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Improvement of Traffic Project Performance Adopting Integrating BIM and VISSIM

Cải thiện hiệu quả dự án giao thông bằng cách tích hợp BIM và VISSIM

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ABSTRACT
Infrastructure decisions greatly affect society for a long time. Hence, it is necessary to evaluate the effectiveness of traffic construction in the present and future. Traffic modeling has proven to be an effective tool to analyze and evaluate the impact of traffic projects through various simulation scenarios. It is also a vital tool to obtain suitable traffic planning decisions. VISSIM is being widely implemented in the traffic simulation field. Besides, Building Information Modeling (BIM) technology is being widely applied to road and bridge projects to enhance the quality and efficiency of the whole project process. This study proposes the integration of BIM and VISSIM simulation for improving construction management. To achieve the objective, firstly, we suggest the design idea for the traffic project. Secondly, the author builds models and simulates traffic using VISSIM software. The goal of this step is to evaluate the effectiveness of the project in the future. Thirdly, the appropriate design is implemented by the Civil 3D software. Lastly, the three-dimensional (3D) model is exported via the InfraWorks software to visualize this project. The empirical project is applied to evaluate the efficiency of this proposed approach. The result shows that the hybrid method between BIM and VISSIM is promising to be used for monitoring and improving traffic project management.

Keywords: Traffic project optimization, VISSIM simulation, Building information modeling (BIM), Infrastructure management, Project evaluation.

Từ khóa: Tối ưu hóa dự án giao thông, Mô phỏng VISSIM, Mô hình thông tin công trình (BIM), Quản lý cơ sở hạ tầng, Đánh giá dự án.

1. INTRODUCTION

The process of urbanization generates a new face for economic development. However, the transport infrastructure quality is not synchronized with the speed of urbanization. Urban traffic in big cities of our country is a dilemma for managers leading to environmental pollution and traffic jams, especially during rush hours. The current urban traffic situation is the result of the high urbanization rate, the rapid increase of private vehicles, and increasing traffic demand [1]. Many solutions have been proposed to improve the quality of urban transport such as upgrading infrastructure, developing public transport, and improving traffic organization measures. However, focusing only on developing infrastructure does not entirely solve the traffic problem. On that basis, traffic management and adjustment solutions are proving effective in improving the level of service (LOS).

The urban transport system is very complex and includes many components such as the interchange system, the road network, and the transport facilities. In recent years, simulation is proving to be an effective tool to improve traffic quality. The simulation assumes scenarios and analyzes designed options in order to choose the optimal solution. It is completely superior to traditional methods. In addition, the simulation tool also helps to reduce costs and ensure navigability based on the ability to analyze different scenarios in specific traffic conditions. In short, traffic simulation increases the efficiency of traffic management and exploitation by offering different options for complex traffic problems.

Besides, Traffic modeling has been widely applied to construction management to reproduce traffic on the road based on actual observation. It embedded mathematical models into simulation software based on the experience of the creator [2]. In other words, traffic models played an important role in traffic engineering for scenario planning, assessment, and management [3], such as improving smooth flow for the intersection [4]. With the outstanding development of science and technology, traffic management and design are constantly improving. Complex problems at intersections and roads are solved through simulation and scenario analysis based on real traffic networks. On that basis, traffic simulation software is increasingly needed in the field of design and management besides specialized design software such as Nova, Autocad, Infaworks, Civil 3D, etc. Currently, there are many traffic simulation softwares being applied such as VISSIM [5,6], AIMSUM [7], PARAMICS [8], SUMO [9], etc. In traffic simulation softwares, VISSIM is widely applied in specific practical conditions. VISSIM is capable of modeling and analyzing diverse traffic flows with many objects such as cars, motorbikes, buses, bicycles, trucks, and pedestrians. In addition, VISSIM also supports the simulation of many types of terrain and traffic networks flexibly. For instance, Lin et al. [10] modeled the road network through the VISSIM simulator. This paper used delay time, speed, and queue length to evaluate the simulation model. Duy and Hien [11] applied VISSIM for building two-wheeled traffic simulations in the context of Vietnam conditions. Lu et al. [12] calibrated the characteristics of the car-following model based on real video through VISSIM. These experiments show that the proposed method outperformed traditional methods. However, VISSIM software cannot build an accurate model with the plan view and create a 3D model similar to the real observation.

