By the Book: Is Induced Travel Missing from Transportation Engineering Textbooks?

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ABSTRACT:

Induced travel is the new travel that materializes in the aftermath of an expansion of transportation infrastructure (e.g., a wider road). Accounting for induced travel is essential for accurately describing the long-term benefits and environmental impacts of a project. However, engineers rarely account for induced travel during project planning and design, in part due to unfamiliarity with or skepticism about induced travel. To probe this missing piece of engineering practice, this research focuses on whether transportation engineering textbooks introduce students to the concept of induced travel. Based on a systematic review of seven textbooks, coverage of induced travel appears incomplete. Some textbooks omitted the idea entirely and those that did include it offered only partial coverage. Textbooks either defined the term, indicated its expected magnitude, used the concept in a problem set, or described the implications for practice and policy. However, no single textbook included all these essential elements. Beyond this, all textbooks placed a greater emphasis on accommodating demand rather than managing it. Textbooks offered an asymmetric portrayal of how drivers adjust to traffic conditions. They tended to emphasize that drivers avoid congested areas and de-emphasized that drivers are also attracted to uncongested routes. In short, the engineering textbooks reviewed here leave students unprepared to understand induced travel or its implications. To improve, teaching materials should: 1) clearly define induced travel and distinguish it from other terms, 2) indicate the expected magnitude of induced travel, 3) feature the concept in problem sets to be consistent with engineering's signature pedagogy, 4) describe the implications of induced travel for engineering practice, and 5) introduce students to foundational debates about transportation policymaking.

AUTHOR KEYWORDS (OPTIONAL): Congestion, Engineering education, Threshold concepts, Highway capacity, Textbook analysis

INTRODUCTION:

In 2022, our research team interviewed 16 instructors of transportation engineering classes to explore whether and how they explained induced travel, the phenomenon in which a wider roadway encourages more driving (see Background for more detail). These interviews revealed wide variation in coverage. Some instructors made induced travel central to their teaching and used the idea to challenge core tenets of the traditional predict-and-provide paradigm. Others omitted the topic for a host of interrelated reasons.

Intriguingly, some instructors told us that induced travel was not featured in the engineering textbooks they used. While some of them supplemented the primary text with outside sources, many others hewed closely to the textbook. For them, if induced demand wasn't in the book, it wasn't in the class. Were these assessment accurate? Was induced travel really missing from textbooks?

The purpose of this research is to richly characterize how induced travel is covered in a sample of transportation engineering textbooks. Specific questions guided the methods and data collection: Do textbooks mention the topic at all? Do they define it clearly? Indicate the expected magnitude of induced travel? Incorporate the concept into problem sets? Describe the implications for practice and policy? This work answers those questions based on a systematic review of seven of the most frequently assigned transportation engineering textbooks.

To be clear from the outset, the goal of this research is not to comment on the overall quality of the textbooks or question their use in the classroom. Instead, the aim is to characterize the coverage—or lack thereof—of induced travel. The following section elucidates the importance of induced travel, clarifies the rationale for a textbook review, justifies the research questions, and outlines anticipated findings.

BACKGROUND AND PROJECT RATIONALE

Defining induced travel

Induced travel is the new travel that materializes in the aftermath of an improvement in transportation infrastructure. When it comes to driving, induced travel captures the idea that widened roadways increase driving as people respond to the newly free-flowing lanes by switching from other modes, making longer trips, and making more trips (see Fig 1.). The idea is not new. Suspicion that new road capacity created more travel was raised over 100 years ago (Ladd 2012). The idea was more formally theorized and popularized in the 1960s by Anthony Downs' "The Law of Peak Hour Expressway Congestion" (Volker and Handy 2022; Downs 1962; 1992). Induced travel is consistent with economic principles (Noland and Lem 2002); as roadway capacity is added, the costs of travel decrease, and the quantity demanded increases (see Fig 2.).

Induced travel is measured as an elasticity: the percentage change in vehicle miles traveled (VMT) divided by the percentage change in lane miles. A low elasticity suggests that drivers do not adjust much to new capacity. A higher elasticity, by contrast, indicates greater responsiveness from drivers. A review from Handy and Boarnet (2014) found the elasticity for highway expansions was "close to 1.0" (p. 4). In other words, a 10% increase in road capacity is followed by a 10% increase in VMT within a few years. As a result, the new capacity does not reduce congestion in the long-term. In the years since that review, several scholars have come to similar conclusions about the magnitude of induced travel (Volker, Lee, and Handy 2020). Nevertheless, important questions remained about the amount of variation across different contexts (location, roadway type, initial amount of congestion, etc.).

A 2022 review of empirical studies offers new evidence that induced travel trends are more uniform than previously thought (Volker and Handy, 2022). In the long-term—that is three to ten years after construction—elasticities for induced travel range between just 0.77-1.06[1]. According to the authors, this finding holds across a range of roadway types (i.e., FHWA facility classes 1-4: Interstates, highways, major arterials, and minor arterials). The authors also found similar elasticities across urban and rural areas and across pre-widening congestion levels. Most

[1] There is more variation in the short-term (1-3 years post construction), where elasticity estimates range between 0.28-0.76.

importantly, they conclude that there is "at most a minimal substitution effect"; drivers are not simply "substituting" the newly expanded highway for a different route they were taking previously (p. 11). If this is true, most of the increase in VMT is truly new, it is not the result of drivers shifting from other routes.

Induced travel in the classroom

Induced travel is a paradigmatic "threshold concept," a term coined by education scholars Meyer and Land to describe ideas that are troublesome and transformative (J. H. F. Meyer and Land 2005). Once understood, threshold concepts lead one to see the world differently, but this transformation is hard-earned because threshold concepts are counterintuitive. In emphasizing the transformational nature of threshold concepts, Meyer and Land seek to distinguish them from core concepts. The *aha moment* of crossing the threshold represents, "a significant shift…akin to a portal, opening up a new and previously inaccessible way of thinking about something." (p. 1) Examples of threshold concepts include limits in pure mathematics, opportunity cost in economics, and entropy in physics.

