Research and Practice on Transportation BIM Curriculum Design for Applied Talent Cultivation: Postprint

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Abstract

To meet societal demand for transportation BIM professionals, a "1+1" teaching model for cultivating transportation BIM application capabilities is proposed based on an analysis of BIM technology development trends in the transportation industry and the current status of computer application courses offered in transportation-related majors. The model develops students' BIM modeling capabilities from two perspectives: routes and structures. In the teaching implementation plan, the entire teaching process is divided into four interconnected and progressively transitional stages. Through pedagogical approaches including CAD-BIM bridging teaching segments, comparative teaching methodology, and project-driven comprehensive practice, students can rapidly comprehend the progressive characteristics of BIM technology relative to CAD technology, master fundamental BIM skills, and acquire practical competencies.

Full Text

Preamble

Research and Practice on the Teaching Program of Transportation BIM for Application-Oriented Talents

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Abstract

To cultivate transportation BIM talents that meet social demands, this paper proposes a "1+1" teaching mode for developing transportation BIM application capabilities based on an analysis of BIM technology development trends in the transportation industry and the current state of computer application courses in transportation-related majors. This mode develops students' BIM modeling abilities through two distinct aspects: route design and structural components. The teaching implementation plan divides the entire instructional process into four interconnected, progressively advancing stages. Through teaching methods such as CAD-BIM transitional instruction, comparative teaching, and project-driven comprehensive practice, students can quickly grasp the progressive characteristics of BIM technology compared with CAD technology, master fundamental BIM skills, and develop practical competencies.

Keywords: BIM; Highway CAD; Teaching Mode; Comparative Teaching; Project-Driven

0 Introduction

In recent years, with qualitative leaps in computer hardware and software technology, computer-aided design in engineering fields has gradually transitioned from the traditional CAD stage to the BIM stage. In addition to encompassing all CAD functions and various architectural and structural information, BIM technology also incorporates economic and management information throughout the entire project lifecycle [1]. International practices have demonstrated that applying BIM technology to engineering design, construction, operation, and maintenance phases can significantly improve construction efficiency and substantially reduce project risks [2].

To rapidly cultivate a cohort of application-oriented talents that meet BIM technology development needs, many universities have initiated BIM education programs. For instance, Zhang Jingxiao et al. [3] employed Outcome-Based Education (OBE) as their pedagogical philosophy, constructing a logical framework for BIM engineering capability training for construction engineering students and establishing an outcome-oriented BIM capability development path model. Huang Jian et al. [4] analyzed the training objectives, job requirements, and required BIM competency characteristics for engineering cost management majors, proposing specific and feasible reform measures for curriculum systems and practical teaching. Lu Haiyan et al. [5] integrated BIM and VR technologies into civil engineering CAD teaching based on China' s civil engineering talent training programs and teaching conditions, with research showing that the new teaching model not only enabled students to understand and apply BIM and VR technologies but also enhanced their innovation and practical abilities. He Rui et al. [6] introduced BIM technology teaching into undergraduate civil engineering drawing classrooms, transforming traditional civil engineering drawing instruction into a new system integrating manual drawing, computer 2D drafting, and computer 3D modeling. Miao Dun [7] explored the construction of a new teaching system for architectural engineering drawing based on BIM modeling, unifying engineering drawing learning with the BIM modeling process to strengthen students' spatial thinking abilities.

Compared with the construction industry, the development status of BIM technology in the transportation industry, the policy environment for BIM technology promotion and application, and the applicability of BIM software all differ significantly. Consequently, the training and teaching models for BIM talents in transportation-related majors cannot simply replicate those from the construction industry. The objective of this research is to investigate pathways for cultivating transportation majors' BIM application capabilities and explore implementation routes for BIM technology teaching in transportation-related majors, based on the actual circumstances of BIM technology development trends in the transportation industry and the current state of computer application courses.

1 Construction of the Teaching Mode for Transportation BIM Application Capability Development

Unlike traditional two-dimensional road CAD design systems, the road modeling process based on BIM technology primarily comprises two components: "route BIM modeling" and "structural component BIM modeling" [8]. "Route BIM modeling" involves constructing three-dimensional route models based on horizontal, vertical, and cross-sectional geometric design data, while "structural component BIM modeling" involves building 3D models of bridges, culverts, tunnels, and traffic safety facilities along the roadway. When assembled, these form a complete road 3D information model. The route 3D model serves as the main body and foundation of the entire road model and as the reference system for assembling other structural component models—this represents the primary difference between linearly distributed transportation BIM models and building BIM models.