Currently, 3D models have recently been used in government transport infrastructure projects. Nevertheless, BIM not only focuses on 3D modeling but also deals with other issues such as digitized information about the project's time, cost, and life cycle. This is extremely important for transport infrastructure projects, especially for large and complex projects. Recently, BIM has been one of the promising technologies to obtain a potential design along with the infrastructure settings [13-15]. BIM has become an effective tool for developing smart cities in the era of internet-of-things and big data. Hence, BIM can improve the life cycle of the project, including planning, design, construction, management, and maintenance. Previous works regarding the application of BIM in traffic infrastructure projects mainly focus on the functions of BIM technology and future development. For example, Borrmann et al. [16] applied geographic information systems (GIS) and BIM in planning the design and construction of shield tunnels. Other researchers used BIM technology for roadways [17,18] and bridges [19,20].

In this work, we suggest a hybrid method that combines BIM technology and VISSIM simulator for improving construction quality. First, we survey the research area and propose the design idea. Second, the VISSIM is applied to simulate traffic flow based on a real survey to analyze and evaluate the design plan based on the measures of effectiveness (MOEs). Third, the Civil 3D software is applied to implement this optimal design. Finally, the InfraWorks software is applied to build the 3D model to visualize the project. Overall, the major contributions of this study are as follows.

– An enhanced hybrid method is proposed that integrates BIM and VISSIM for improving the effectiveness of traffic management. These experiments show that the proposed process could be reliably designed and managed traffic project

– The 3D model from Civil 3D and InfraWorks improves the accuracy of the plan view similar to the actual survey.

– The experimental results for a road design in Khanh Hoa province demonstrate the significant effect of the proposed method.

The remaining paper is organized as follows. Section 2 presents the proposed method architecture, BIM implementation, VISSIM simulation, and measures of effectiveness. Section 3 describes the case study and its results, and Section 4 concludes this work.

2. METHODOLOGIES

2.1 *Proposed model architecture*

In this work, we proposed an approach to enhance the quality of traffic design by integrating BIM and VISSIM. This approach included the following steps: offering ideas, setting and simulating traffic, evaluating design options, designing roads, building 3D models, and completing the project. Firstly, we survey the research area and propose the design plan. Secondly, the VISSIM is applied to simulate traffic flow based on the on-site observation. Thirdly, we analyze and evaluate the design plan based on the measures of effectiveness (MOEs). Next, the Civil 3D software is applied to implement the appropriate design. Finally, InfraWorks software is used to build the 3D model of the project. Figure 1 expresses the research flow architecture.

