Collaborative Sciences Center for ROAD SAFETY

FINAL REPORT

Using Safe Systems approach to assess traffic impact and land development

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16. Abstract			

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Traffic impact analysis (TIA) is an important piece of transportation planning, design, and construction. The practice is conventionally deployed as a means to minimize and mitigate the traffic congestion impacts of new development by tying roadway capacity improvements to land development permits. Many city and state governments view the TIA process as a critical means of generating needed infrastructure improvements, and its use has become ubiquitous among DOTs across the US. However, there is a paucity of research into the relationship between land development and road safety outcomes. Prior work in the US southeast also suggest that current TIA practices in that region do not consider TIA's direct impacts on road safety or its potential role in shaping safe systems.

This project addresses these gaps by:

1. evaluating whether, how, and the extent to which current TIA practices in the US southeast incorporate road user safety into assessments of impacts of land development or into strategies to mitigate those impacts, and
2. identifying opportunities to integrate safe systems concepts and metrics into the development review process, and
3. advancing a new, safe systems-approach to estimating and minimizing the safety impacts of new land development

Through a multi-stage qualitative analysis of interviews and focus groups with public and private sector TIA practitioners, we uncover and unpack self-defeating narratives about the complex relationship between safety and congestion. We also identify potential entry points within TIA practice for integrating safety-centered outcome metrics, and develop practical guidance for bringing TIA practice in closer alignment with safe systems concepts.

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Introduction

Traffic impact analysis (TIA) is an important piece of how transportation systems are planned, designed, and built. In the United States (US), cities and states use TIA to predict how local land use changes will affect transportation system operations, and determine what, if any, roadway capacity improvements (e.g., the construction of additional lanes in the right of way) are required to maintain desired levels of service across the transportation system (Giuliano and Hanson, 2017). Local and state governments can then require land developers to provide identified improvements as a condition of development permit. Thus, the TIA process is frequently viewed as a critical means of generating needed infrastructure improvements, and its use has become ubiquitous among state and local governments across the US (Schneider, Shafizadeh and Handy, 2015). Because of its ubiquity, TIA exerts a powerful influence on urban land use and transportation systems alike.

As conventionally practiced, TIA focuses on estimating the number of trips a new development will generate, and then assessing the impact of this travel on the surrounding transportation network (Currans, 2017). This is typically assessed using level of service (LOS) as a performance measure, which is a measure of the amount of delay experienced by motorists (e.g., Othayoth and Rao, 2020; Martín, Romana, and Santos, 2016). Where a new development is projected to produce unacceptable levels of vehicle delay (e.g., congestion), the developer can be required to modify the site plan, to upgrade or expand existing roadway capacity to mitigate anticipated congestion, or to pay impact fees to the local government, which is presumed to use these revenues to modify the local infrastructure to accommodate the new traffic (Cervero, 2003; DeRobertis, Eells, Kott, and Lee, 2014).[1]

Focusing on proactively accommodating development-induced motor vehicle traffic may negatively impact the safety of road users. For example, adding travel lanes lengthens crossing distances for pedestrians, thereby increasing their exposure to crash risk (Stipancic et al., 2020). Development-induced trips can lead to additional conflicts between road users, thus increasing the number of crashes (Ewing and Dumbaugh, 2009). The result is that efforts to reduce the congestion impacts of a new development can produce negative safety outcomes, particularly for pedestrians and other vulnerable road users (VRUs).

However, little attention has been given in peer-reviewed literature as well as in practice to the potential of TIA to enhance or detract from traffic safety. The omission of safety as an integral component of the TIA process is surprising, given TIA's power to influence not only the design of the transportation network surrounding a proposed development, but also site access, site configuration, and the production and severity of conflicts between road users (Noland, 2021). With rising numbers of fatal and serious injury crashes occurring on US roadways (Stewart, 2022) and rapid growth in towns signing on to Vision Zero and mounting local road safety campaigns, there may be an opportunity to reconsider TIA's influence on road safety.

Recent research focusing on evolution of TIA practice in the US southeast suggests that practitioners in that region tend to operate under the presumption that transportation networks brought "up to standard" (i.e., conforming with current planning and street design guidance) will necessarily result in safety improvements (Combs, McDonald, and Leimenstoll, 2020).[2] The result is that congestion-mitigation efforts, such as lengthening signal cycle lengths and increasing crossing distances through the addition

[1] While this is the rationale for impact fees, in practice these funds are often treated as general revenue and used for purposes entirely unrelated to the development itself (Estill, Powell, and Stringham, 2017).

[2] More specifically, it is presumed that recommendations codified in design manuals are based on a substantive understanding of their safety effects, which is demonstrably untrue (Dumbaugh and Gattis, 2005; Hauer, 2000)

of turn lanes or through lanes are regarded as being safety “improvements,” but in reality may increase vehicle speeds and increase the number of potential conflicts for all road users.

Research objectives

Ongoing conversations with planners and engineers demonstrate a clear gap in the guidance on relationships between land development and safety. This research is a foundational step in a much-needed bridge between research and practice. Our objective is to develop and advance a new, safe systems-informed approach to TIA, which we dub “SafeTIA.” By demonstrating how the development review process can be used to promote safety rather than simply reproducing the negative outcomes of an auto-oriented planning approach, this project highlights the role of land use and development review in safety and provides safety performance metrics that can provide meaningful, realistic, actionable outputs of TIAs.

