

# Design and Integration of Transit-Oriented Development in Transportation Education\*

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Transit-oriented development (TOD) is an effective planning strategy that has continued to gain interest for over a quarter century since the term has been coined. TOD is a mixed-use development that concentrates on connecting spaces and infrastructure around successful transit service in order to provide high mobility. To prepare for continued implementation, TOD needs to be fully integrated into curricula to expose and attract the next generation of transportation engineers and planners. This study focuses on an evaluation of existing TOD pedagogical efforts across the nation in order to identify the level of integration. A survey is conducted on higher education programs throughout the United States in order to provide an update on module versus full course level integration and determine existing pedagogical methods/resources used in the classroom. In addition, a case study application focused on the development and implementation of a TOD module to a sustainable transportation engineering course at Bucknell University is provided with the goal of integrating the module into similar courses throughout the country.

**Keywords:** transit; education; pedagogy; sustainability; transportation; planning

## 1. Introduction

A community centered on transit design provides accessibility in a way that supports mobility independence while fostering a number of economic, societal, and environmental benefits. Transit-oriented development (TOD), coined by Peter Calthorpe in 1993 [1], defines this goal of sustainable community growth around a transit facility/network. Over a quarter century later, the term continues to serve as a fundamental principle in urbanism and smart growth development in practice [2–4].

A traditional TOD plan includes mixed-use development centered on a local bus or railway station, with high density development surrounding the station. Reflecting the pedestrian scale, a one-quarter to one-half mile buffer from the stop includes a gradation of lower density spreading outwards [2]. A successful TOD supports walkable, mixed-use, and dynamic urban places which can lead to continued urban growth [5, 6]. Additional benefits of transit design include reduced greenhouse gas emissions, improved air quality, reduced traffic congestion, and improved land conservation [7–9].

As transit-oriented efforts to increase ridership and serviceability in the field continue, goals to integrate TOD principles in the classroom increase as well. More specifically, teaching transit-oriented concepts including terminology, planning methods, design approaches, and case study applications, not only exposes students to design opportunities but also can help to guide their post-graduation career

plans. In particular, sharing the opportunities and potential benefits of TOD planning can attract and inspire future transportation engineers and planners to continue the growth of TOD communities throughout the country.

The goals of this research are two-fold: (1) to investigate the existing TOD pedagogical efforts across the nation through the implementation of a national survey of existing programs and (2) to develop and implement a TOD module to an undergraduate upper level civil engineering elective course. The national survey includes an assessment of transit-oriented classes and modules to determine the level of engagement and student learning across programs. Recommendations on TOD learning and concept availability are provided. The results of the survey provide insight into interest and opportunity for additional TOD integration. One method to increase TOD integration that can be easily adopted is through the dissemination of a TOD module for existing courses. Therefore, a TOD module is shared in depth based on development and implementation to an existing transportation planning course. The pedagogical materials of the TOD module are shared with the goal of integrating the module into similar courses throughout the country.

## 2. Existing Transit-Oriented Development Pedagogical Efforts

In order to gather information regarding existing educational efforts in transit-oriented development, a survey of existing programs throughout the

United States is used. The following section explains the survey process and the results in order to identify current level of exposure and concept availability in planning programs.

### 2.1 Survey Methodology

A national survey on transit-oriented development pedagogical efforts was conducted using the following steps: (1) identify a list of planning programs to survey, (2) develop survey instrument, (3) distribute survey and collect results, and (4) analyze data.

#### 2.1.1 Program List

For step 1, the list of programs was compiled using three Planning Accreditation Board's [10] list of accredited planning programs as well as the U.S. News and World Report's Best Graduate City Management and Urban Policy Programs [11]. The accredited list includes 75 different institutions (combination of bachelor's, master's, and Ph.D. programs) across the country (50 states). In order to include programs that are not accredited, the top 25 schools from the U.S. News and World Report's Best Graduate City Management and Urban Policy Programs [11] were also included. The rankings include both accredited and non-accredited schools as well as programs in public administration, public policy, and other related programs with urban planning. Out of the top 25 programs ranked, 11 are not accredited programs so these additional 11 were added to the 75 accredited schools. Therefore, in total, 86 (75 accredited plus 11 non-accredited) planning programs were included in the survey. Transportation planning programs were selected for the survey as they offer the most direct information regarding transit-oriented development to both planners and engineers.