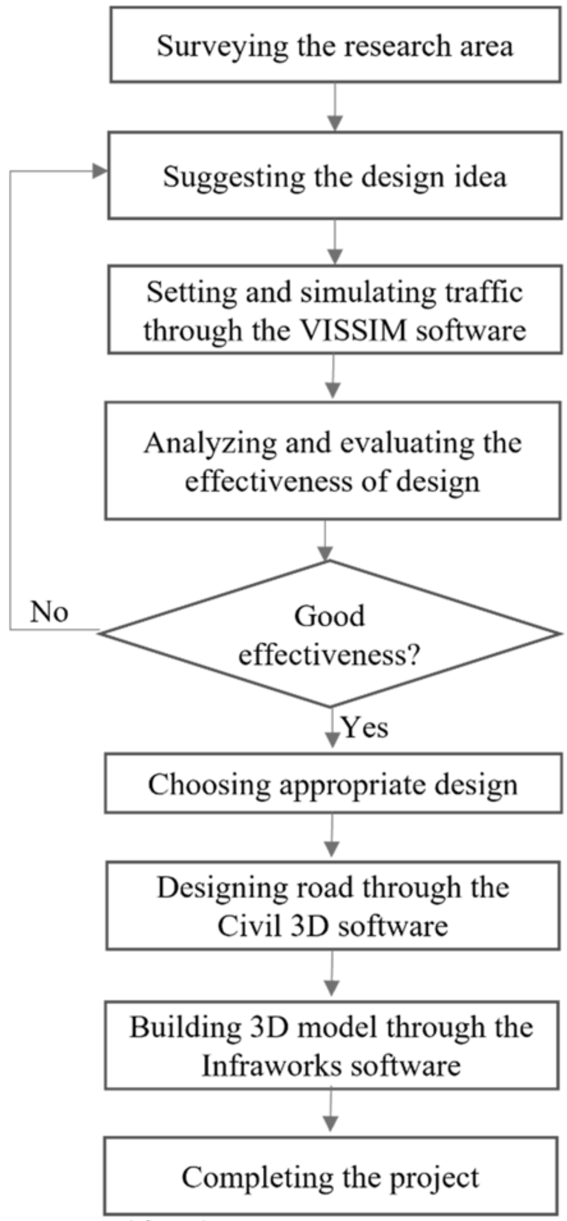

Figure 1 Research flow architecture

Regarding the details of the proposed method, firstly, the survey of the study area includes the following tasks, (1) Conducting a survey on road geometry data (e.g., road width, number of lanes, curb width, and curb width); (2) Determining the composition and traffic of vehicles in peak hours. Secondly, the design idea is to propose multiple options for alignment layout, cross section, plan and profile. Thirdly, the simulation model is built according to route survey data such as the number of lanes, lane width, traffic volume, and vehicle components. Besides, it is necessary to consider other factors such as the direction of turning of the vehicles entering the intersection and the starting position of the vehicles in the model. Next, the analysis and evaluation of the model are based on the correlation between the output data and the standard. The evaluation results include the entire speed. On that basis, the author will evaluate the option to proceed to the next steps. Finally, the selected option will be designed based on Civil 3D software. In addition, the 3D model of the road is also built through InfraWorks software to make the design more intuitive.

2.2 *Simulation methodology*

VISSIM is a software developed by PTV company for micro-traffic simulation. This software can simulate multi-modal traffic flow including pedestrians, bicycles, motorcycles, cars, trucks, etc. The simulation includes building a traffic network, simulation, and exporting the results. These results are displayed visually and used to analyze vehicle flow effectively. In addtion, microscopic traffic simulation models are often used for small and medium-sized road networks depending on the memory and speed of the computer. They describe the relationship between vehicles through the driver behavior regarding the car-following model. This model understands all the position and timing parameters for entire vehicles being simulated every second. Thanks to these above characteristics, the accuracy of the results outperforms. Figure 2 illustrates the car-following model architecture.

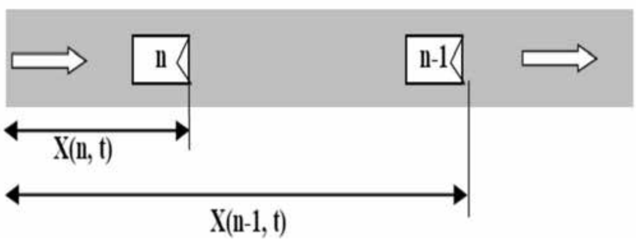

Figure 2 Car-following model architecture

In addition, the basic concept of Wiedemann's psycho-physical car-following model is that faster vehicles will slow down when approaching slower vehicles [21]. The reaction depends on the different speeds, distances, and driver behavior. In each state, the acceleration response will depend on the velocity, relative velocity, distance, and individual characteristics of the driver object. The driver moves from one state to the other as soon as he reaches a certain threshold (e.g., the relative velocity and the distance between the two vehicles). This perceived ability is not the same among drivers. The combination of psychological and physical factors of each person will determine the driver's cognitive ability.

Furthermore, lane-changing behavior is an important component of micro-traffic simulation. A lane change can occur when it is necessary for road movement, changing in speed, or avoiding vehicles exiting the traffic flow. Lane-changing is considered feasible if there is an acceptable gap for the vehicle to change lanes safely. Most studies emphasize the gap acceptance model [22]. Gipps [22] describes the structure of the lane change decision model regarding the gap acceptance distance.

2.3 *BIM technology*

Fundamentally, the utilization of BIM technology in traffic projects is similar to the way in other fields. Various BIM softwares are widely applied in the transportation projects, such as AutoCAD Map 3D, ReCap, InfraWorks, Revit, AutoCAD Civil 3D, Robot Structural Analysis Professional, etc. In this work, we use AutoCAD Civil 3D and InfraWorks to import survey data, design, and building the 3D model. Particularly, AutoCAD Civil 3D flexibly designs options through its ability to update and manage its data. InfraWorks has a strong ability to build 3D models to create a more visual view for traffic projects.