This research lays the groundwork for a future demonstration effort that will aim to assess how the SafeTIA approach could be used to proactively prevent real-world road user safety problems, both in the southeast US and beyond. This will be achieved by identifying real-world projects with a known crash history, and then applying the SafeTIA framework to identify the types of modifications to the design and configuration of the project would have been recommended through its use. These will in turn be compared to documented inter-road user conflicts for the site to understand the extent to which SafeTIA would have prevented the creation of the underlying conditions associated with these crashes. Of particular focus will be the siting and configuration of commercial uses on arterial thoroughfares, which are known to be especially problematic in urban areas.

Ultimately, we hope to partner with a municipality to test SafeTIA’s performance with respect to a new development proposal. This *in situ* demonstration project would entail a full analysis of the SafeTIA framework, and hopefully demonstrate that safety can be achieved in addition to mobility benefits through the nexus between development review practices and safe systems, evaluate the shortcomings of existing procedures to demonstrate the gaps safe systems approach can fill, and partner developers and communities to find implementable solutions.

Summary of products

This project produced two main deliverables: (1) a qualitative analysis of interview and focus group data on perspectives on safety among TIA practitioners and (2) a Safe Systems Traffic Impact Analysis Framework (“SafeTIA”) informed by the opportunity levers identified in the analysis. The interview/focus group analysis is described in an academic journal article titled “Recurrent Patterns in the Application of Traffic Impact Analyses: Safety First or Last?” This article was submitted for peer review on July 20, 2022 and is currently undergoing revisions. The submitted pre-review version of the article is included in this report. The final version will be appended upon publication. The SafeTIA framework is included in this report. It should be considered a prototype; future research will seek to evaluate the framework’s effectiveness and feasibility.

The data collection instruments are included as appendices to this report. Redacted interview transcripts will be uploaded in the UNC Dataverse under a maximum 12-month embargo to allow for publication.

Part 1. Analysis

Study Aims

The objectives of this analysis are to 1) explore ways in which prevailing TIA practices neglect road user safety and 2) to discern potential mechanisms for centering VRU safety as an explicit outcome of the TIA process. Based on prior research into drivers of innovation in TIA practices (Combs, McDonald and Leimenstoll, 2020; Combs and McDonald, 2021), we hypothesized that road user safety represents a tangential or negligible concern in contemporary TIA practices in the US, superseded and subsumed by concerns over congestion mitigation. We employ an analysis of interviews and focus groups with planners, engineers, and developers involved in local TIA practices in four states in the US southeast to interrogate the persistence of the congestion mitigation-safety causality paradox.[3]

We specifically address three research questions:

1) How does road user safety feature in contemporary TIA practices in the US southeast?;
2) What are the barriers to introducing road user safety as a central goal in the development review process?; and
3) What might serve as leverage points—places in complex systems where even small shifts can lead to fundamental changes in the entire system (Abson et al., 2017)—in conventional TIA practices that could conceivably lead to downstream improvements in road user safety?

This research highlights specific assumptions and narratives used in southeastern transportation planning and engineering practices that primarily relegate the role of improving safety through development to mitigating congestion as part of the TIA process. The report begins with a brief introduction to the systems archetype-informed theoretical basis of this study. It then describes the grounded theory and causal loop diagramming methods applied to identify two interrelated systems archetypes that depict causal relations between conventional TIA practice and road user safety considerations. Results center around the developed causal loop diagram, illustrating how it aligns with common systems archetypes and depicting circumstances when TIA practices do not adhere to the archetypes. A practical discussion and conclusion follow the results, outlining study limitations and implications for enhancing TIA procedures. The results of this study can be used as a theoretical basis for developing novel TIA practices that meaningfully incorporate safety evaluations and use those evaluations to influence development practices.

Theoretical Basis

Systems Archetypes

This examination of conventional TIA practices is framed around "systems archetypes" or generic representations of systems that classify and illustrate the structures of system functioning over time (Senge, 1990). Systems archetypes lend insight into common, recurring patterns of behavior that drive organizational systems, and help discern points of leverage toward disrupting and changing those behaviors and thus, changing the system (McLean et al, 2019). It may be helpful to think of systems archetypes as prevailing narratives or storylines of systems in the world. For example, induced travel demand is consistent with a "fixes that fail" systems archetype were road expansions temporarily "fix" the

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[3] Given the exploratory and unprecedented nature of this analysis, we focus on the southeast explicitly, recognizing the confounding influence that regional variations in planning and land development cultural and political contexts may have on our analysis. Future research is necessary to extend the generalizability of our results to other contexts.

symptom of traffic congestion, but eventually “fail” when the additional capacity attracts more traffic, thereby creating a need to provide ever more roadway capacity.

Systems archetypes have been used to describe common, recurring patterns of system behavior in such domains as business, construction safety, economics, and ecology (Sterman, 2001; Nguyen and Bosch, 2013; Guo, Yiu, and González, 2015; Hallett and Hobbs, 2020). In the present study, we focus on the “Seeking the Wrong Goal” and “Fixes that Fail” systems archetypes. The team selected these systems archetypes given their intuitive, concise depiction of system relationships and feedbacks, as well as their ability to present a narrative-forward, stylized interpretation of how road user safety interplays with conventional TIA practices.