Does induced travel meet the troublesome-transformative criteria? It does. In our experience, students can often repeat the idea verbatim but struggle to apply the concept to different settings. Many students also struggle to make sense of evidence for induced travel because it is impossible to observe the counterfactual (i.e., we cannot see what would have happened if we had not widened the roadway) (Gorham 2009).

Induced travel is also transformative. Agencies have traditionally justified road widening projects with promises to relieve congestion and offer faster travel times. Yet given the realities of induced travel, these benefits will often be short-lived. Similarly, the predicted environmental benefits of "smoothing" stop-and-go traffic may be outweighed by the additional vehicles attracted to uncongested streets. $$$$ Taken together, Ladd (2012) concludes that, "an acknowledgement of induced traffic poses a fundamental threat to established methods of transportation planning." (p. 21)

Textbook review rationale

A textbook review, the method employed here, is a subset of an established type of qualitative scholarship known as document reviews. In this method, documents—here, textbooks—serve as the source of data and scholars systematically review the data to identify key themes and compare patterns across texts. Document review includes a series of formal steps, including identifying, analyzing, and synthesizing the text or other materials (Bowen 2009).

Textbooks are an especially rich source for scholarly inquiry. Textbooks play a unique organizational role because they are "institutional artefacts that configure entire academic subject fields" (Palmer, Simmons, and Hall 2013, 485). Textbooks, are thus "key sites for assessing how scholarly ideas are developed and understood." (Koschmann and Campbell 2019, 173). Comparative textbook analysis initially focused on social studies, but has expanded to include math and other subjects in the 21st century (Fan 2013; Nichols 2003; Chu 2017).

While textbook reviews can serve a range of purposes (i.e., to help educators select a textbook, to assess general quality, and to consider representation and diversity), it is increasingly popular to critically assess coverage of a specific topic. Consider an example from physics, where a textbook review found that Pascal's principle is covered poorly in undergraduate texts (Anselmo, Hidalgo, and Queiroz 2020). Similarly, a textbook review in

chemistry found that descriptions of the Brønsted-Lowry Acid-Base equilibria were muddled and inconsistent (Meister et al. 2014). These authors persuasively argue that these topics are foundational to the undergraduate curriculum and therefore merit careful inclusion in textbooks. This article makes an analogous claim with respect to induced travel.

Finally, a textbook review is especially relevant to this topic because engineering instruction relies heavily on textbooks (Lee et al. 2013). This fact that was reinforced repeatedly by interviews with engineering instructors (Ralph 2024).

Research question rationale

In exploring coverage of induced travel in engineering textbooks, this study focuses on five questions, discussed in turn below.

#1: Do textbooks define induced travel?

This study explores whether and how textbooks define induced travel, focusing on the scope of behavioral adjustments, economic accuracy, and neutrality. This focus on definitions is important because induced travel is often used interchangeably with induced demand, latent demand, and other related terms. To make matters worse, these terms often mean different things to different people. Competing definitions often include very different scopes of behavioral adjustments: are we only talking about entirely new trips or are longer trips to more distant destinations also included?

A related definitional challenge is that some people use faux economic terms like "latent demand", which Gorham (2009) explains is economically meaningless:

> If we reduced the price of a hamburger at a fast-food restaurant from $1.25 to $1.00, we would expect to see an increase in demand for hamburgers… However, the notion that these income and substitution effects reveal some kind of "latent" demand for hamburgers is *prima facie* absurd. People would consume even more hamburgers if they were all free. Should we then say that the "latent demand" for hamburgers is the amount of hamburgers people would consume if they were free? The same is true with travel. (p. 9)

Beyond being economically meaningless, Gorham (2009) argues that the term "latent demand" is emotionally laden:

> [It] evokes a notion of underlying, "pent-up" or "frustrated" demand for transport that consumer may have, but are unable to exercise… What stands between the public and the fulfillment of their "demand" is a politicians' decision to invest (or not) in a given transport facility or service. (p. 8)

Historian Brian Ladd (2012) makes a similar point about the phrase "repressed traffic." Its use, he argues, is emotionally charged because it implies "that someone had been deprived of a fundamental right to mobility." (p. 18).

#2: Do textbooks indicate the magnitude of travel likely to be induced?

This study assesses whether textbooks describe the *magnitude* of travel that might be induced, likely in the form of an elasticity. This is important because the expected magnitude of induced travel profoundly affects the associated policy implications. If new capacity is likely to attract

only a few vehicles, engineers could largely disregard induced travel and proceed with capacity expansions. If, however, the amount of induced travel is rather large, engineers should carefully consider it in their project selection process.

#3: Do textbooks incorporate induced travel in problem sets?
Many professions have well-established, industry-wide instructional practices that comprise their signature pedagogy; law schools use the Socratic method and medical schools use clinical rounds (Shulman 2005). Engineering's signature pedagogy features lectures and problem sets (Lucas and Hanson 2016) and, given their prominence, this study assesses whether induced travel is included in any problem sets and end-of-chapter questions.

#4: Do textbooks help students grapple with the implications of induced travel for engineering practice?
Induced travel has profound implications for well-established engineering practices. Projects that seem reasonable if we ignore induced travel may not pencil out if we consider it. To make informed decisions, induced travel should be incorporated into cost-benefit analyses and other assessment tools. Do textbooks mention these implications for practice?

#5: Do textbooks help students grapple with the implications of induced travel for policy?
Students—and their instructors—need scaffolding to fully explore the significant ramifications of induced travel for transportation policy. These debates can be polarizing. While some are quick to say that adding any new capacity is futile, others suggest that we should *always* build regardless of the amount of induced travel we can expect. But the action, so to speak, lies between these extremes. Do textbooks prepare student for these discussions?

Anticipated findings
There are several reasons to think that engineering textbooks would give induced travel short shrift. As noted at the outset, many instructors indicated that the concept was missing from the textbooks they used in class (Ralph 2024). Induced travel is also notably absent from the "Body of Knowledge," a publication of the American Society of Civil Engineers (American Society of Civil Engineers 2019; 2008) that guides the accreditation process and the Fundamentals of Engineering (FE) Exam, which most undergraduate engineers take FE just before or after graduation. Induced travel is not explicitly mentioned in the Body of Knowledge, nor is it listed in the associated FE reference materials or practices tests. As the FE exam hews more and more closely to practice and less to fundamental concepts and math, it is even less likely that induced travel will be included (Bruhl 2023).