2.4 *Evaluation indicator*

The MOEs were used to evaluate the performance of the simulation model. The goal of this evaluation is to measure the quantity of the achievement of the traffic project. The MOEs include speed, delay, queue, stops, density, travel time, and travel-time variance. Nevertheless, within the limit of our work, we just considered the average speed. In which, the average speed is the mean value of the speed for entire vehicles in the simulation model. The average speed is applied to determine the LOS based on the highway capacity manual (HCM 2000). The urban street LOS is shown in Table 1.

Table 1 Urban street LOS [23]

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	> 41
B	> 56–72	> 46–59	> 39–50	> 32–41
C	> 40–56	> 33–46	> 28–39	> 23–32
D	> 32–40	> 26–33	> 22–28	> 18–23
E	> 26–32	> 21–26	> 17–22	> 14–18
F	≤ 26	≤ 21	≤ 17	≤ 14

3. EXPERIMENTAL CASE

3.1 *Background*

This project is built at Cam Hoa Commune, Cam Lam District, Khanh Hoa Province. The Bac Vinh Cuu Loi road is about 2980 meters long. This link would connect to Highway 1. The specific geographic location of the Bac Vinh Cuu Loi road is shown in Figure 3. The main objectives of this project are to improve travel efficiency and safety by constructing the Bac Vinh Cuu Loi road, and contributing to economic growth in the Cam Lam region. According to TCVN 4054-2005, we choose the design level of Bac Vinh Cuu Loi road as grade IV. In addition, the speed design is V_{tk} = 60km/h.

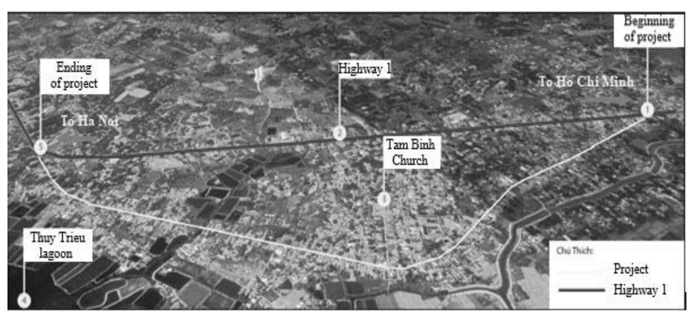

Figure 3 The location of the research area

3.2 *Data collection*

Based on a manual survey, the traffic data were obtained for Bac Vinh Cuu Loi road for one day at rush hours. Bac Vinh Cuu Loi Road has one lane with a width of 3.5 meters in each direction. Meanwhile, Highway 1 has two lanes with a width of 3.75 meters in each direction. For Highway 1 to Ho Chi Minh, motorcycles account for 39%, cars for 24%, buses for 9%, and trucks for 28%. For Highway 1 to Ha Noi, motorcycles account for 45%, cars for 25%, buses for 12%, and trucks for 33%. Regarding the turning direction, the straight direction accounts for 70%, and the turning direction accounts for 30%. The survey is from 6-8 AM and 4-6 PM. A summary of current traffic survey data is shown in Table 2.

