Research and Practice on the Teaching Scheme of Transportation BIM Courses for Applied Talent Training: Postprint

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Abstract

To cultivate transportation BIM professionals who meet societal demands, a "1+1" teaching model for developing transportation BIM application capabilities is proposed based on analysis of BIM technology development trends in the transportation industry and the current status of computer application courses in transportation-related majors. This model cultivates students' BIM modeling capabilities from two aspects: route and structure. In the teaching implementation plan, the entire teaching process is divided into four interconnected and progressively transitional stages. Through teaching methods such as CAD-BIM bridging teaching segments, comparative teaching approaches, and project-driven comprehensive practice, students can quickly understand the progressive characteristics of BIM technology compared to CAD technology, master the fundamental skills of BIM technology, and acquire certain practical capabilities.

Full Text

Preamble

Research and Practice on Teaching Programs for Transportation BIM Courses for Application-Oriented Talent Cultivation

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Abstract

To cultivate transportation BIM talents that meet societal demands, this paper proposes a "1+1" teaching model for developing transportation BIM application competencies. This model is 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. The approach develops students' BIM modeling capabilities through two distinct pathways: route modeling and structural modeling. The teaching implementation plan divides the entire instructional process into four interconnected, progressively advancing stages. Through pedagogical methods including CAD-BIM transitional instruction, comparative teaching, and project-driven comprehensive practice, students can quickly grasp the progressive characteristics of BIM technology compared to CAD, 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 technologies, computer-aided design in engineering fields has gradually transitioned from traditional CAD to BIM. Beyond 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 demonstrate that applying BIM technology in engineering design, construction, operation, and maintenance phases can significantly improve construction efficiency and substantially reduce project risks [2].

To rapidly cultivate application-oriented talents meeting BIM technology development needs, numerous universities have initiated BIM education initiatives. For instance, Zhang Jingxiao et al. [3] employed Outcome-Based Education (OBE) as their pedagogical philosophy, constructing a logical framework for BIM engineering competency cultivation in construction engineering majors and establishing an outcome-oriented BIM competency development pathway model. Huang Jian et al. [4] analyzed the training objectives, position 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, demonstrating that the new teaching model not only familiarizes students with BIM and VR technologies but also enhances their innovation and practical abilities. He Rui et al. [6] introduced BIM technology into civil engineering drawing courses for undergraduates, transforming traditional teaching 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 transportation industry differs significantly in BIM technology development status, policy environment for BIM promotion and application, and suitability of BIM software. Consequently, BIM talent cultivation and teaching models for transportation-related majors cannot simply replicate those from the construction industry. This research aims to investigate pathways for cultivating transportation students' BIM application competencies and explore implementation routes for transportation BIM technology teaching, based on the actual conditions of BIM technology development trends in the transportation industry and the current state of computer application courses in transportation majors.

1 Construction of the Teaching Model for Transportation BIM Application Competency Development

Unlike traditional 2D road CAD design systems, road modeling based on BIM technology primarily comprises two components: "route BIM modeling" and "structural BIM modeling" [8]. Route BIM modeling constructs three-dimensional route models based on horizontal, vertical, and cross-sectional geometric design data, while structural BIM modeling builds 3D models of bridges, culverts, tunnels, and traffic safety facilities along the roadway. Assembling these two components forms a complete road 3D information model. The route 3D model serves as the main body and foundation of the entire road model and acts as the reference system for assembling other structural models—a key difference between linearly distributed transportation BIM models and building BIM models.

Therefore, to develop students' transportation BIM application competencies, instruction must cover both "route BIM modeling" and "structural BIM modeling" technologies separately. Route BIM modeling technology can be understood as an upgraded stage where traditional 2D road design technology integrates 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. Structural BIM modeling technology, however, represents an entirely new field not previously covered in CAD courses, necessitating new dedicated courses.

Based on this analysis, we propose a "1+1" teaching model for transportation BIM application competency development [Figure 1: see original paper]. On one hand, the existing "Road Engineering CAD" course for majors such as road and bridge engineering, and traffic engineering is enhanced with route BIM modeling content, building upon students' mastery of traditional route CAD fundamentals to further teach basic BIM concepts and modeling techniques. On the other hand, a new course "Transportation Structural BIM Modeling" is established, utilizing common structural BIM modeling software to teach fundamental principles and implementation techniques of transportation structural BIM modeling for elective study by students in road and bridge, bridge, and tunnel engineering majors. The "1+1" teaching model aligns with actual BIM technology applications. In the BIM era, due to the large information volume and substantial modeling workload involved in road 3D models, multidisciplinary collaborative work is emphasized—route specialists complete route modeling while bridge, tunnel, and other specialists handle various structural modeling tasks. Consequently, transportation BIM teaching need 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 modeling during graduation design and technology competition phases.