Moreover, a 2021 survey of transportation students found that fully 30% of engineering students believed that widening a road was "likely to ease congestion in the long-term" (Ralph et al. 2022). By contrast, just 7% of transportation planning students held this view. This suggests that engineering students may be relatively less familiar with induced travel, perhaps because it is missing from their textbooks.

Finally, despite its importance, induced travel has not been widely incorporated into engineering practice. For instance, Volker, Lee, and Handy (2020) note that induced travel is often missing from environmental reviews. The link between practice and textbooks is a bit like the chicken and the egg; if it isn't used by practicing engineering, why would it be in a textbook?

METHODS

Textbook sampling strategy

Textbooks were selected from the syllabi of traffic engineering courses using purposeful sampling, the most common sampling strategy employed in textbook reviews (Chu 2017). Syllabi primarily came from an open-source compendium called Open Syllabus . Open Syllabus is a non-profit research organization that started at Columbia University. They scrape the internet for syllabi from higher education institutions and conduct content analysis for education researchers. The site has over 18 million unique syllabi in its database. A search for "traffic engineering" textbooks yielded 88 results. From this list, five textbooks appeared on more than 100 syllabi[2], and were retained for analysis. Two additional titles came from the collected syllabi of the sixteen faculty who participated in interviews on teaching transportation courses in engineering programs (Ralph 2024). These two textbooks represent key elements not captured by the initial list of five. One provides an extended discussion of induced travel (Handbook of Transportation Engineering), while the other provides an up to date look at the state of the practice as it is the most recently published of the textbooks (Transportation Engineering: A Practical Approach). See Table 1 for the list of textbooks, authors, and sources.

Content Analysis

The search function in Adobe Acrobat PDF Reader was used to scan all seven textbooks and find each instance of a list of search terms that were compiled from the literature. See Table 2 for the search terms and number of occurrences. Some terms—like LOS and FFS—occurred hundreds of times across the textbooks. To make the process more manageable, only the priority search terms were used for the problem sets, stand-alone formulas, and case studies. All search terms were used when searching the main texts. Two instances of "induced" referred to the titles of papers in citations; the associated text was incorporated in the analysis. The key word search was supplemented with a careful reviewing the Tables of Contents and Index to identify potentially relevant sections (e.g., "Congestion" and "Traffic Demand Modeling").

Each keyword and accompanying sentences were extracted into an editable Word document, resulting in approximately 85,000 words of text. The extracted text was scanned, and irrelevant text was omitted. For instance, the word "induced" is present in several textbooks, but often in the context of bridge trusses and structural engineering concepts. This winnowing step left approximately 11,000 words of relevant text.

Caveats

Important caveats and practical limitations deserve mention. This review is not exhaustive of every textbook on the market, nor can we guarantee that some indirect reference to induced travel has not been overlooked. Moreover, this analysis only applies to the edition of the textbooks reviewed here. Other editions—particularly those published more recently—might provide more in-depth coverage of induced travel. Like all research, textbook reviews are inherently interpretive; another research team may have asked different questions and come to

[2] The nature of the associated classes varied considerably: some were for undergraduates; others were for graduates. Some were required; others were electives.

different conclusions. Nevertheless, this work employs well-established methods designed to maximize rigor and minimize bias.

To be clear, this review does not constitute an endorsement, nor is it an assessment of the overall quality of the selected textbooks. This review is very narrowly focused on a single topic and is silent on other important considerations for selecting a textbook (e.g., the clarity of the problem sets and the coverage of other essential concepts). The intention is not to criticize the textbook authors/editors or the instructors who use these textbooks in class; there is a lot to cover in an introductory transportation engineering textbook. The aim is simple: to make the case that induced travel is a threshold concept worthy of inclusion, to accurately characterize existing coverage, and to offer practical advice for improving teaching materials.

RESULTS

Characterizing induced travel

Coverage of induced travel varied considerably across the textbooks, but no textbook included all five elements of quality coverage (see Fig 3.). Three textbooks (Traffic and Highway Engineering, Transportation Engineering: A Practical Approach, and ITE's Traffic Engineering Handbook[3]) completely omitted any mention of induced travel or any of the other related search terms used here. While some limits to coverage were expected, the complete omission from three textbooks was a surprise. The remaining four textbooks covered induced travel but did so incompletely. In characterizing coverage across texts, this article highlights relative strengths and weaknesses.

Transport Planning and Traffic Engineering

Transport Planning and Traffic Engineering explains the complicated aftermath of a roadway expansion with several definitions. "Reassigned traffic" is "the amount of existing same-destination traffic that will *immediately* transfer from the existing road(s) that the new road is designed to relieve." (p. 30; Emphasis added) This very short-term effect is followed by "generated traffic," which includes induced, converted, and development traffic. The authors explain:

> Induced traffic consists of traffic that did not exist previously in any form and which results from the construction of the new facility. (p. 31)

In defining induced traffic, the authors are especially focused on entirely *new* trips, that is the:

> Extra journeys by existing vehicles as a result of the increased convenience and reduced travel time via the new road. (p. 31)

By focusing only on new trips, this textbook's definition of induced traffic is narrower than "induced travel" or "induced VMT", both of which include longer trips to more distant destinations (Gorham 2009; Volker, Lee, and Handy 2020; Noland and Lem 2002). Thus, by definition, induced traffic will be relatively smaller in magnitude and perhaps more easily dismissed.

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[3] ITE's Traffic Engineering Handbook does include an oblique reference to the challenge of long-term congestion relief, discussed in the "Accommodate vs. Manage" section.

Another shortcoming of this textbook's coverage is the lack of empirical evidence about the extent of induced demand. How much new traffic is a project likely to induce? This textbook offers only a *qualitative* indication of the amount of traffic to expect in a single, abstract example:

> If the journey time by the new road divided by the time by the quickest alternative route, i.e. the travel time ratio, is high it can be expected that the amount of induced traffic will be low. (p. 31)

Beyond this, the text offers no equations, elasticities, or data about induced travel that could easily be incorporated into a problem set. A further shortcoming is the absence of any problem sets, which are central to engineering's signature pedagogy (Shulman 2005; Lucas and Hanson 2016). Finally, this textbook does not describe any implications for policy or practice.