Therefore, to develop students' transportation BIM application capabilities, it is necessary to teach both "route BIM modeling" technology and "structural component BIM modeling" technology separately. The "route BIM modeling" technology can be understood as an upgraded stage where traditional 2D road design technology incorporates BIM concepts. For example, established domestic road CAD software such as WeiDi, EICAD, and Hongye have all launched new BIM-based versions in recent years. The "structural component BIM modeling" technology, however, represents an entirely new field not previously covered in CAD courses, requiring new dedicated courses.

Based on this analysis, we propose a "1+1" teaching mode for developing transportation BIM application capabilities (Figure 1 [Figure 1: see original paper]). On one hand, route BIM modeling content is added to the "Road Engineering CAD" course offered in majors such as road and bridge engineering and traffic engineering. On this foundation of mastering traditional route CAD basic skills, students further learn fundamental route BIM concepts and modeling techniques. On the other hand, a new course titled "Transportation Structural Component BIM Modeling" is established, selecting commonly used structural component BIM modeling software to teach the basic principles and implementation techniques of transportation structural component BIM modeling, available as an elective for students in road and bridge, bridge, and tunnel engineering majors. The "1+1"teaching mode aligns with the actual application of BIM technology. In the BIM stage, due to the large information volume and significant modeling workload involved in road 3D models, multi-professional collaborative work is generally emphasized—route professionals complete route modeling while bridge, tunnel, and other professionals complete various structural component modeling tasks separately. Consequently, transportation BIM teaching does not require every student to master all modeling techniques. For example, in our university' s road and bridge major BIM teaching, we focus primarily on route modeling techniques, while guiding interested and capable students to learn structural component modeling during graduation design and technology competition phases.

2.1 Teaching Software Selection

Currently, BIM software applied in China' s transportation industry falls into two main categories: foreign and domestic. Foreign software primarily originates from Autodesk (Platform A) and Bentley (Platform B), as shown in Table 1 , each including corresponding route modeling software and structural component modeling software that support full lifecycle BIM application for engineering projects. Domestic transportation BIM software comes from several road CAD software vendors upgrading their original CAD products, such as EICAD 3.0 software and Hongye Roadleader software, which currently only feature route modeling functionality and are limited to the design phase. The main advantages and disadvantages of domestic and foreign transportation BIM software platforms are compared in Table 2 .

Table 1 Major Foreign Transportation BIM Software Platforms

Platform	Route Modeling Software	Structural Component Modeling Software
Autodesk	Civil 3D	Revit, Dynamo, etc.
Bentley	PowerCivil	OpenBridge Modeler, CivilStation, ProStructural, AECOsim Building Designer, etc.

Table 2 Comparison of Advantages and Disadvantages Between Domestic and Foreign Transportation BIM Software Platforms

Category	Advantages	Disadvantages
Foreign Software	Complete route and structural component modeling functions; supports full lifecycle BIM application for engineering projects	Poor support for domestic standards and drawing specifications; requires extensive customization in application
Domestic Software	Supports domestic technical specifications; supports 2D construction drawing output conforming to domestic standards	Currently only features route modeling function; has not yet launched structural component modeling software; limited support for full lifecycle BIM application

Although some transportation projects in China have begun experimenting with BIM technology applications, transportation projects still predominantly rely on traditional 2D design due to the absence of normative documents for BIM models and BIM deliverables standards. Table 2 reveals that neither foreign nor domestic software can fully satisfy the current application status of the transportation industry, necessitating combined usage. Based on this reality, a "domestic + foreign" software configuration mode is recommended for transportation BIM teaching. Domestic software primarily selects EICAD 3.0 and Roadleader software—both widely used design software in domestic highway and urban road design institutes that students encounter during the 2D design phase of route CAD instruction. Foreign software instruction focuses primarily on Bentley's series of software, as Bentley's products feature deeper professional customization for the transportation industry and enjoy broader application and promotion domestically. Additionally, Autodesk's Civil 3D software is selected as the transitional teaching software from CAD to BIM technology to help students understand the transition characteristics from CAD to BIM.