#### 2.1.2 Survey Instrument

The second step included developing an online survey instrument that could be used to assess the level of integration of transit-oriented development concepts into planning programs through both courses offerings as well as modules within courses. The survey was developed using Google [12] Forms, and the instrument was reviewed and approved by the Institutional Review Board at Bucknell University. The survey included eight questions as listed below:

1. Institution Name.
2. Department/Program Name.
3. Planning Related Degree(s) Offered.
4. TOD Courses – List any courses (course number, title, student level, and description) offered at your institution that include “transit-oriented development” in the course title or has

a primary focus on “transit-oriented development”. If none, write N/A.

5. TOD Course Summary – Provide a summary of the activities/assignments provided in courses listed in question #4 (or please send a syllabus).
6. TOD Modules within a Course – List any courses (course number, title, student level, and description) that offer a module or brief portion of the course devoted to “transit-oriented development” (other than those previously identified in questions #4 and #5). If none, write N/A.
7. TOD Module Summary – Provide a summary of the module activities/assignments provided in course listed under question #6 (or please send the activity/assignment documentation).
8. Provide any additional information regarding your institution's efforts to teach transit-oriented development concepts.

The questions were developed with the intention to learn the level of integration and exposure students have to TOD. Therefore, two general categories were used: (1) TOD courses and (2) TOD modules. TOD courses are those where the primary focus of the course is centered on transit-oriented development while modules are lessons or a brief portion of the course devoted to TOD. Survey respondents were asked to identify both and provide information on course (or module) materials to support their existing efforts.

#### 2.1.3 Survey Distribution

Once the survey tool was complete, representatives at each institution were emailed the survey link. The representatives were either program directors or department chairs with the intention that they have oversight over the entire program and course offerings. The representatives were notified that if they could not complete the survey on behalf of the program, that they could forward the link to another person at the program who has more information on this topic. In addition, the instructions included the purpose of the survey, how to complete the survey, information about the IRB approval process (stating that their participation in the survey serves as their agreement to allow the information to be shared/published), as well as email contact information for questions. The survey instrument was available for 9 days and there were a total of 25 responses out of 86 institutions, which is a 29% response rate.

### 2.2 Survey Results

To analyze the survey data, the following methods were used: (1) comparison of program levels/types,

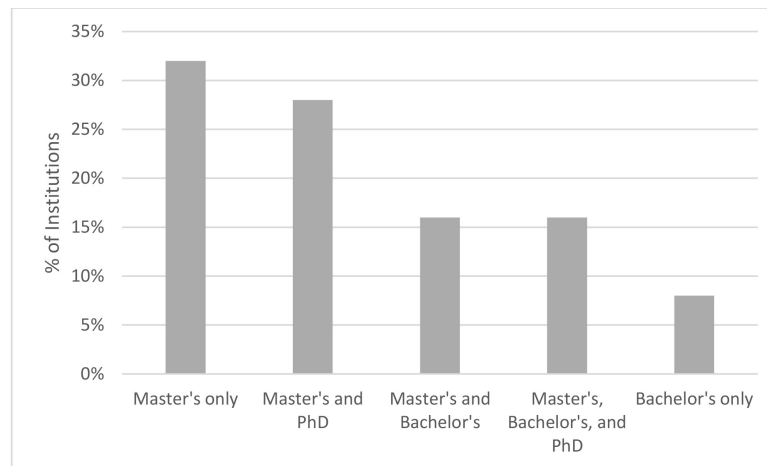


Fig. 1. Planning Program Degrees Offered by Participating Institutions.