Handbook of Transportation Engineering

The Handbook of Transportation Engineering differs markedly from the first example. The only relevant passage begins by describing a key motivation for capacity expansions— "service times will fall" —but only, "as long as increases in demand...do not overtake these expansions" (p. 320) The textbook clarifies that demand often overshoots the expansion:

> Yet, in many markets, capacity is so constrained and pent-up demand so significant that travel times and speeds on expanded sections of the network may not fall in any perceptible way.

The text lists several sources of increased demand including, "natural growth, changing preferences, and substitution (of origins, destinations, routes, modes, departure times, and other choices)" and helpfully quantifies the expected magnitude of induced travel by citing scholarly literature and summarizing the consensus:

> Elasticity estimates of almost 1.0 (suggesting that new road space is almost precisely filled by new miles traveled) are not uncommon. (p. 320)

However, the textbook immediately tempers expectations, noting:

> Several of these studies draw largely on California data, where congestion is relatively severe. In less congested regions, elasticities are expected to be lower. (p. 320)

In addition to induced travel, the textbook meticulously describes several practical considerations that might make roadbuilding unattractive:

> Even so, at roughly $1 million per added lane mile for freeway construction costs alone (Kockelman et al. 2001, Klein 2001), *funding constraints* regularly preclude major supply-side solutions. And in regions not in attainment with *air quality* standards and/or wishing to limit sprawl and other features of long-distance driving, building one's way out of congestion may not be a viable option. Right-of-way acquisition, traffic diversion delays during construction, and other features of major highway projects in congested areas will add further to the overall expense of such projects. (p. 320)

Finally, this excerpt closes by noting that road widening may still be desirable even if travel is induced:

> Even though VMT may rise in proportion to expanded capacity, with congestion remaining high, there may be sufficient benefits accruing to warrant such expansions. For example, if households can afford better homes and enjoy more choice in stores, schools, jobs, and other activities, thanks to expanded travel options, those benefits should be recognized. (p. 320)

This excerpt has many strengths and weaknesses. It was the only textbook to indicate the amount of induced travel that might be expected and was alone in pointing students to additional resources. Most importantly, this text helps students prepare for difficult policy discussions by helping them understand that roadway investment decisions are not black and white. However, the excerpt does not use the term induced travel, nor does it explicitly define it. Moreover, the text does not explain elasticity, a concept that may be unfamiliar to some students. Finally, this text uses emotionally laden terms like "pent-up demand."

Principles of Highway Engineering & Traffic Analysis

Unlike the previous examples, Principles of Highway Engineering & Traffic Analysis incorporates induced travel in a problem set.[4] The question has many strengths: it unambiguously acknowledges that drivers will be attracted to an uncongested route and describes the amount of traffic that is likely to be induced. Notwhithstanding these strengths, this textbook falls short in its coverage of induced travel. Beyond this single question, the remainder of the textbook does not include any other reference to induced travel or any of the other relevant search terms. While it is certainly important to include induced travel in problem sets, it is not, by itself, sufficient.

Traffic Engineering:

Thus far, each textbook has included a single reference to induced travel. By contrast, the textbook Traffic Engineering discusses the concept in two chapters, revealing profound contradictions in coverage. The introductory chapter contains several unambiguous statements about the limits to traditional capacity expansion:

> The essential truth, however, is that traffic engineers cannot simply build their way out of congestion. (p. 16)

> Given the transportation demand cycle, it is not always possible to solve congestion problems through expansion of capacity. (p. 24)

Given these realities, the textbook poses a reframed motivating question for engineers:

> A real question "is not how much capacity is needed to handle demand?" but rather, "how many vehicles and/or people can be allowed to enter congested areas within designated time periods?" (p. 13)

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[4] Key text of the question: Each 1-minute reduction in route travel time will attract an additional 500 vehicles per hour. What will the user equilibrium flows and total hourly origin destination demand be after the capacity improvement? (p. 328)

Given this introduction, students may be forgiven for some confusion when they reach Chapter 9 "Volume Studies and Characteristics" where the authors introduce the idea of a "hidden bottleneck" that only becomes apparent after an expansion. The textbook explains:

> It was not obvious because the existing demand was constrained from reaching the segment due to an upstream bottleneck. Such a constraint is often referred to as "*demand starvation*." (p. 168; emphasis added)

The textbook goes on to advise:

> In designing corrective highway improvements, it is critical that all downstream points be evaluated properly to identify such hidden bottlenecks. The improvement project would have to address both the existing and hidden bottlenecks to achieve a successful result. (p. 168)

Throughout, the authors encourage students to recognize, "the difference between observed volume counts and *true demand*." (p. 168; emphasis added)

This section illustrates several important points. First, there is a subtle, yet important distinction implied by the word choice. Rather than refer to a more neutral term like "induced travel," the authors use the negatively charged phrase "demand starvation" (Gorham 2009). Similarly, the phrase "corrective highway improvements" implicitly suggests that widening the roadway will eliminate congestion (i.e., achieve "a successful result"). Overall, this section differs in tone and message from the introductory section. Despite unambiguously warning of the futility of trying to build our way out of congestion in the opening chapter, Chapter 9 implicitly instructs students to accommodate traffic, cautioning that to do so successfully, they must do a better job of identifying "true demand" and making *all* the improvements necessary. Taken together, these chapters offer a puzzlingly contradictory lesson for students.

Indirect evidence that textbooks minimize induced travel:

Beyond their limited coverage of induced travel, the textbooks also tended to minimize the importance of the concept in two indirect ways, detailed in turn below.