2.2 Teaching Scheme Design

The transportation BIM course teaching implementation plan is illustrated in Figure 2 [Figure 2: see original paper]. The entire teaching process is divided into four stages. The first stage is route CAD instruction, which covers traditional road CAD course content and primarily develops students' fundamental ability to use computer tools to assist engineering design. This content serves as both the foundation for students to learn BIM technology and essential skills for graduates to engage in transportation design projects. The second stage is CAD-BIM transitional teaching, which familiarizes students with basic BIM concepts and the main upgraded features of road BIM software compared to road CAD software. The third stage constitutes the main body of transportation BIM modeling instruction, divided into "route BIM modeling" and "structural component

BIM modeling." Our university' s road and bridge major classroom instruction primarily focuses on "route BIM modeling," while "structural component BIM modeling" is arranged for interested students during technology competitions or graduation design phases. The fourth stage is the BIM comprehensive practice phase, which cultivates students' practical ability to comprehensively apply BIM technology through arranging BIM training projects in technology competitions or graduation design phases.

2.3 Teaching Hour Arrangement

The hour allocation for the four teaching stages is shown in Table 3 . Practical session hours are primarily incorporated into after-class assignments, technology competitions, and graduation design phases.

Table 3 Teaching Hour Arrangement for Transportation BIM Courses

Teaching Stage	Teaching Objectives	Teaching Content	Classroom Hours	Practical Hours
Route CAD Instruction	Master basic skills of road engineering computer-aided design	(1) Digital terrain model theory and application; (2) Route horizontal, vertical, and cross-section computer-aided design processes and implementation methods; (3) Road engineering drawing and quantity output technology	Classroom instruction	After-class assignments

Teaching Stage	Teaching Objectives	Teaching Content	Classroom Hours	Practical Hours
CAD-BIM Transitional Instruction	Understand typical features of upgrading from CAD to BIM	(1) BIM concepts; (2) Main changing features of road CAD software upgrading to BIM stage; (3) Typical BIM software (Civil 3D) route modeling process	Classroom instruction	After-class assignments
BIM Modeling Instruction	Master basic BIM modeling skills	(1) Modeling techniques of major domestic road BIM software (EICAD 3.0, Hongye Roadleader); (2) Bentley PowerCivil modeling technology	Classroom instruction	After-class assignments, technology competitions, graduation design
BIM Comprehensive Practice	Develop BIM application practical abilities	Bentley structural component software usage techniques	Technology competitions, graduation design	Technology competitions, graduation design

3 Introduction to Key Teaching Segments and Methods

Transportation BIM teaching is an entirely new course without directly applicable teaching methods for reference. Through teaching practice explorations with the 2014 and 2015 cohorts, we have summarized several methods to improve teaching effectiveness, with the main points described below.

3.1 Emphasizing CAD-BIM Technology Transition Teaching

BIM technology is regarded as another technological revolution in the engineering field following CAD technology [9]. When students first encounter BIM, they are both curious and full of doubts—wanting to understand what is new about BIM technology and how it improves upon CAD technology. To help students quickly familiarize themselves with road BIM technology characteristics, we designed a CAD-BIM technology transition teaching segment covering three main aspects:

1. **Basic BIM concepts and domestic/international development trends.**
2. **Main technical change characteristics of road CAD technology upgrading to the BIM stage.** We summarized the primary technical changes from road CAD systems to BIM stage from five aspects: workflow, design object organization mode, automation and intelligence level, collaborative work mechanism, and deliverables format, as shown in Table 3.
3. **Explanation of Autodesk Civil 3D software route modeling technology.** Civil 3D is an earlier route BIM modeling software from Autodesk. It is selected as the transition stage teaching software because, first, both it and widely used domestic road CAD software are based on the AutoCAD platform, so students face no unfamiliarity with the interface and basic operations; second, current major domestic route BIM modeling software EICAD 3.0 and Roadleader are both based on Civil 3D' s software concepts. Understanding Civil 3D' s modeling approach enables rapid mastery of EICAD 3.0 and Roadleader software.