(2) geographical distribution of TOD integration using geographic information systems (GIS), (3) comparison of TOD course offerings, and (4) comparison of TOD module offerings.

Each survey respondent was asked to provide their institution's program name as well as planning related degree(s) offered. Fig. 1 provides a summary of the number of institutions offering bachelor's, master's, Ph.D. or a combination of those three degrees.

As shown, master's level is the most widely offered planning degree as it is offered at all institutions except two (bachelor's only). A combination of program names such as urban and regional planning, urban studies, urban policy, urban design, as well as city and regional planning were found across the participating institutions.

The next analysis was comparing the level of TOD integration (course or module) based on questions #4–7. The institutions were asked to provide both courses with TOD as a primary focus (or titled TOD) as well as courses that provide TOD modules (minor focus). Therefore, there were four levels of integration at the institution based on this question: course(s), module(s), both, or none. It should be noted that since the participants could explain the level of integration through a summary of the course and/or module (questions #5 and #7), there were four submissions where it was found that a participant incorrectly completed the survey by inputting a TOD module into the question about TOD courses or vice versa. Therefore, based on the summary, the determination of module or course was made, however, future work would include completing a detailed syllabi comparison of all courses and courses with modules to more formally characterize the two categories, to avoid any error in responding and/or interpreting the results. Also, it is understood that those institutions that do not

have any TOD course or module are less likely to participate in the survey which is why there perhaps are only two respondents with “none”. One of those two institutions said they do reference the topic in design studios, but it must not be at the level of a full module or course, since they replied that there are no modules or courses offered.

Institutions that only offer TOD module(s) are the most prevalent with 16 schools (64%). Four schools (16%) offer both at least one course and at least one module within an existing course, reflecting a “deep” integration of TOD at various levels and topics. Three schools (12%) provide only TOD specific course(s) which are either titled “TOD” (one of the three schools) or provides TOD as a primary focus, such as through an elective on TOD or a capstone design course which is based on a TOD design. Therefore, a total of 92% of participating institutions offer module(s), course(s), or both. Fig. 2 displays the results by % of institution offering TOD courses and modules.

A spatial analysis was used to compare location of institutions offering TOD courses and modules. As shown in Fig. 3, many of the schools that participated are in locations where transit is widely used including major metropolitan areas, specifically those in the northeast corridor (Massachusetts, New York, New Jersey, Maryland, and Virginia) as well as southern California. This may reflect the amount of transit resources, expertise, and awareness that is gained from teaching in those locations. Perhaps this also suggests a need for extra assistance/resources to enable TOD to be offered to students throughout the nation, especially in places that are lacking in transit connectivity.

In order to gain more insight into the modules and courses, follow up questions (#5 and #7) asked the respondent to provide information on the course (providing the syllabi or explaining the

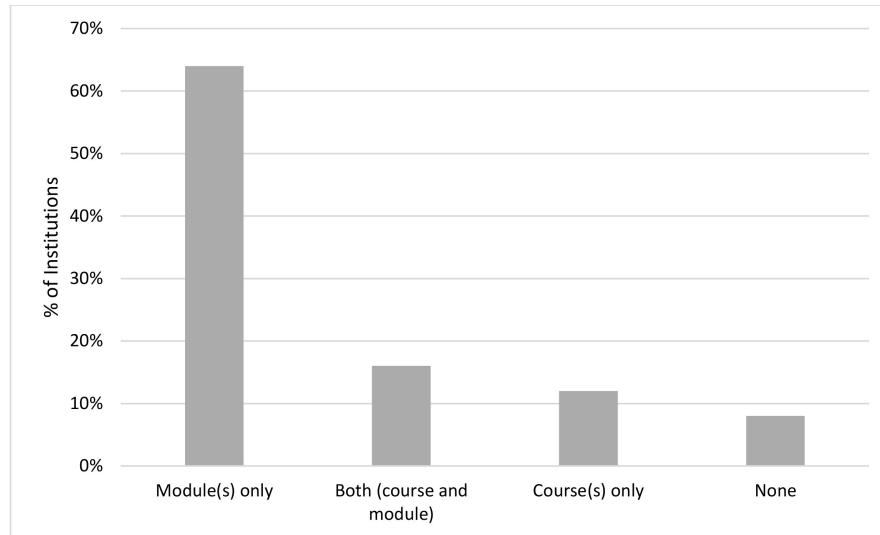


Fig. 2. TOD Integration by Participating Institutions.