2.1 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 , both offering corresponding route and structural modeling software supporting full lifecycle BIM applications. Domestic transportation BIM software represents upgrades from several road CAD software vendors based on their original CAD products, such as EICAD 3.0 and Hongye Roadleader, currently featuring only route modeling capabilities limited to the design phase. Table 2 compares the main advantages and disadvantages of domestic and foreign transportation BIM software platforms.

Table 1: Major Foreign Transportation BIM Software Platforms

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

Table 2: Comparison of Domestic and Foreign Transportation BIM Software Platforms

Platform	Advantages	Disadvantages
Foreign	Complete route and structural modeling functions; supports full lifecycle BIM applications	Poor support for domestic standards and drawing specifications; requires extensive customization
Domestic	Supports domestic technical specifications and 2D construction drawing output per national standards	Only features route modeling; no structural modeling software; limited support for full lifecycle BIM applications

Although some transportation projects in China have begun experimenting with BIM technology applications, the lack of standardized specifications for BIM models and deliverables means that traditional 2D design remains dominant. As Table 2 indicates, neither foreign nor domestic software currently fully meets the transportation industry' s application status, necessitating combined usage. Based on this reality, transportation BIM teaching should adopt a "domestic + foreign"software configuration. Domestic software primarily includes EICAD 3.0 and Roadleader—software whose 2D versions are taught during the route CAD phase and widely used in domestic highway and urban road design institutes. Foreign software instruction focuses on Bentley' s platform series, as Bentley software offers deeper professional customization for the transportation industry with broader domestic application and promotion. Additionally, Autodesk' s Civil 3D is selected as the CAD-BIM transitional teaching software to help students understand the transition characteristics from CAD to BIM.

2.2 Teaching Program Design

The transportation BIM course teaching implementation plan is illustrated in Figure 2 [Figure 2: see original paper]. The entire teaching process divides into four stages. The first stage is route CAD instruction, covering traditional road CAD content to develop students' fundamental abilities in using computer tools for engineering design. This content serves as the foundation for learning BIM technology and equips students with essential skills for transportation design projects after graduation. The second stage is CAD-BIM transitional teaching, primarily familiarizing students with BIM concepts and the main upgraded features of road BIM software compared to road CAD software. The third stage constitutes the core of transportation BIM modeling instruction, divided into "route BIM modeling" and "structural BIM modeling." Our university' s road and bridge major focuses classroom instruction on route BIM modeling, while structural BIM modeling is arranged for interested students during technology competitions or graduation design phases. The fourth stage is BIM comprehensive practice, where BIM training projects selected from technology competitions or graduation design phases cultivate students' practical abilities in comprehensive BIM application.

2.3 Class Hour Arrangements

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

Table 3: Class Hour Arrangements for Transportation BIM Courses

Teaching Stage	Teaching Objective	Teaching Content	Classroom Hours	Practical Hours
Route CAD Teaching	Master basic road engineering CAD skills	(1) Digital terrain model theory and application; (2) Route horizontal, vertical, and cross-section CAD processes and implementation methods; (3) Road engineering drawing and quantity output techniques	Classroom instruction	After-class assignments
CAD-BIM Transitional Teaching	Understand typical features of CAD-to-BIM upgrade	(1) BIM concepts; (2) Main technical changes in road CAD software upgrading to BIM; (3) Typical BIM software (Civil 3D) route modeling workflow	Classroom instruction	After-class assignments

Teaching Stage	Teaching Objective	Teaching Content	Classroom Hours	Practical Hours
BIM Modeling Teaching	Master basic BIM modeling skills	(1) Domestic road BIM software (EICAD 3.0, Hongye Roadleader) modeling techniques; (2) Bentley PowerCivil modeling techniques	Classroom instruction	After-class assignments, technology competitions, graduation design
BIM Comprehensive Practice	Develop practical BIM application abilities	Bentley structural software for bridges and other structures	Technology competitions, graduation design	Technology competitions, graduation design

3 Key Teaching Components and Methodologies

Transportation BIM teaching represents a completely new course without directly applicable teaching methods to reference. Through teaching practice with our university' s 2014 and 2015 cohorts, we have identified several effective teaching methods, with the main points summarized below.

3.1 Emphasizing CAD-BIM Technology Transition Teaching

BIM technology is regarded as another technological revolution in engineering following CAD technology [9]. When first encountering BIM, students are both curious and perplexed—wanting to understand what makes BIM novel and how it improves upon CAD. To help students quickly familiarize themselves with road BIM characteristics, we designed a CAD-BIM transitional teaching component covering three aspects: (1) Basic BIM concepts and international/domestic development trends; (2) Main technical changes when upgrading from road CAD to BIM, summarized across five dimensions: workflow, design object organization mode, automation and intelligence level, collaborative work mechanisms, and deliverable formats, as shown in Table 3; (3) Autodesk Civil 3D software route modeling techniques. Civil 3D, as an early route BIM modeling software from Autodesk, serves as an ideal transitional teaching tool because, like widely used domestic road CAD software, it is based on the AutoCAD platform—eliminating interface and basic operation unfamiliarity. Moreover, current domestic route BIM software EICAD 3.0 and Roadleader are based on Civil 3D' s conceptual framework, so understanding Civil 3D' s modeling approach enables rapid mastery of EICAD 3.0 and Roadleader.