Avoidance vs. Attraction

The textbooks offered an asymmetric portrayal of how drivers adjust to traffic conditions. Nearly all the texts clearly explained that drivers *avoid* congested areas. For example:

> A feature shared by recurring and incident-induced bottlenecks is the adjustment in traffic flow that may occur as travelers choose other routes and/or different trip departure times, *to avoid the bottleneck area*. (Principles of Highway Engineering & Traffic Analysis p. 166; emphasis added)

> Determining true demand requires an estimation of how many motorists changed their routes *to avoid the subject location*. It also requires knowledge of motorists who either traveled to alternative destinations or who simply decided to stay home (and not travel) as a result of congestion. (Traffic Engineering p. 178; emphasis added)

Largely absent from the textbooks was any discussion of drivers being *attracted* to uncongested, free-flowing routes. Yet avoidance and attraction are two sides of the same coin. Across the

seven textbooks, just one described drivers' *attraction* to uncongested roadways. However, the text somewhat confusingly referred to both attraction and avoidance at once, likely sowing confusion for students:

> As new roads are constructed, as operational improvements are made, and/or as roads gradually become more congested, traffic will divert as drivers change routes or trip-departure times in an effort to avoid congestion and improve the level of service that they experience. (Principles of Highway Engineering p. 285)

The textbooks' asymmetric focus on avoidance subtly prioritizes the harms of congestion (avoided trips or travel along non-preferred routes), while de-emphasizing the potential for induced travel (more or longer trips on un-congested routes).

Accommodate vs. Manage

The textbooks also tended to place a relatively greater emphasis on accommodating demand rather than managing it. As Table 2 illustrates, all seven textbooks reviewed here universally emphasized the "need" to "accommodate" vehicle demand, an ethos that appeared foundational to the textbooks. For example, the ethos of accommodating demand informed problems sets where students are asked to determine the number of lanes "required" or necessary" to achieve a desired level of service. Similarly, most textbooks included a statement about the ability of road widening to ease congestion, which is consistent with the idea that engineers should accommodate demand. For example:

> If more lanes were in the peak period direction, the congestion would be mitigated. (Transportation Engineering: A Practical Approach p. 245).

> Points of recurring congestion are often well-suited for supply-side solutions. (Handbook of Transportation Engineering p. 320).

Textbooks gave relatively less attention to managing demand. While most textbooks mentioned the idea, these references were infrequent and limited in scope compared to the more foundational theme of accommodating demand. When textbooks did mention demand management, they tended to emphasize that management was part of a relatively new shift in practice:

> We have observed a clear shift in transportation policies away from construction of new facilities and toward more efficient management of an existing transportation system to meet the ever-increasing transportation demand. (Handbook of Transportation Engineering p. 718)

Similarly, the Traffic Engineering Handbook explains the initial emphasis on road building, the disappointing results, and the recent embrace of management:

> However, increasing congestion, even as the highway network continued to grow in subsequent decades, led to the realization that adding capacity, while useful for a period

> of time, was not the only solution to the congestion problem. [5] As a result, the management of traffic demand also became part of the traffic engineering profession as a way to address congestion. (Traffic Engineering Handbook p. 30)

Textbooks took diverging views on the *value* of demand management. Most pointed to important benefits of managing demand, including "the optimization of the transportation network" (Transportation Engineering: A Practical Approach p. 234), "providing travel choices (Traffic Engineering Handbook p. 30), or the ability to "foster livability" (Transportation Engineering: A Practical Approach p. 234). However, one textbook was notably less buoyant. The opening chapter of Principles of Highway Engineering explains, "Trying to manage the demand for highways also has its problems." (p. 4) In particular, the text warns against "directing people toward travel modes that inherently provide lower levels of mobility." (p. 4)

DISCUSSION: FIVE CRITERIA FOR INCLUDING INDUCED TRAVEL

The results indicate that the engineering textbooks reviewed here offer incomplete coverage of induced travel. A five-part framework should guide the inclusion of induced travel in the curriculum.

Criteria #1 Clearly—and neutrally—define terms

Instructional materials should provide a clear definition of induced travel and its conceptual underpinnings. The definition should use neutral terms like induced travel or induced VMT rather than terms like demand starvation or latent demand (Gorham 2009). Ideally, materials should include both a conceptual explanation and one grounded in economic analysis (see Fig. 1 and 2), because the latter can be intimidating for some students.

Criteria #2: Provide empirics for the amount of travel likely to be induced

Teaching materials should include up-to-date and accurate information about the extent of induced travel students might expect to see. The induced travel calculator is an online tool that students can use to explore the anticipated effects of roadway widening (Volker and Handy 2022). The interface is user-friendly (see Fig 4.) and the accompanying documentation is accessible and informative (see https://ncst.ucdavis.edu/research-product/induced-travel-calculator).

Ideally, teaching materials should also describe the challenges of accurately quantifying induced travel (Gorham 2009) and this uncertainty should translate into a *range* of elasticity estimates. Materials should also identify contexts in which the amount of induced travel is likely to be very high (e.g., locations where there is persistent severe congestion). The nature of uncertainty and variability across contexts could be reinforced by pairing the induced travel calculator with real-world data from historic road widening projects. Students could use the calculator to estimate the amount of induced travel they would expect to see and compare their results to what actually happened.

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[5] This is the closest the ITE Handbook got to discussing induced travel and it is not especially clear. A simple revision could help: "Increasing congestion, even as the highway network continued to grow in subsequent decades, led to the realization that adding capacity, while useful for a period of time, was not a long-term solution."

Criteria #3 Incorporate induced travel in problem sets.
Teaching materials should be consistent with engineering's signature pedagogy. That is, they should include problem sets and equations. Relying on qualitative descriptions of induced travel or open-ended reflections could make it seems as though induced travel is an "extra" concept, different from the rest of the material covered in class. Moreover, it is essential that induced travel is not treated as a stand-alone topic. Rather, textbooks should explicitly note whenever induced travel is relevant to a problem set. For example, when instructing students to calculate the new level of service after a capacity expansion, textbooks should remind students that this improvement in service is likely to be short-lived as drivers adjust.

Criteria #4 Describe the implications for practice
Teaching materials should clearly describe the implications of induced travel for engineering practice. Specifically, textbooks should illustrate how the decision to omit or incorporate induced travel meaningfully alters the results of environmental assessments, cost-benefit analysis, and project prioritization. Textbooks should describe the limitations of existing forecasts and introduce the conceptual, methodological, and data challenges of making improvements. As practice evolves, textbooks should offer advice on how to incorporate induced travel in a systematic way.