Figure 4 Buiding model through VISSIM

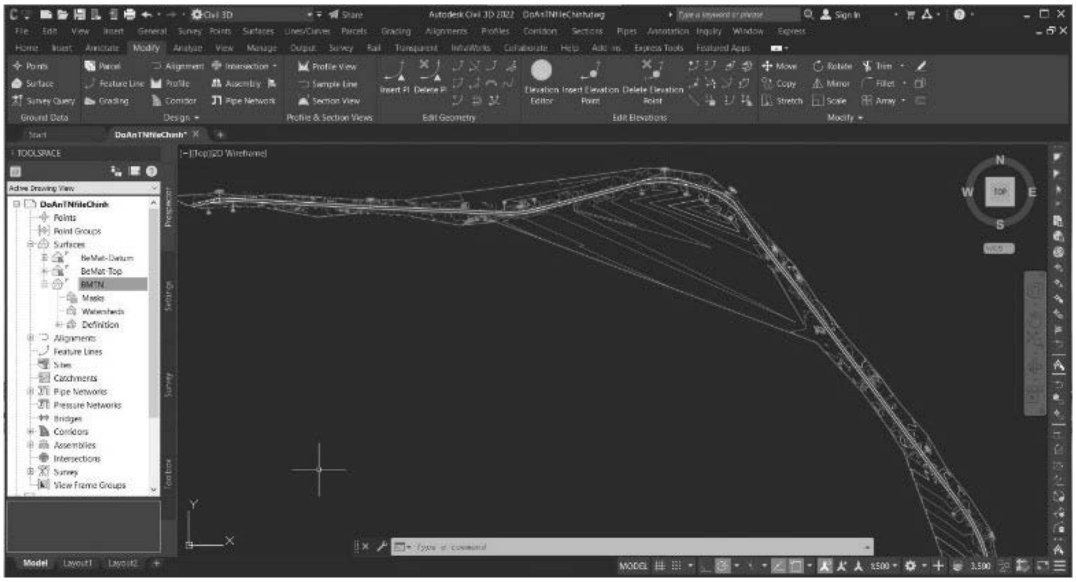

Figure 5 Autocad Civil 3D interface

Table 2 A summary of current traffic survey data

Vehicle types	Traffic volume (Vehicles/day)	Traffic volume (Vehicles/hour)
Highway 1 to Ho Chi Minh		
Motorcycle	1680	235
Car	1071	142
Bus	374	52
Truck	1215	170
Highway 1 to Ha Noi		
Motorcycle	1907	267
Car	1071	150
Bus	500	70
Truck	1428	200

3.3 *Model buildup*

First, we need to build this road into the VISSIM simulator. The Bing map is used as background in order to generate links and connectors. Figure 4 illustrates the building model of road establishment. Next, the traffic demand data are based on the on-site observation that applies to vehicle inputs. Inputting traffic volumes are figured out in Table 2. Then, we need to determine route decisions that define the route destination through different proportions of decision paths. In addition, we define the priority rule at intersections. The simulation time is 3600 seconds.

Figure 6 InfraWorks interface

3.4 *Designing road and modeling 3D*

The digital terrain model was carried out by Autocad Civil 3D through the points of the survey. Subsequently, we generated horizontal alignment, vertical alignment, and a generic assembly template based on the digital terrain model. In particular, a series of elements interfering with the project layout has been inserted, such as connecting to the existing road network, arranging the drainage system, and complying with the regional planning. The horizontal-vertical alignment was generated on the basis of the project features revealed in the road design standard and the boundary constraints. Furthermore, the 3D model was carried out on the generated Autocad Civil 3D model. This model was imported and implemented through InfraWorks. The interfaces of Autocad Civil 3D and InfraWorks are shown in Figures 5, 6 respectively.

4. ANALYSIS OF EXPERIMENTAL SIMULATION

4.1 *Simulation results*

After building the model, the author conducts simulations and tests the outputs from the model. Based on simulation results, the authors compare with corresponding parameters in HCM 2000 to evaluate LOS. The raw data of simulation results are shown in Figure 7.

The average speed of the Bac Vinh Cuu Loi road was 42.5 km/h according to simulation results. Based on the HCM 2000, the Bac Vinh Cuu Loi road achieved the LOS B corresponding to class III. These experiments show that the designed option has good effectiveness. Therefore, we choose this designed option.