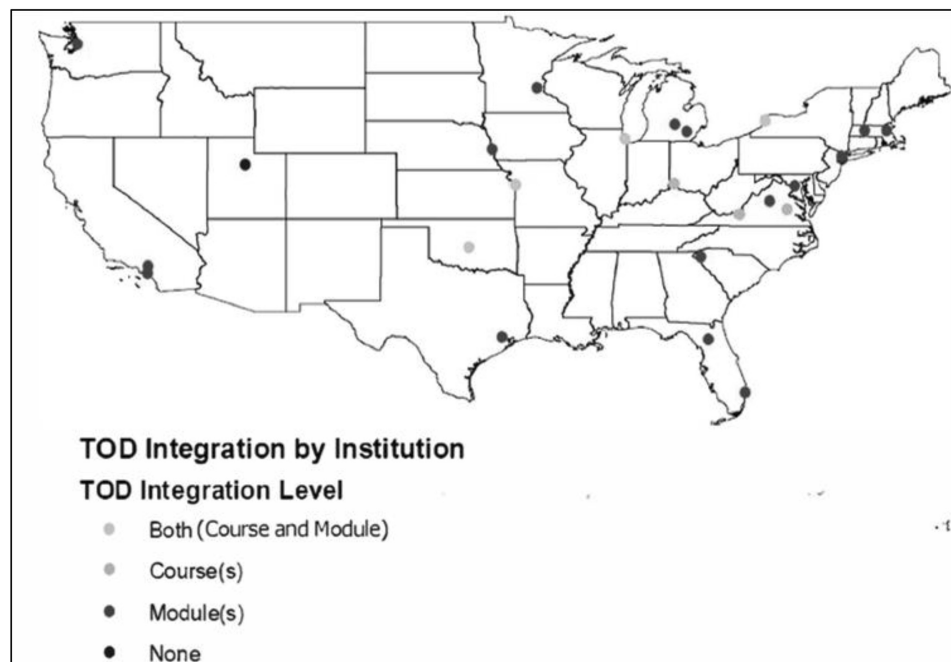


Fig. 3. Map of TOD Integration Level by Participating Institutions (source data 13, 14).

course) and module (describing or sending relevant assignments and activities). After reviewing the responses to question #5 (TOD course), it was evident that project-based experiences are prevalent. Although the lectures offer a foundation for learning about TOD, most TOD courses provide a real world transit project (sometimes with real clients) which students investigate and provide recommendations on planning and design. Also the connection of financial feasibility and TOD was common as this sub-topic was incorporated through both discussion as well as project-based learning.

For question #7 (TOD module), there was a variation on the amount of TOD teaching/learning from approximately two weeks to one lesson. Also, the overall emphasis on general transit topics varied substantially as there were courses called “Public Transportation Planning and Management” to “Sustainable Transportation”.

In terms of the TOD module explanation, sub-topics such as policy, financing, planning, and connection to land use were common. Also, case studies on local transit-oriented developments (existing and future) are typical as well, providing students an exposure to real world examples and

application of TOD concepts. One example is an assignment that has the students evaluate parking opportunities that support usage of an existing transit route. Park and ride facilities are investigated/designed based on pricing, capacity/demand, and connectivity. Also, field trips and guest lectures (by local transit authorities, engineers, and planners) are incorporated in support of the modules. Many of the modules provide some “local” connection, meaning there is some effort to connect the topic to the local town/metropolis. This is especially the case if there are nearby existing or proposed TOD projects. Also, the modules tend to be offered either before or after lessons on bicycle/pedestrian mobility, suggesting the strong connectivity between non-motorized mobility and transit, specifically for the “first and last mile” of the trip.