Criteria #5: Introduce debates about policy
The fact that travel is induced when we add capacity should not be the end of the discussion, but the beginning. Textbooks should prepare students for these debates by providing contrasting positions and posing thought provoking-questions for reflection. Given that congestion-relief is often short-lived, when and where should we embrace capacity expansions? How should we trade off competing needs? Who should make these decisions? Textbooks should provide the scaffolding to engage meaningfully with these important questions.

CONCLUSIONS:

This review of transportation engineering textbooks reveals that coverage of induced travel is often incomplete. Some textbooks omitted the idea entirely and those that did include it offered only partial coverage. Textbooks either defined the term, indicated its expected magnitude, used the concept in a problem set, or described the implications for practice or policy. However, no single textbook included all these essential elements. Beyond this, all textbooks placed a greater emphasis on accommodating demand rather than managing it. Textbooks also offered an asymmetric portrayal of how drivers adjust to traffic conditions; they tended to emphasize that drivers avoid congested areas and de-emphasized that drivers are also attracted to uncongested routes.

Today's textbooks largely leave transportation engineering students ill-prepared to consider induced travel. In light of increasing interest in induced travel at the state and federal levels, incorporating the concept into curricula will be critical to engineering education. New and improved teaching materials will be needed if tomorrow's engineers are to understand induced travel, grapple with its implications, and productively contribute to policy decisions.

REFERENCES:

American Society of Civil Engineers. 2008. *Civil Engineering Body of Knowledge for the 21st Century*. American Society of Civil Engineers. https://doi.org/10.1061/9780784409657.

———. 2019. *Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer*. Third Edition. Reston, VA: American Society of Civil Engineers. https://doi.org/10.1061/9780784415221.

Anselmo, D. H. A. L., J. M. Hidalgo, and D. M. Queiroz. 2020. "Pascal's Principle Revisited: A Critical Review of Physics Undergraduate Textbooks." *European Journal of Physics* 41 (6): 063001. https://doi.org/10.1088/1361-6404/aba646.

Bruhl, Jakob C. 2023. "The FE Exam for Civil Engineers Has Drifted Away from the Fundamentals." *Journal of Civil Engineering Education* 150 (1): 02523001. https://doi.org/10.1061/JCEECD.EIENG-2033.

Chu, Yiting. 2017. "Twenty Years of Social Studies Textbook Content Analysis: Still 'Decidedly Disappointing'?" *The Social Studies* 108 (6): 229–41. https://doi.org/10.1080/00377996.2017.1360240.

Downs, Anthony. 1962. "The Law of Peak-Hour Expressway Congestion." *Traffic Quarterly* 16 (3): 393–409.

———. 1992. *Stuck in Traffic*. 1st ed. Washington, DC: Brookings Institution Press.

Fan, Lianghuo. 2013. "Textbook Research as Scientific Research: Towards a Common Ground on Issues and Methods of Research on Mathematics Textbooks." *ZDM* 45 (5): 765–77. https://doi.org/10.1007/s11858-013-0530-6.

Gorham, Roger. 2009. "Demystifying Induced Travel Demand." Sustainable Urban Transport Technical Document #1. Eschborn, Germany: Gesellschaft für Technische Zusammenarbeit. https://sutp.org/publications/demystifying-induced-travel-demand/.

Handy, Susan L., and Marlon G. Boarnet. 2014. "Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions." Policy Brief. Sacramento, CA: California Air Resources Board. http://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.

Koschmann, Matthew A., and Tajshen G. Campbell. 2019. "A Critical Review of How Communication Scholarship Is Represented in Textbooks: The Case of Organizational Communication and CCO Theory." *Annals of the International Communication Association* 43 (2): 173–91. https://doi.org/10.1080/23808985.2019.1590785.

Ladd, Brian. 2012. "'You Can't Build Your Way out of Congestion.' – Or Can You?" *DisP - The Planning Review* 48 (3): 16–23. https://doi.org/10.1080/02513625.2012.759342.

Lee, Christine S., Nathan J. McNeill, Elliot P. Douglas, Mirka E. Koro-Ljungberg, and David J. Therriault. 2013. "Indispensable Resource? A Phenomenological Study of Textbook Use in Engineering Problem Solving." Journal of Engineering Education. John Wiley & Sons, Ltd. April 1, 2013. https://onlinelibrary.wiley.com/doi/abs/10.1002/jee.20011.

Lucas, Bill, and Janet Hanson. 2016. "Thinking Like an Engineer: Using Engineering Habits of Mind and Signature Pedagogies to Redesign Engineering Education" 6 (2): 4–13.

Meister, Erich C., Martin Willeke, Werner Angst, Antonio Togni, and Peter Walde. 2014. "Confusing Quantitative Descriptions of Brønsted□Lowry Acid□Base Equilibria in Chemistry Textbooks – A Critical Review and Clarifications for Chemical Educators." *Helvetica Chimica Acta* 97 (1): 1–31. https://doi.org/10.1002/hlca.201300321.

Meyer, Jan H. F., and Ray Land. 2005. “Threshold Concepts and Troublesome Knowledge (2): Epistemological Considerations and a Conceptual Framework for Teaching and Learning.” *Higher Education* 49 (3): 373–88.

Meyer, Michael D. 1990. Review of *Review of Principles of Highway Engineering and Traffic Analysis*, by Fred L. Mannering and Walter P. Kilareski. *Transportation Science* 24 (4): 308–10.

Nichols, Jason. 2003. “Methods in School Textbook Research.” *History Education Research Journal* 3 (2): 11–26. https://doi.org/10.18546/HERJ.03.2.02.

Noland, Robert B., and Lewison L. Lem. 2002. “A Review of the Evidence for Induced Travel and Changes in Transportation and Environmental Policy in the US and the UK.” *Transportation Research Part D: Transport and Environment* 7 (1): 1–26. https://doi.org/10.1016/S1361-9209(01)00009-8.