Seeking the Wrong Goal

Among the most powerful ways to shape the behavioral patterns of systems is to define the goals of the system. This is because systems tend to produce what is asked of them to produce (Meadows, 2008). As Meadows (2008) illustrates, if national security is to be defined by the amount of military spending, the system will produce military spending, not necessarily national security. This is an instance of “confusing effort with result”, among the common ways systems can be designed around the wrong goal (Meadows, 2008; Johnston, Matteson, and Finegood, 2014). Applied to the present study, the ostensible goal of TIAs is to provision sufficient roadway capacity to accommodate motor vehicle traffic to effectively ameliorate driver delay (Kasmalkar and Suckale, 2021). As we will argue in this paper, such focus on mitigating developing-induced traffic congestion in the face of rising roadway deaths and fatalities amounts to “seeking the wrong goal,” whereas we affirm that road user safety constitutes an appropriate goal for TIA.

Fixes that Fail

Commonly aligned with "Seeking the Wrong Goal” archetype is the “Fixes that Fail” systems archetype. In fixes that fail situations, identified problems inspire resolution-seeking behaviors. In these situations, solutions that alleviate more salient symptoms are quickly implemented, yet the unintended consequences of the “fix” typically exacerbate the problems. “Over time, the problem symptom returns to its previous level or becomes worse.” (Kim and Lannon, 1997, p. 12). In the present study, we explore how conventional TIA practices often lead to the application of “fixes that fail” to both attenuate traffic congestion and commonly introduce traffic injury risk in the wake of land developments.

Methods

Data collection

To address our three research questions, the research team conducted semi-structured interviews with 41 municipal planning and engineering professionals involved in TIA processes in the southeast US states of Maryland (MD), Virginia (VA), and North Carolina (NC). These professionals were recruited from the same sample of 63 municipal and county governments and followed the same recruitment procedures as Combs, McDonald, and Leimenstoll (2020), and represent localities ranging in population from 12,920 (Davidson, NC) to 1.048 million (Montgomery County, MD).[4] Interviews were conducted in 2019 and analyzed in 2021. Interview questions were designed to uncover procedures for measuring road safety indicators (e.g., crashes, vehicle speeds), the guidance professionals sought on incorporating

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[4] Based on US Census 2020 estimates

traffic safety into TIA practices, as well as whether and to what extent TIA practices have been shaped by public concerns around road user safety.[5]

We supplemented the interviews with focus groups in 2021 of 12 private developers with direct experience working with TIA processes, representing firms ranging across the southeast US from Tennessee (TN) to NC and south to Florida (FL). The participating firm representatives had experience with all types of development except for industrial uses. Development locations included urban cores, suburban, and exurban development. The focus group members and focus groups were organized with the assistance of the Southeast Florida/Caribbean Chapter of the Urban Land Institute (ULI). Senior development industry ULI members received an email describing the nature of the research related to TIA and soliciting participation. This approach ensured that the focus group members had hands-on experience with TIA processes and were senior enough in their roles to have a thorough understanding of TIA and development review process complexities. All focus group members were provided with the verbal informed consent wording by ULI and focus group moderators before agreeing to participate in the focus groups.

The developers in the focus groups ranged from CEOs to vice presidents, including at least two members with multi-state development portfolios valued in the billions of US dollars. All companies represented in the focus groups are headquartered in Florida with a majority of developments in the southeastern United States. Their extensive experience provides insight into TIA in theory and practice. The role of safety as a component of TIA elicited responses largely not reflected in the peer-reviewed real estate or planning literature regarding the private-sector perspective.

Both the interviews and the focus groups focused on eliciting perspectives on the role and limitations of TIA practices in shaping roadway safety. Additionally, while TIA is largely based on quantitative inputs, the interviews and focus groups revealed qualitative information regarding the TIA process and planning, engineering, and developer dynamics. While TIA is a relatively static tool, the interviews and focus groups provide dynamic insight into the TIA process.

Analytical Approach

Analysis proceeded in three inter-related stages. In the first stage, the research team employed a grounded theory analysis of transportation professionals' responses to interview questions designed to explore the nature and degree of consideration for road user safety in TIA processes. Grounded theory applies procedures to interpret, organize, elaborate, and relate data to themselves through the acts of coding and categorizing meaningful groups of text and developing emergent theory (Corbin and Strauss, 2014). The team reviewed transcripts of interviews with TIA-experienced transportation professionals, highlighting key terms and phrases that reflected relationships between road user safety and TIA conceptualizations and practices. Then, in NVivo qualitative analysis software (version 10; QSR International, 2014), the team grouped like terms and phrases into thematic codes (e.g., "conflating driver level of service with safety").