References and resources to support TOD modules were shared by some of the participating institutions. Table A1 (located in the Appendix) is a selected list of readings associated with TOD modules.

Again, this is a selective list and is not comprehensive, but does provide a foundation of relevant background materials. The list includes a mix of both academic journal publications as well as government/agency reports. This reflects the fact that the topic is not only embedded in research efforts but also is a current and timely topic, so agency reports provide relevant data and statistics on transit usage and funding.

Overall, the TOD modules provide students a strong overview of the topic. Although the opportunity for “depth” comes with a full course, a TOD module embedded in transportation and land use courses within urban planning programs provides relevant information and examples to expose students to TOD opportunities and challenges. For more information related to full course options focused on not just transit oriented development but the larger topic of public transportation in transportation curricula, refer to Oswald Beiler [34].

### 3. Transit-Oriented Development Module

Similar to the modules identified through the survey, a TOD module has been developed and is explained in detail for purposes of dissemination to other institutions. The module level integration can be one of the first steps that faculty can pursue to begin to expose students and can be relatively straightforward since it can be implemented in existing courses. This module was developed and implemented (four times) as part of an upper level civil and environmental engineering elective, Sustainable Transportation Planning, at Bucknell Uni-

versity [35]. By presenting this module, it serves as an example of how TOD can be implemented at a variety of engineering or transportation programs throughout the nation.

In connection to the survey results, this particular module does incorporate many of the “trends” found across the institutions offering modules such as exposure to relevant TOD topics such as pricing, land use connection, and planning. Also, the use of real world examples is incorporated through a case study discussion as well as through supplementary activities (guest lecture and field trip). The following section provides a detailed explanation of the module development, components, implementation process, relevant activities, as well as reflections and recommendations. For more information about the overall Sustainable Transportation Planning course, refer to Oswald Beiler [35].

#### 3.1 Module Development and Implementation

The TOD module (lesson) was developed as part of an upper level (predominantly senior) undergraduate elective course in civil and environmental engineering called Sustainable Transportation Planning [34]. Since Bucknell University does not have an urban planning program, the concepts and principles are embedded into the transportation engineering course which emphasizes planning and engineering design methods for multimodal facilities (transit, bicycle, and pedestrian).

The module is titled “Transit-Oriented Development” and the following lesson objectives are used as a foundation for what the student should learn by the end of the class:

1. Describe common forms of transit mobility by comparing and contrasting characteristics.
2. Discuss transit-oriented development (TOD) in the context of smart growth and new urbanism design principles.
3. Evaluate an example of a TOD in the field through a case study.
4. Explore how pricing influences ridership through calculating transit elasticity.

Each lesson objective is addressed through either lecture material, group exercises, case study investigation, or computational practice problems. The specific methods are discussed in the following section.

In terms of reading material, the following items are assigned to students in preparation for the class:

- J. Tumlin, *Sustainable Transportation Planning-Chapter 8 “Transit”*, Wiley and Sons, New Jersey, 2012 [36].

