure the safety and smoothness of the road surface. In places with more serious pollution, scientific planting should be carried out to increase the green area and reduce air pollution.
Conclusion

Under the guidance of the concept of sustainable development, the design, construction, and maintenance of green roads are carried out, in order to provide a theoretical basis and scientific basis for the evaluation of green roads and to put forward certain reference opinions for the construction of green roads in the future.

Acknowledgements

Evaluation of green highway in Heilongjiang Province Based on BIM Technology, Science and technology project of Heilongjiang Transportation Department, Project Number: J-20181215.

Declarations

Conflict of interest  The authors declare that they have no competing interests.

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