In the second phase of the analysis, the team adapted methods advanced by Yearworth and White (2013), to place thematic codes into NVivo's matrix framework to illustrate relationships among codes developed in the grounded theory analysis. This matrix rendered interactions among codes visually and facilitated the transition to the third and final analysis stage: development of a causal loop diagram, a type of systems map that shows how interrelated components of the system interact through nonlinear

[5] The list of localities in which interviews were conducted, and the interview and focus group protocols are included as supplementary materials.

relationships and feedbacks to produce different outcomes. In building the causal loop diagram, the team drew upon findings from NVivo's matrix analysis and the academic literature on relations among development-induced travel demand, motor vehicle traffic volumes, traffic injury, and congestion-attributed motorist delay (e.g., Zolnik, 2018; Hymel, 2019; Saha, Dumbaugh and Merlin, 2020; Kasmalkar and Suckale, 2021) to depict variables, the direction and type of relations between them, and the nature of loops, which depict the type of behavior the system produces (Figure 1). By representing the evident neglect of road user safety in conventional TIA practice from a causal perspective, the team became more aware of the recurrent structural forces that perpetuate common TIA-influenced outcomes, seeing how these dynamics closely aligned with common systems archetypes, namely the "Seeking the Wrong Goal" and "Fixes that Fail" archetypes.

Results

Archetypal Consideration of Safety within Conventional TIA

Based on our three-staged analysis, empirical research on induced travel demand, motor vehicle congestion-road user safety relationships, and systems theory, the team designed a causal loop diagram to depict relationships among traffic safety and prevailing TIA practices (Figure 1). The following narrative describes each of the diagram's variables, the relational directions between variables, the emergent reinforcing (R) and balancing (B) feedback loops inherent in safety-TIA dynamics, as well as how variable relationships and feedback loops align with systems archetypes. Throughout the narrative, illustrative quotes from interview and focus group respondents provide textual context around each variable and dynamic in Figure 1.

Figure 1 illustrates the position of traffic injury within conventional TIA practice. At the center of this diagram lies traffic engineers' professional judgment regarding the road safety implications of proposed development (*Professional Judgment re: Safety*). As one transportation engineer explained, *"Us being local, we're gonna know where there may be some hotspots or something like that, for traffic or, you know, some that analysis don't pick up on so we got to take our judgment and use that also."* Another engineer shared, *"We do use anecdotal information when it's brought to our attention by the state traffic engineers, but as a rule, we do not quantify traffic safety, traffic stats or crashes… we do it anecdotally and not quantitatively."* And another transportation engineer offered, *"We glean more from our past experience in safety studies, and just our local knowledge of the area, we don't refer to any technical manuals for guidance on that."*

TIA—focused on securing sufficient roadway and parking capacity to ensure tenable "level of service" for motorists in the wake of land developments—catalyzes traffic engineers' professional judgement about what, if any, safety mitigations might be introduced to approve development site designs. During this time, external actors sometimes express concerns about safety and place pressure on traffic engineers to address these concerns (*Pressure to Address Concerns*). Regarding this pressure, a transportation engineer said, *"…if a safety matter is identified by the government team that reviews the TIAs then we do require the developer to assess it."* And another engineer shared, *"[safety] does not really come up in conversation unless someone specifically knows it's an issue."*

Seeking the Wrong Goal in Conventional TIA

When TIA-facilitating traffic engineers desire to mitigate safety concerns, they typically seek to improve safety via proactively addressing motor vehicle traffic congestion (*Safety via MV Congestion Mitigation*). This goal emerges from professionals' reliance on their prior experiences and engineering judgment and is an illustration of a "**Seeking the Wrong Goal**" systems archetype. That is, TIA practices often succumb to "confusing effort with result" (in Donella Meadows' words, Meadows, 2008) by framing safety as an outcome associated with mitigating traffic congestion. One transportation engineer expressed this concept as follows:

> *"it's really capacity analysis, but some of what we have actually addressed are concerns about queuing. So, it's like, from a safety perspective, we do look at vehicular queues. And even if there is a bad condition, is the site making it worse? And can they accommodate that, we then consider a traffic backup or something like that being a safety issue that could potentially be mitigated by a site."*