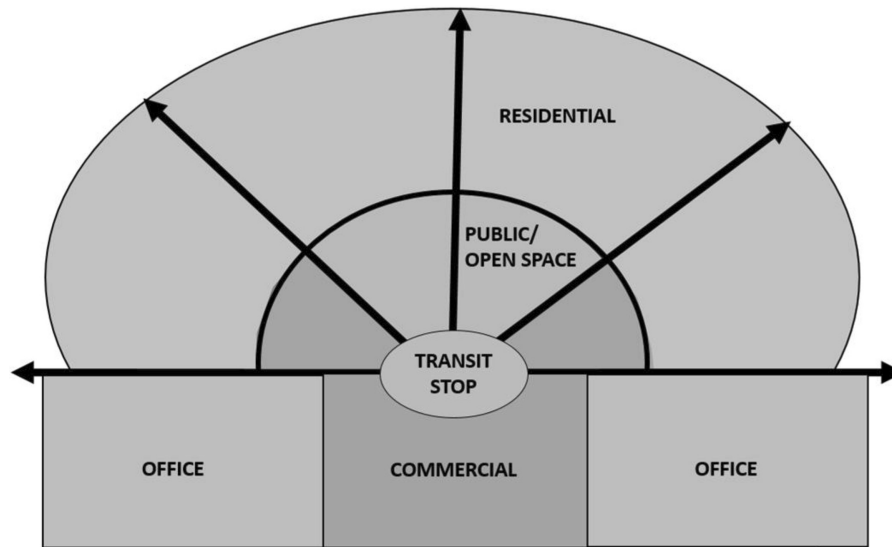


Fig. 4. TOD Layout for Board Exercise.

- D. Youker, *Now Boarding the 5:15 Express*, American Planning Association, 2011 [37].
- J. Fricker, and R. Whitford, *Fundamentals in Transportation Engineering*, 2nd Edition, 6th Printing, The Scholar Collection, 2018 [38].

These reading assignments are incorporated into the lesson through discussion as well as sample problems. By having the student read the information prior to class, they can effectively contribute and build on the fundamental knowledge gained from the reading.

In terms of the overall module, there are four primary module sections that reflect the four objectives. The first section focuses on learning the differences in transit types (local and regional systems) and when they are applicable in the field. A “think-pair-share” exercise is used to ask the students to identify at least four types of transit modes (based on the reading or their own travel experiences) and describe their unique characteristics (size, speed, function, service area, right-of-way/infrastructure requirements, ridership, operations and maintenance costs, etc.). The students share their responses, and then as a class, we discuss local transit forms first (bus, express bus, bus rapid transit) as well as regional (light rail, heavy rail, and high speed rail). We compare and contrast the opportunities and challenges associated with each transit mode and images are projected as they relate to each type. Also, we discuss when different modes would be appropriate in application, such as in providing transit service in a more rural area (bus) versus a highly populated urban area (light rail or heavy rail).

Once the transit modes are understood, then we

discuss the connection to urban design through basic concepts in TOD. The traditional TOD layout is taught through an interactive student experience. Using the whiteboard, a transit line and stop are drawn. The students then take turns coming up to the board to indicate where various types of land use (commercial, office employment, open/public space, residential, etc.) should be in relation to the transit stop. They continue working until the layout looks something similar to Fig. 4 (general concept of commercial and open space surrounding the stop with residential/office at the periphery of a walkable distance). The concept of “walkability” is then discussed in terms of what is a comfortable distance that allows someone to walk to a transit stop. The range of a quarter mile to a bus stop and a half mile to a train station are discussed [38]. Also, the concept of transit-oriented development (TOD) versus transit-adjacent development (TAD) is discussed in terms of differences in street pattern, density, parking, and land use [5].

The next section of the class is devoted toward a case study example of a TOD. Images and reference material from the Wilmington Area Planning Council (WILMAPCO) on Elkton, Maryland’s TOD Plan [39] is shared with the students. This particular location was selected as the instructor formerly worked for WILMAPCO and had experience with this particular location, however, a case study within any location, can be used. The case study includes sharing resources including the Elkton TOD Plan [40], maps of the TOD layout, and images of TOD-related facilities. After reviewing materials, a group discussion is held on the strengths of the design as well as challenges in

implementation. In following up, the students identify ways to address potential challenges as well as discuss how these approaches can be applied to other locations.

The final portion of the class is devoted to discussing the relationship between pricing and ridership (which is typically already identified as a challenge through the case study evaluation conducted prior). The demand elasticity of ridership with respect to fare is taught using Equation 1 where “ $\varepsilon$ ” stands for the elasticity (also referred to as the shrinkage ratio), “ $Q$ ” is the quantity of service or ridership, and “ $P$ ” is price [38].

$$\varepsilon = \frac{\% \Delta Q}{\% \Delta P} = \frac{(Q_1 - Q_0)/Q_0}{(P_1 - P_0)/P_0} = \frac{(Q_1 - Q_0)P_0}{(P_1 - P_0)Q_0} \quad (1)$$

Two sample problems are provided to the students as classwork exercises as listed below.