Table 3 Main Technical Change Characteristics from Road CAD System to BIM Stage

Aspect	Road CAD System	Road BIM System
Workflow	Sequential process of horizontal, vertical, and cross-section design	Three-dimensional collaborative optimization design of horizontal, vertical, and cross-section with building road 3D information model as main line
Design Object Organization	Data file-based organization mode; design objects can be generated from data files without association between design objects	Object-oriented thinking; dynamic association relationships exist between design objects

Aspect	Road CAD System	Road BIM System
Automation and Intelligence	Cross-section design uses “slope template + human-computer interaction” mode with low efficiency	Assembly and component technology greatly improves automation and intelligence level of cross-section design
Collaborative Work Mechanism	“Stand-alone” work mode; mainly used by design units with heavy inter-professional coordination workload	Through unified collaborative work platform, achieves connection and collaboration among all project lifecycle phases, participants, and specialties
Deliverables Format	2D horizontal, vertical, and cross-section design drawings	Digital road 3D information model

3.2 Extensive Use of Comparative Teaching Method

Transportation BIM teaching involves numerous software tools, including both road CAD software as prerequisite courses and domestic/foreign road BIM software. To enable students to master various software usage methods within limited class hours, we extensively employ comparative teaching methods, summarizing similarities and differences between software from multiple perspectives: road CAD vs. BIM software, foreign BIM software vs. domestic BIM software, and among domestic BIM software. For example, in teaching the difficult concept of “road assembly,” we compare Civil 3D software with EICAD 3.0 software, as shown in Figure 3 [Figure 3: see original paper] and Figure 4 [Figure 4: see original paper]. Civil 3D automatically determines cut/fill slopes and their gradations through “conditional cut” and “conditional fill” components. EICAD 3.0 uses logical components such as “intersection point judgment,” “termination point judgment,” “component jump point judgment,” and “assembly jump point judgment” to automatically select appropriate slope templates. The comparative teaching method enables students to quickly master EICAD 3.0 and Roadleader software after learning Civil 3D, significantly improving road BIM course teaching efficiency.

3.3 Implementing Project-Driven Comprehensive Practice

Compared with other specialized courses, road software courses demand higher hands-on practical abilities from students. In addition to requiring students to complete a certain amount of practical exercises after each class, we annually select one or two sub-projects from faculty research projects as topics for student technology competitions or graduation design, requiring students to complete the topics according to actual project work content and deliverables standards. Practical topics derived from actual engineering projects not only provide students with opportunities to apply classroom learning to project practice but also further enhance their systematic and normative project completion abilities, cultivating their capacity to independently analyze and solve problems, enabling them to quickly qualify for road BIM designer positions after graduation. Figures 5 and 6 respectively show municipal road BIM models and highway BIM models produced by students participating in the "Challenge Cup" competition and "Energy Saving and Emission Reduction" competition in 2017.

4 Teaching Effects

We selected several road and bridge major graduates from the 2013 and 2014 cohorts for teaching effect comparison experiments. The 2013 cohort only received traditional road CAD course instruction during the theoretical teaching phase, supplementing transportation BIM knowledge and operational skills during graduation design. The 2014 cohort underwent transportation BIM teaching and practice according to the proposed teaching scheme. Teaching effect tests were arranged during the graduation design phase, combining students' graduation design topics to conduct both transportation BIM theoretical tests and practical ability tests. The results are shown in Figure 7 [Figure 7: see original paper]. The figure reveals that the 2014 cohort' s theoretical and practical scores were significantly higher than those of the 2013 cohort. Additionally, 2014 graduates, having proficiently mastered BIM skills, were widely welcomed by employers in the job market, with BIM-related employment rates markedly higher than the 2013 cohort (Figure 7).

5 Conclusion

As national promotion of BIM technology intensifies, the transportation industry' s demand for application-oriented BIM talents is experiencing explosive growth, necessitating the establishment of BIM-related courses in university transportation-related majors. Based on analysis of BIM technology development trends in the transportation industry and the current state of computer application courses in transportation majors, this paper proposes a "1+1" teaching mode for developing transportation BIM application capabilities, selects domestic and foreign software that aligns with actual application conditions, and divides the entire teaching process into four stages: route CAD instruction, CAD-BIM transitional instruction, BIM modeling instruction, and BIM comprehensive practice. Through teaching methods such as CAD-BIM technology transition instruction, comparative teaching, and project-driven comprehensive training, students can quickly understand BIM characteristics and master BIM operational skills based on their learning of fundamental road CAD skills.

Since transportation BIM technology is still in the promotion stage overall, with relevant technical standards yet to be issued and no unified BIM application software platform existing, teaching should closely monitor domestic and international transportation BIM technology development trends and industry information to dynamically adjust annual teaching content accordingly. Only through this approach can we achieve effective teaching and learning, truly cultivating transportation BIM talents that meet social demands.

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Note: Figure translations are in progress. See original paper for figures.