Palmer, Mark, Geoff Simmons, and Matthew Hall. 2013. “Textbook (Non-) Adoption Motives, Legitimizing Strategies and Academic Field Configuration.” *Studies in Higher Education* 38 (4): 485–505. https://doi.org/10.1080/03075079.2011.583983.

Ralph, Kelcie M., Nicholas J. Klein, Calvin Thigpen, and Anne Brown. 2022. “Are Transportation Planning Views Shared by Engineering Students and the Public?” *Journal of Planning Education and Research*. https://doi.org/0 10.1177/0739456X221097840.

Ralph, Kelcie and Ellen White. 2024, forthcoming. “Do Engineering Instructors Teach Induced Travel? If Not, Why Not?” *Transportation Research Record*.

Shulman, Lee S. 2005. “Signature Pedagogies in the Professions.” *Daedalus* 134 (3): 52–59. https://doi.org/10.1162/0011526054622015.

Strauss, Anselm, and Juliet Corbin. 1994. “Grounded Theory Methodology: An Overview.” In *Handbook of Qualitative Research*, 273–85. Thousand Oaks, CA, US: Sage Publications, Inc.

Volker, Jamey M. B., and Susan L. Handy. 2022. “Updating the Induced Travel Calculator.” NCST-UCD-RR-22-34. Davis, California: National Center for Sustainable Transportation. https://escholarship.org/uc/item/1hh9b9mf.

Volker, Jamey M. B., Amy E. Lee, and Susan Handy. 2020. “Induced Vehicle Travel in the Environmental Review Process.” *Transportation Research Record* 2674 (7): 468–79. https://doi.org/10.1177/0361198120923365.

DATA AVAILABILITY STATEMENT:

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request. (Extracted text from keyword search)

588 **TABLES:**

589 **Table 1.** Publication details of the engineering textbooks reviewed here

Title	Authors	Year	Source
Handbook of Transportation Engineering	Edited volume with multiple authors. Edited by Myer Kutz	2003 (1st edition)	Interview
Principles of Highway Engineering & Traffic Analysis	Fred L. Mannering and Scott S. Washburn	2012 (5th edition)	Open Syllabus
Traffic and Highway Engineering	Nicholas Garber and Lester A. Hoel	2009 (4th edition)	Open Syllabus
Traffic Engineering	Roger P. Roess, Elena S. Prassas, and William R. McShane	2010 (4th edition)	Open Syllabus
Traffic Engineering Handbook	Edited volume published by the Institute of Transportation Engineers. Edited by Anurag Pande and Brian Wolshon	2016 (7th edition)	Open Syllabus
Transportation Engineering: A Practical Approach to Highway Design, Traffic Analysis, and Systems Operation	Beverly Kuhn	2019	Interview
Transport Planning and Traffic Engineering	Edited volume with multiple authors. Edited by C.A. O'Flaherty	1997 (1st edition)	Open Syllabus

590 **Note:** While some textbooks had more recent editions, some were not available in digital form.

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592 **Table 2.** Key Term and Related Term Search Results

Priority Terms (Occurrences across all textbooks)	**Related Terms (Occurrences across all textbooks)**
Induced (81)	Level of service (962)
Latent (33)	Congestion (920)
Suppressed (5)	LOS [level of service] (796)
Triple convergence (1)	Free flow (514)
Jevon's paradox (0)	Accommodate (453)
Iron law of congestion (0)	FFS [free slow speed] (451)
Braess's paradox (0)	Alleviate (27)
	Relieve (26)

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595 **Table 3.** The need to accommodate demand in transportation engineering textbooks

Textbook	Excerpts and page numbers
Handbook of Transportation Engineering	-A well-designed transportation facility … accommodates traffic demand during its lifetime. (p. 58) -[Engineers] attempt to find future transportation improvements that will meet the need of the future travel demand. (p. 216)
Principles of Highway Engineering & Traffic Analysis	-Engineers must seek to provide a sufficient highway level of service…for future traffic volumes. (p. 285)
Traffic and Highway Engineering	-The results [of forecasts] can be used in the planning and design phase to determine lane requirements necessary to achieve a given LOS. (p. 424) -The nation's highway system will be required to accommodate increasing numbers of motor vehicles. (p. 1133)
Traffic Engineering	-Forecasts based on observed trends can be used to help plan improved or new facilities to accommodate increasing demand. (p. 107)
Traffic Engineering Handbook	-A multimodal approach "maintains the need to accommodate vehicular traffic service levels" (p. 320) -The use of volume-to-capacity ratios …is a common and simple means of identifying when the need for new capacity is triggered. (p. 326)
Transportation Engineering: A Practical Approach	-Agencies [conduct analysis] to ensure that the transportation system can accommodate population and economic growth" and "to mitigate or prevent congestion. (p. 211)
Transport Planning and Traffic Engineering	-Traffic engineers need to ensure that roads are able to accommodate as much traffic as possible. (p. 272)

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FIGURE CAPTION LIST:

Fig. 1. Conceptual Explanation of Induced Travel

Fig. 2. Economic Explanation of Induced Travel

Fig. 3. Induced Travel Calculator from the National Center for Sustainable Transportation (Sample Inputs and Results