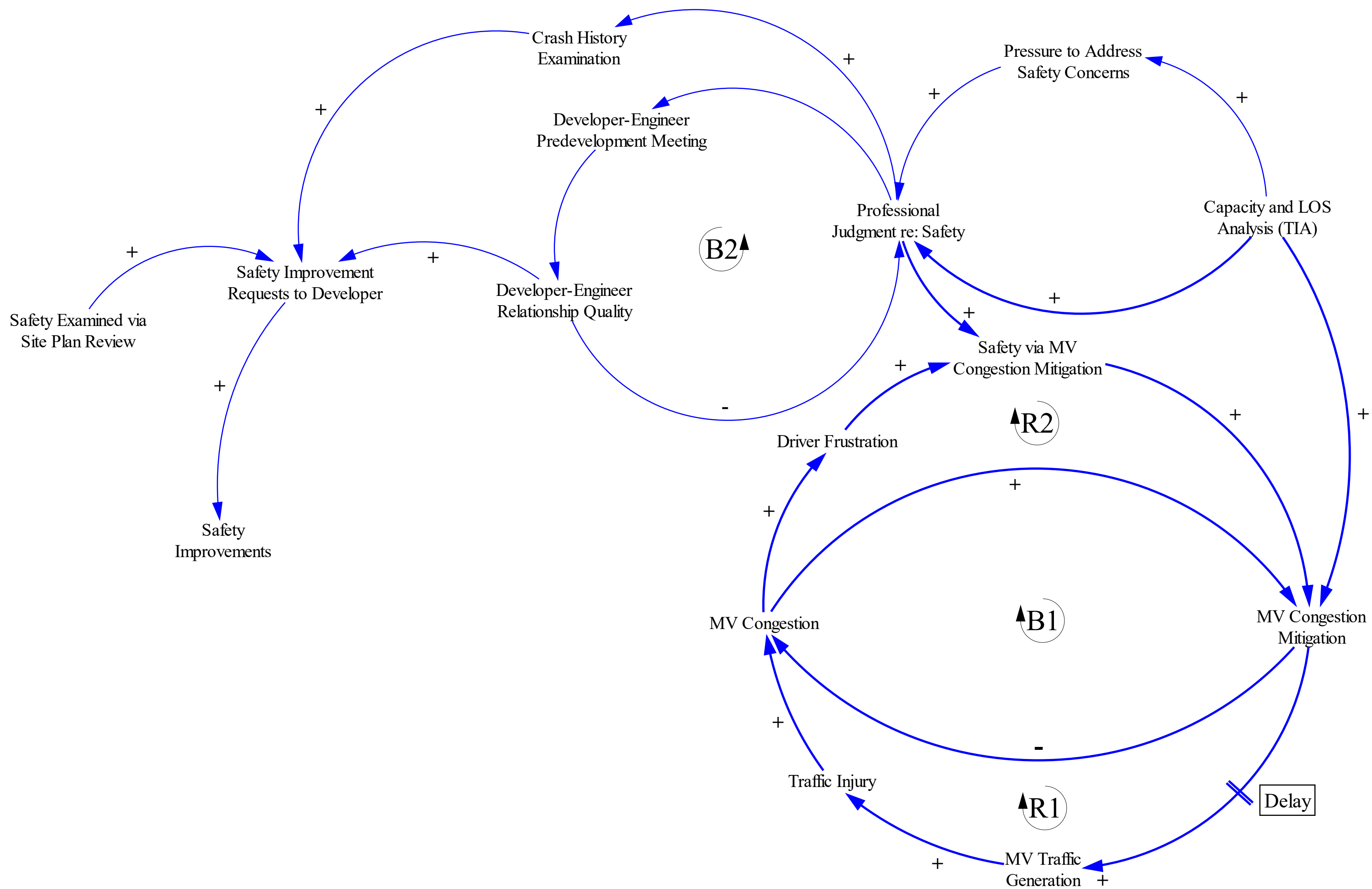

Figure 1. Causal loop diagram illustrating the role of safety in contemporary TIA practice

In some instances, engineers' professional judgment leads to examining sites' and areas' crash histories (*Crash History Examination*), which can inform requests to developers to integrate safety improvements into their site designs (*Safety Improvement Requests to Developer*). Without examination of site-related crash histories, engineers may request developers to address site-specific safety concerns. Developers also receive requests to address site-related safety concerns from separate development review processes (*Safety Examined via Site Plan Review*). A transportation planner the team interviewed said:

> *"The multimodal transportation assessment process serves a public communications purpose. In having it be prepared by the developer and be presented and distributed by our site plan review committee, those are public meetings, the materials for those meetings are published online, the neighborhood is notified of the process and involved through various types of outreach. Those are opportunities for neighborhood members to help the developer and staff identify additional problems that might not have been highlighted in the TIA."*
>
> A different transportation planner said:
>
> *"The specific studies that our CTR [comprehensive transportation review] recommends is crash analysis. It looks at pedestrian and bicycle safety studies, impact on seniors and pedestrians with disability. Those are what we specifically asked to be looked at as part of CTR. And we look at for impact on users of transit stations, schools, and daycares. We also need to look at traffic calming."*
>
> A developer reflected upon his role in addressing safety by sharing:
>
> *"…from my perspective, the challenges and this figuring out how do we address the safety situation, it's all the different entities that are involved, because you have the State Department of Transportation and the county, then you have the city and everyone has their own idea of what they would like. And, you know, the only way I was able to kind of get over that was getting all of them in the room and kind of have them point fingers at each other, but that doesn't happen all the time.*

Both engineers' and additional staff requests to shore up site-related safety can result in the implementation of safety improvements (*Safety Improvements*). Although these requests may be proactive, there are occasions where issues are addressed for an existing site based on a need for future site plan approval due to unforeseen issues overlooked in the original site plan. Developers stated that this situation could occur but was atypical, as one developer put it:

> *"Well, …I'm dealing with that situation right now on a retail project…we have, you know, a [large supermarket anchor] and all that, where it would be nice if the county would nicely come back to us and say 'hey, can you do something about this?' What they basically said to us was 'well, you know what, we didn't catch this at our site review approval…but when you get ready to come in for this pad and you want this permit, we're going to put this particular item on it, where you give up certain easements or create a difference." You can't build it, so you've already had a plan that is based on this model, and it's geared toward that and doing what they're asking me is to reduce your square foot size or create parking issues, so yeah, I'd be happy to help you except I would need some relief in parking. Well, you go to the parking guy and the parking guy says 'I'm not doing that.'"*