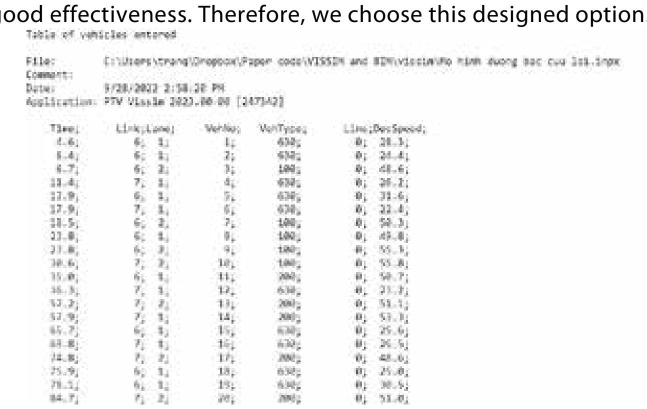

Figure 7 Simulation results

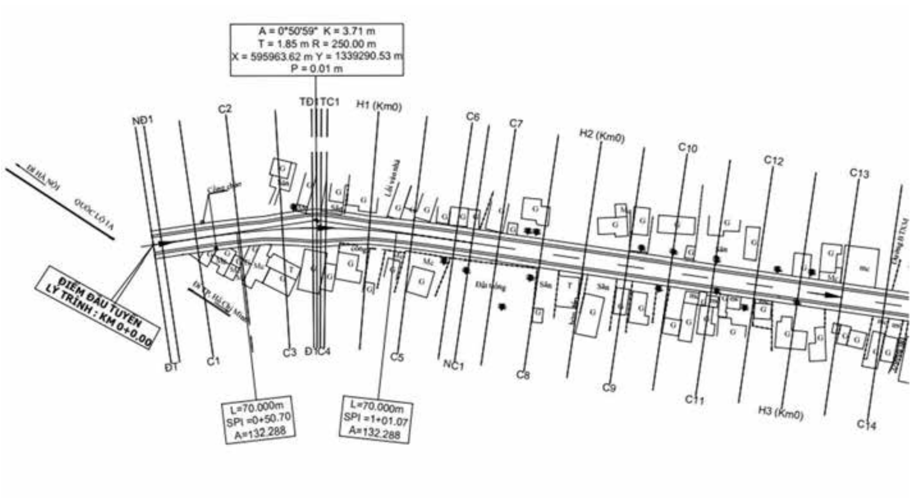

Figure 8 The plan view for a section of the design road

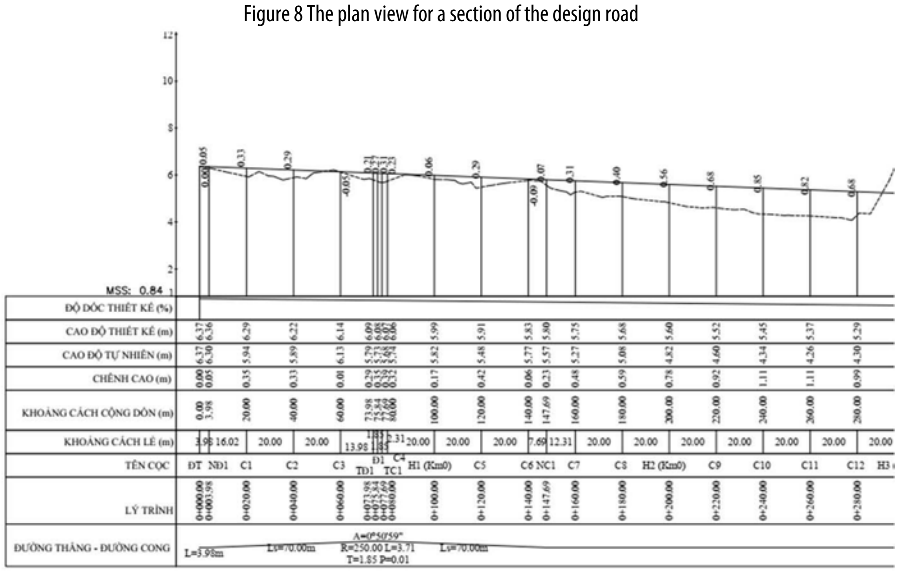

Figure 9 The profile for a section of the design road

Figure 10 The 3D model of the design road

4.2 *Designing road and modeling 3D*

After choosing the optimal design option, we proceed to design the plan view and profile using Autocad Civil 3D software, which is shown in Figures 8, 9 respectively. Finally, the study conducts the modeling. 3D modeling of the road with InfraWorks software to enhance the visualization of the design option. Figure 10 illustrates the 3D model of the designed road.

5. CONCLUSIONS

This study proposed the hybrid method to improve the effectiveness of traffic project management through BIM and VISSIM. This study also presented the experimental results regarding the simulation and design of the road project. From the experimental result, it can be concluded. First, the VISSIM simulator can optimize the design idea. Second, BIM technology achieves high performance for implementing the appropriate option. Last, the hybrid approach between BIM and VISSIM is promising to be improved the quality of traffic projects. Further works need to be considered the effects of other technologies and evaluated various types of traffic projects.

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