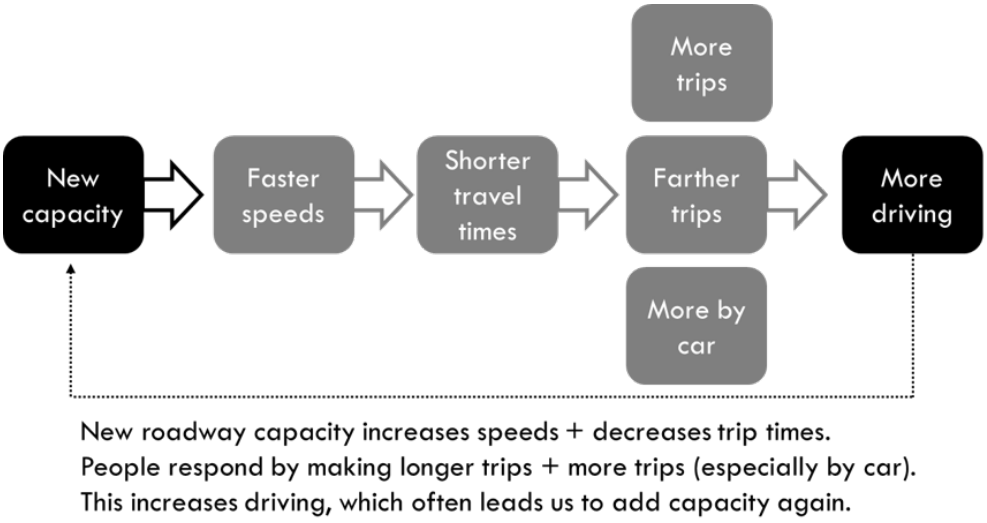

Fig 1 Conceptual Explanation of Induced Travel

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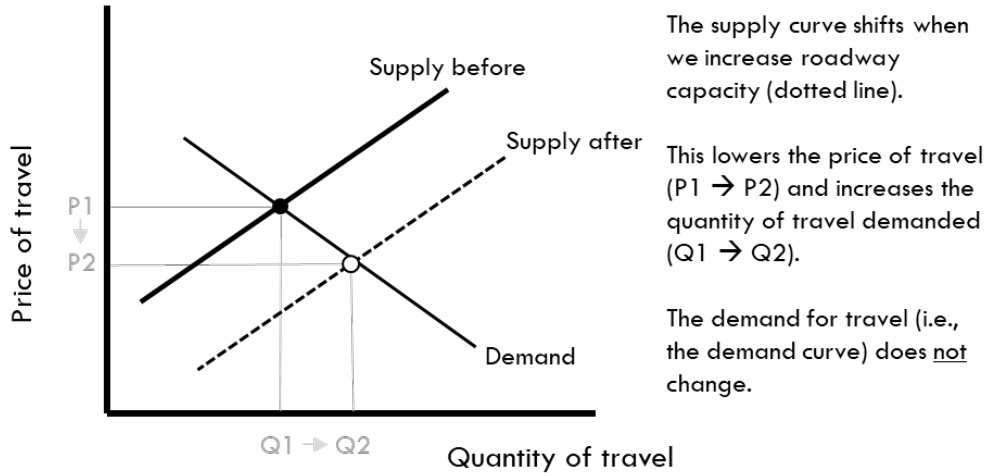

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616 **Fig 2** Economic Explanation of Induced Travel

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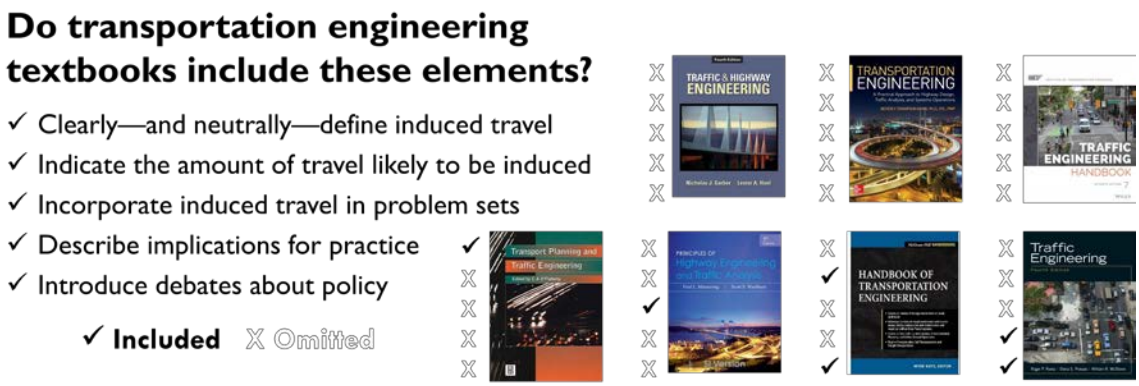

Fig 3 No textbook included all five elements of quality coverage of induced travel.

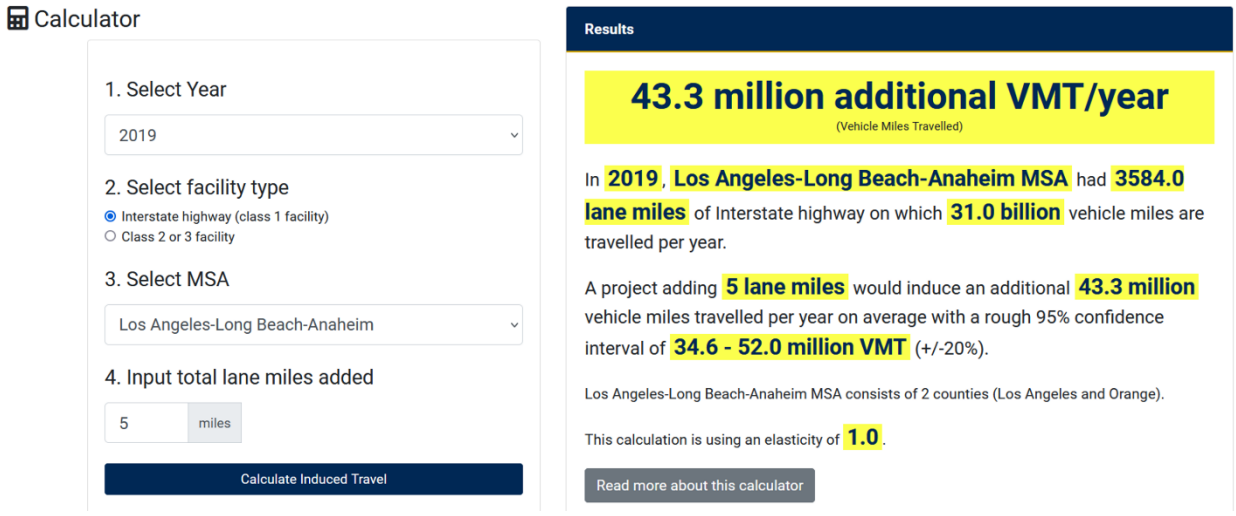

Fig 3 Induced Travel Calculator from the National Center for Sustainable Transportation (Sample Inputs and Results