Conventional TIA as an Archetypal Fix that Fails

Though road user safety is sometimes considered in common TIA practices, the predominant orientation to safety is to seek the goal of proactively managing traffic congestion by drawing upon the TIA level of service results and aligning designs with greater capacity for motor vehicle throughput and circulation (*Safety via MV Congestion Mitigation*). In the short term, this alleviates site-induced traffic congestion (*MV Congestion*) (**B1**). However, as is well-documented in observational studies (e.g., Zolnik, 2018; Hymel, 2019), over the intermediate term, the expansion of road capacity generates traffic (*MV Traffic Generation*) and presents or exacerbates traffic injury risks (*Traffic Injury*), especially for people traveling outside of motor vehicles (Saha, Dumbaugh and Merlin, 2020). In turn, induced traffic and injury-provoked travel delays exacerbate traffic congestion (**R1**) (Kasmalkar and Suckale, 2021).

Additionally, given development-induced traffic congestion coupled with reports of conflicts, crashes, injuries, and driver frustration (*Driver Frustration*), professionals, guided by TIA procedures (*Professional Judgement re: Safety*), aim to simultaneously address safety and congestion through reinvigorating efforts to ease congestion (*MV Congestion Mitigation*) (**R2**). Together, Reinforcing loops 1 and 2 (**R1** and **R2**), along with Balancing loop 1 (**B1**), reflect a **"Fixes that Fail"** systems archetype. Transportation engineers commonly perceived the amelioration of drivers' frustration with being stuck in traffic (e.g., maintaining an acceptable level of service to drivers) as a means of improving traffic safety. The following are two examples of this kind of logic, as expressed by traffic engineers:

> *"But I think it's kind of an inherent understanding that when you take care of extreme congestion and delays, that by itself helps proactively avoid certain safety issues. Because with extreme congestion and delays, there could be human factor, driver frustration, that could increase the risk of several safety factors."*

> *"Level of service is dictating congestion in the area and all that. So obviously, there's more congestion is going to impact safety, it can be more apt to be unsafe. So, you want to keep that level of service as best as you can with that impact coming in."*

In some cases, development-induced traffic congestion and crashes may lead to developer intervention to seek solutions that might not be outlined or required based on TIA procedures. A multifamily developer discussed an urban area undergoing multiple high-density residential developments where the street network consisted largely of two-way stop signs:

> *"…we had an intersection right next to the property that was a two-way stop and now it is a four-way [stop] and, our leasing staff out there, they watched and almost, you know, weekly, almost and sometimes accidents occur because of that. So, we went back to the city and said 'look, you really need to put in a four-way stop here.' But again, as a residential developer I can't foresee [agreeing to make changes to a plan after site plan approval] where, unless it was really impacting our project and the marketing and the safety of our project really benefited us directly…"*

From a developer standpoint, safety is part of the consumer experience, and if a site lacks reliable access, it can result in bad experiences that may drive tenants and customers away. Thus, in other cases, developers can counteract or "balance" engineers' overreliance on their professional judgment in carrying out and interpreting their TIA. This is reflected in the **B2** balancing loop (Figure 1). And the influence of the developer on the engineers' judgment appears to be mediated by a *Developer-Engineers Predevelopment Meeting*, in which the engineer who over relies on his/her professional judgment is less likely to meaningfully engage. Once a predevelopment meeting is held, developer-engineer rapport can improve (and thus the quality of their relationship), which tends to lead to a greater number of safety requests sent to the developer.

The developer perspective on the process reinforces "**Seeking the Wrong Goal**" and "**Fixes that Fail**" archetypes in the TIA process and broadens several aspects of the conceptual model. In discussion around the TIA process, developer insight at the beginning of the development process, even before more formal steps such as site plan review, focus on the planning/engineering staff member's background (*Professional Judgment).* Two different avenues underlie professional judgment: the developer/professional relationship and the professional's experience. Developers who have worked with the same cities, typically larger cities as well as growing suburbs, tend to build relationships with transportation professionals within the city. This relationship and previous experience, assuming it was a positive experience, means that the developer and professional possess a basic level of understanding of the city's policies as well as any additional expectations that might go above and beyond the bare minimum requirements for traffic impact assessment. Based on experience and an existing relationship, the approach to safety improvement requests to the developer was often mutually beneficial to both parties.

Issues related to professional judgment often occurred when the professional might have less experience related to TIA and safety concerns, resulting in the use of boilerplate approaches to development that might not make sense. As an example, using a manual related to urban TIA and safety concerns in a suburban or exurban area might result in a mismatch between development scope and scale ("**Seeking the Wrong Goal**"). Developers stated this issue as occurring due to either negotiating with an early-career planner or engineer, or due to someone starting in a new position in a city and applying past experiences to current development that might not align.

One complex issue from the development side relates to whose professional judgment reigns supreme. In many developments, the governmental entity may include city, county, regional, state, and/or federal oversight. Oftentimes, for larger-scale projects, this professional judgment leads to conflicting goals between the governmental entities, causing development and site plan confusion. In one anecdote, a developer discussed issues regarding conflicting transportation guidelines between two departments within the same city. The best way to resolve this type of situation is to get all the parties in the same room early in the project to minimize the likelihood that the "wrong goals" are sought, ideally at a pre-development meeting long before the formal submission of site plans.