- TOD Town raised its average fare from 40 cents to 50 cents. As a result, daily ridership fell from 6,604 to 5,943 riders. Compute the TOD Town’s transit demand elasticity with respect to fare.
- The Bison Bus Company offers special service to university students in a service area near campus called the Bison Zone. Bison Bus Company plans to increase the Bison Zone fare from 25 cents to 35 cents starting January 1. Last spring 227,000 riders paid the Bison Zone fare. How many Bison Zone riders can the company expect next spring? Use an elasticity value of  $-0.33$ .

The students work in pairs to complete the two problems and then volunteers demonstrate how to solve them on the board. The relationship of ridership decreasing as fare increases (and vice versa) is discussed and then the open question of how to reduce fare rates is proposed. Market instruments (including subsidies, monthly ridership programs, employer provided passes, etc.) are discussed as ways to reduce rates and increase ridership.

Lastly, the elasticity equation is discussed as a way to compare ridership to other transit criteria such as serviceability. If the value of “ $P$ ” is substituted for “ $S$ ”, reflecting serviceability, the same relationship applies. The concept of serviceability is taught and students identify factors like headway (time between transit vehicles) that would enable acceptable versus unacceptable service.

The lesson concludes with a discussion of places they have been that reflect TODs. Each student shares one minute of their experience by telling the class about the location and characteristics that reflect a TOD. If they have not been to a TOD, they respond with a place they think could benefit from TOD design and explain why.

### 3.2 Supplemental Activities

In addition to teaching the module, the following is a selected list of activities that were implemented related to the TOD module:

- Module on transit design – Following the TOD lesson, an engineering-focused lesson is taught including principles of pedestrian and transit station planning, concourse walkway design based on peak flow rates, bus capacity and ridership, and heavy rail transit vehicle travel regimes.
- Bus tour around Williamsport, PA – A local transportation planner from Lycoming County, PA led a 90-minute bus tour around downtown Williamsport including a number of stops that reflect transit and walkable neighborhood development efforts.
- Guest Lecture from Centre Area Transportation Authority (CATA) – A former employee of CATA (mass transit agency in State College, PA) provided a lecture on transit management based on their experiences in overseeing vehicle fleets, transit facilities, transit planning, and transit operations & maintenance issues.
- Course projects – Based on the relevant community/campus projects, the students have the opportunity to work on a transit related project such as improving the Bucknell University Shuttle efficiency and routing.
- Exam questions – Direct assessment questions on examinations provide level of student knowledge with regard to TOD concepts. The questions vary in levels of thinking from “understanding” (identifying terminology) to “creating” (solving open ended design problem).

### 3.3 Reflections and Recommendations

This module was taught as part of the Sustainable Transportation Planning course four times (in 2012, 2013, 2015, and 2016). Each time the lesson was slightly revised to incorporate new information with regard to innovations in transit-oriented development. In particular, updates on regional rail versus high speed rail [41] applications are incorporated into the first lesson objective. Also, with recent developments in hyperloop design, the discussion of mass transportation in connection to TOD is expanded to include future opportunities [42]. Future module implementations will similarly undergo a revision process in order to reflect the current practice.

In terms of engagement, the supplemental activities are critical to student learning and emphasize the connection in the field. The bus tour allows students to see transit facilities and land use development strategies as well as understand the context for how and why TOD planning is needed.

Also, it reiterates the challenges associated with implementation which typically arise again for those students that select a transit-related course project. The guest lecture provides insight into transit management as well as opens the discussion of careers in transit. This is timely as the students are primarily seniors and planning their post-graduation careers.