Table 3: Main Technical Changes from Road CAD to BIM Systems

Aspect	Road CAD System	Road BIM System
Workflow	Sequential process: horizontal → vertical → cross-section design	3D collaborative optimization design centered on building road information models
Design Object Organization	Data file-based organization; design objects generated from files without inter-object relationships	Object-oriented approach with dynamic relationships between design objects
Automation & Intelligence	Cross-section design using "slope template + human-computer interaction" with low efficiency	Assembly and component technology significantly improving cross-section design automation and intelligence
Collaborative Work Mechanism	Standalone mode, mainly used by design units with heavy inter-disciplinary coordination	Unified collaborative platform enabling coordination across project lifecycle phases, participants, and disciplines
Deliverable Format	2D horizontal, vertical, and cross-section drawings	Digital 3D road information models

3.2 Extensive Use of Comparative Teaching Methods

Transportation BIM teaching involves numerous software packages, including prerequisite road CAD software and domestic/foreign road BIM software. To enable students to master various software within limited class hours, we extensively employ comparative teaching methods, identifying similarities and differences across multiple dimensions: road CAD vs. BIM software, foreign vs. domestic BIM software, and among domestic BIM software. For example, in teaching the challenging concept of "road assembly," we compare Civil 3D and EICAD 3.0 software, as shown in Figure 3 [Figure 3: see original paper] and Figure 4 [Figure 4: see original paper]. Civil 3D uses "conditional cut" and "conditional fill" components to automatically determine cut/fill slopes and their staging. EICAD 3.0 employs 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. This comparative approach enables students to quickly master EICAD 3.0 and Roadleader after learning Civil 3D, significantly improving teaching efficiency.

3.3 Implementing Project-Driven Comprehensive Practice

Compared with other specialized courses, road software courses demand stronger hands-on practical abilities. Beyond requiring students to complete practical exercises after each class, we annually select one or two sub-projects from faculty research programs as topics for student technology competitions or graduation design projects, requiring students to complete them according to actual project work content and deliverable standards. Practical topics derived from real engineering projects provide students with opportunities to apply classroom knowledge while enhancing their systematic and normative project completion abilities, cultivating independent analysis and problem-solving skills that enable them to quickly qualify as road BIM designers after graduation. Figure 5 [Figure 5: see original paper] and Figure 6 [Figure 6: see original paper] respectively show municipal road and highway BIM models created by students for the "Challenge Cup" competition and "Energy Saving and Emission Reduction" competition in 2017.

4 Teaching Effectiveness

We conducted a comparative teaching effectiveness experiment with selected graduates from the 2013 and 2014 cohorts of the road and bridge major. The 2013 cohort received only traditional road CAD instruction during the theoretical teaching phase, supplementing their knowledge with transportation BIM concepts and skills during graduation design. The 2014 cohort completed the full transportation BIM teaching and practice program proposed in this paper. Effectiveness testing for both groups was conducted during the graduation design phase, integrating transportation BIM theory tests and practical ability assessments with students' graduation projects. The results are shown in Figure 7 [Figure 7: see original paper]. The data reveal that the 2014 cohort significantly outperformed the 2013 cohort in both theoretical and practical scores. Additionally, 2014 graduates, having mastered BIM skills, were widely welcomed by employers, with BIM-related employment rates substantially higher than those of the 2013 cohort (Figure 7).

5 Conclusion

As national promotion of BIM technology intensifies, demand for application-oriented BIM talents in the transportation industry is experiencing explosive growth, making it necessary to offer BIM-related courses in university transportation programs. Based on analysis of transportation industry BIM technology development trends and the current state of computer application courses in transportation majors, this paper proposes a "1+1" teaching model for transportation BIM competency development, selects domestic and foreign software aligned with practical application conditions, and divides the teaching process into four stages: route CAD instruction, CAD-BIM transitional teaching, BIM modeling instruction, and BIM comprehensive practice. Through CAD-BIM transitional instruction, comparative teaching methods, and project-driven comprehensive training, students can quickly understand BIM characteristics and master BIM operational skills while learning fundamental road CAD competencies.

Since transportation BIM technology remains in the promotion phase with relevant technical standards yet to be issued and no unified BIM software platform established, teaching should closely monitor domestic and international transportation BIM technology development trends and industry information to dynamically adjust annual teaching content. Only through such adaptive approaches can we achieve effective teaching and learning that truly cultivates transportation BIM talents meeting societal demands.

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