Developers also discussed a need to better delineate retail uses rather than standard, generic terms where a retail use, such as a fast-food restaurant, requires a certain number of square feet and parking spaces along with addressing ingress and egress issues. From a safety perspective, fast food restaurants can have vastly different levels of intensity and following basic guidelines for development may create unintended safety issues. The example provided was of a fast-food restaurant built on an outparcel, causing traffic to block ingress into the surrounding retail center and often backing up traffic into a major thoroughfare. This development, though, followed all guidelines for the development of a fast-food restaurant, but the guidelines failed to account for intensity. Put simply, static codes often fail to account for different land use dynamics. The static nature of codes often results in fixes that fail and/or seeking the wrong goal. These results can largely be minimized through experienced traffic engineers with professional judgment and experience; and receptive developers that are willing to exceed bare minimums outlined in the code to head off current and possible future safety issues.

Findings not Adherent to the Logic of Systems Archetypes

While some representatives were steadfast in their traditional application of the TIA tool, others expressed a desire to better incorporate safety or mentioned how their process was evolving. In some instances, transportation engineers' and planners' desire to improve road user safety was closely linked with questions about how to define and measure safety. The developer perspective focused more on safety in relation to a project's overall marketability.

E.g., from planning and engineering staff:

> *"It seems to me that we are still operating, like we did last century about not having yet updated our ordinance and guidelines to be more quantifiable about the safety issue. And, but we're eager to do that, and we're just a little bit late getting on board. At the state level, and then some of our peer counties, they certainly have gone towards the zero-crash goal, vision zero."*

“I would say we do a pretty good job, but I'm sure it can be improved with more specific standards or something like a checklist where you know, we have them say, is there this? Is there this? Is there this condition? Is there this condition, and something where we could compare from one to another, the kind of conditions that were on each site. And, you know, I think if it was a bit more formalized, that would probably improve the process.”

E.g., from developers:

“I would say, road safety is critical, because, especially nowadays with such a prominence of E-commerce shopping, if the experience isn't good for the consumer, then they will not come back…so road safety has become increasingly more important when we're looking at new developments, and while we're even looking at our existing developments as the program changes.”

“I think it's in the project’s best interest to have their own team, their own engineers looking at it, because I don't always trust the government when it comes to road safety…

…you know where you position your project…just a really high level of focus on accessibility, both in and out of a project. Again, you can create a real hazard if you're not focused on it, but you can also impact the marketability of your project.”

Discussion

Through interviews and focus groups with professionals involved in TIA practice, literature on induced travel demand, congestion-injury-relationships, and systems thinking, as well as in response to our first research question, the research team concludes that road user safety is not explicitly considered in traditional TIA practice in southeastern US cities. Common TIA procedures in this region often “seek the wrong goal” of maintaining the flow of motor vehicle traffic flow, which may come at the expense of road user safety. Traditional efforts to maintain traffic flow by addressing anticipated traffic congestion then become a “fix that fail,” as vehicle traffic increases—induced through expanded capacity and reduced safety or access for non-car road users—cause congestion mitigation efforts to backfire within a few years’ time. Not only do traffic volumes tend to return and even surpass pre-development levels, but development-generated traffic introduces increased risk of traffic injury and an attendant exacerbation of congestion on the surrounding road network.

Regarding our second research question, it appears that contemporary TIA practices in the southeast neglect to incorporate road user safety into its procedures, as popular traffic simulation software and transportation engineers’ prevailing beliefs about the safety benefits of addressing drivers’ delay in accessing developments eclipse due consideration of the safety implications of various land use and development access configurations.

Regarding our third research question, the team found that conceiving of TIA procedures as recurring systems archetypes is a useful method for identifying longer-term solutions to enhancing the safety of road users accessing prospective land developments and to tempering site-induced traffic congestion through providing viable travel mode and route options. As illustrated in the present study, conventional TIA tends to transform the means (e.g., providing sufficient motor vehicle traffic capacity, improving driver level of service) into the ostensible ends of proactively addressing traffic congestion. Improving road user safety via development review processes would require rearranging review procedures to align more closely with compact, street-connected designs, ones which afford safe access to developments via transit, bicycling, walking (Choi and Ewing, 2021).

Implications for Traffic Impact Assessment

Results from the present study suggest a few practical means of improving road user safety via common development processes. First, seek the “right goal” based upon the integrated outcome of safe, multimodal access to land development. Consider the shorter- and longer-term safety implications of proposed solutions to enhance safe access. That is, specify performance measures and end-state goals that reflect the welfare of the system’s users (e.g., by 2030, all users of new developments in our city enter and exit developments without serious injury). Further, be careful not to confuse effort with desired results, as doing so can lead to a system that produces effort rather than result (Meadows, 2008).

Second, alter or amend existing TIA simulation tools to incorporate prospective safety into their algorithms or substituting existing TIA tools with alternative ones that elucidate probable safety impacts of various roadway capacity and land development access and internal circulation designs. These revised or novel simulation tools could conceivably reorient development-related decision-making toward proactively addressing road user safety. Specifically, manipulating this leverage point could disrupt the reinforcing **R1** and **R2** feedbacks depicted in Figure 1, by reorienting the *Safety via MV Congestion Mitigation* variable toward discussion around preventing probable downstream safety issues.