Even though there is one formal lesson titled “TOD”, the discussion of transit transcends the entire class. From the first lesson on the history of transportation planning [43], students watch a video on transportation in San Francisco in the 1900’s and then discuss the differences in “transit” from then to now. Related lessons on concepts such as smart growth, new urbanism [44], complete streets, transit design, policy and pricing, automobile dependence, and climate change are included in the course. Also, the last week of the course is devoted to global perspectives where the students compare and contrast case study locations across the globe with regard to transit and other sustainable transportation systems. Therefore, the TOD lesson is one component of a much larger discussion of public transportation systems. Refer to Oswald Beiler [35] for the complete summary and explanation of the course topics in the Sustainable Transportation Planning course.

For courses that are offered to master’s or doctoral level students, the material and activities can be tailored to a higher level through requiring them to complete additional background readings in order to pose more open-ended practice problems in class. For example, the case study discussion could be more of a group exercise by showing the location’s transportation and land use challenges and having them develop TOD alternatives to solve the problems. Each team could develop a potential plan and then compare and contrast the results. Using higher level thinking exercises can prepare them for upper level field experiences.

In summary, the following recommendations are made with regard to implementing the module:

- Revise material to reflect current TOD practices as well as updates to the planning and engineering policy recommendations (such as the American Society of Civil Engineer’s Policy Statement 494 titled “Public Transportation”) [45].
- Incorporate real world experiences such as field trips and tours.
- Provide guest lecture opportunities to allow for transit planners to share their experiences.
- Engage students in real world transit problems through course projects.
- Explore transit-oriented development concepts throughout the semester through applications

to other course topics such as complete streets, smart growth, and transportation legislation.

- Tailor the material to the level of the students enrolled in the course to prepare them for relevant post-graduation field experience.

#### 4. Conclusion and Future Work

Effective transit-oriented development (TOD) provides transit connection between residential, commercial, office, and public venues through a walkable pedestrian environment [6]. TODs in practice continue to gain support in connection to smart growth and new urbanism planning goals. Efforts to also support TOD in the classroom is essential in order to prepare and inspire future engineers and planners to incorporate and adopt sustainable transit design principles. This study examines the existing pedagogical efforts in undergraduate and graduate level planning programs with regard to teaching TOD principles. A national survey is conducted in order to determine existing courses as well as modules focused on TOD.

The results showed that the primary form of TOD integration across participating institutions was at the module level only, with 16 institutions (64%) offering at least one lesson in an existing course. There are three institutions (12%) offering a course where TOD is the primary focus of the course, such as an elective course called “TOD” (or highly related topic) or a capstone design course on TOD. Four institutions (16%) offer both course and module integration. The spatial analysis suggested that TOD pedagogy tends to be more prevalent at locations where transit is available in practice which therefore, suggests the need for an expansion of expertise and resources to be available to those institution locations that are less transit-focused. Future work includes expanding the survey to include additional planning programs (those that did not respond to the survey) as well as transportation engineering programs similar to the Sustainable Transportation Planning course, as a TOD module may be incorporated in transit-related courses.

In addition to the survey, a TOD module taught as part of a Sustainable Transportation Planning course (upper level civil and environmental engineering elective) at Bucknell University is provided as an example of how to incorporate TOD into an existing course. The module development and implementation as well as supplemental activities are provided in order to disseminate the pedagogical materials to programs throughout the nation. Future work includes continual improvement to the module in order to reflect innovations in practice as



well as comparing direct (exam questions) and indirect (pre-surveys and post-surveys) assessment tools over time to determine changes in student learning. Also, understanding how this topic guides post-graduation career decisions and prepares them for the field would be valuable to explore through an alumni survey.

The results of this study suggest that TOD is a

growing concept within planning programs with many institutions (at least 23) offering a course or a module related to TOD. The example TOD module shared in this study serves as an example for how to incorporate transit-oriented principles into an existing course as a way to prepare and inspire the next generation of transportation engineers and land use planners.

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## 6. Appendix

**Table A1.** List of Readings Associated with Existing TOD Modules

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**Table A1.** (continued)

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