Third and finally, developer, public, or policymaker involvement in the development review process (**B2**) can reorient development discussion away from congestion management and toward safety enhancements (Figure 1). Stakeholder involvement is bound to be less influential than replacing or reshaping the TIA simulation tools employed, as it relies upon the persistent vigilance of residents and decision-makers (see: Kegler and Swan, 2012) to keep road user safety at the center of development-related discourse.

It should be noted that another land development goal that has been sought by states and local agencies in other regions is a reduction in vehicle miles travelled (VMT). For example, in 2018, California enacted legislation that required the estimation of developments’ impacts on VMT rather than LOS for reviews required under the California Environmental Quality Act (CEQA) (Lee and Handy, 2018; Governor’s Office of Planning and Research, 2019). Though likely to result in divergent land use patterns from more conventional TIA approaches, VMT reduction approaches to land development are likely to result in multimodal access improvements, whereas the safety-forward approaches advocated here are intended to ensure no one dies or suffers serious injury in the act of accessing developments.

Study Limitations

Though useful in uncovering underlying structures that perpetuate the traffic injury risks associated with conventional traditional TIA procedures, systems archetypes represent generic behavior of system components and thus do not capture or represent all interacting elements of the system. Moreover, the archetypal orientation of this paper neglects the sundry nuances inherent in TIA practices and procedures. For example, in prior work, Combs and McDonald (2021) discovered widespread tweaking of and experimentation with conventional TIA procedures.

Additionally, the use of causal loop diagram-informed systems archetypes is but one methodology for exploring this complex subject. Alternative theories and methods, such as social practice theory (Svennevik, Dijk and Arnfalk, 2021), stock and flow diagrams, root cause analysis, and system dynamics modeling, among others (Monat and Gannon, 2015) can lend researchers and practitioners distinct insight into potential pathways for change, such as enhancing the safety analytic skills of professionals conducting TIAs or including additional community members’ perspectives in standard development review procedures.

Finally, the current study’s explicit focus on the US southeast limits the generalizability of its findings. Different regions have different cultural and political contexts, and thus embrace different attitudes toward both land development and road transportation priorities. While the regional focus was beneficial in reducing the influence of potentially confounding contextual factors in this exploratory research, future research is necessary to ascertain the extent to which our findings are applicable outside the US southeast.

Prospective Research Opportunities

We wish to acknowledge that recent guidance emerging from professional groups encourage developers and practitioners to consider safety implications in TIA in alignment with the Safe System Approach. For example, the technical brief from the Institute of Transportation Engineers Safety Council encourages the kind of proactive, interdisciplinary approach to development that prioritizes safety that has been discussed throughout this paper (ITE, 2022).

In this work, we explore ways in which conventional TIA practices are arranged around the central goal of traffic congestion management, as well as delayed feedbacks which serve to undermine the realization of this goal. Prospective research could further the present study by collecting procedural information from a broader array of agencies with a stake in TIA processes and developing quantitative estimates of relationships among system elements to place within a systems dynamic model. Additional procedural research could lead to improvements to the TIA process, ideally resulting in shorter time lags between impacts and feedback loops while elevating traffic safety before it becomes an issue.

Conclusion

Through a series of interviews and focus groups with transportation professionals and developers operating in southeastern US states, our research team discovered that conventional TIA practices typically fail to center road user safety. Plus, considering the realities of induced travel demand, these practices often fall short of satisfying their ostensible goals of managing traffic congestion and ameliorating driver delay. In these ways, conventional TIA practice in the US southeast closely aligns with common and inter-related systems archetypes, i.e., “Seeking the Wrong Goal” and “Fixes that Fail.” According to our analysis and these systems archetypes, to incorporate traffic safety in TIA processes, developers, community members, and policymakers can organize and push for safety enhancements in prospective developments. However, to effect lasting change in safety-affected development review procedures and enhance downstream road user safety, alternative methods and tools should inform or wholly revolutionize contemporary TIA practice to proactively, rather than reactively, incorporate road user safety.

Part 2. SafeTIA: a Safe Systems Traffic Impact Analysis Framework

Findings from the interview and focus group analyses identified a potential entry point for bringing road user safety into the development review process: site plan review. This entry point is based on the following themes emerging from the analyses:

1) Developers recognize that a lack of safety is bad for business and are open to implementation of evidence-backed safety countermeasures
2) Existing TIA practices lack explicit safety metrics, and *ad hoc* layering of safety-related countermeasures on top of congestion mitigation obligations is an unwelcome burden
3) Clear standards and processes for assessing and addressing safety issues would:
    a. lessen burdens on developers,
    b. reduce the outsize influence of developer/regulator relationship history on safety outcomes, and
    c. circumvent the subjectivity of professional judgment
4) Site plan review is a leverage point within the developer's purview for introducing, assessing, and improving safety outcomes through land development.

The "Safe Systems Traffic Impact Analysis Framework," or SafeTIA, is meant to guide TIA practitioners through the process of identifying, measuring, and integrating safety into existing TIA practices. It specifically targets the site plan review stage and provides clear steps for practitioners that are meant to complement and enhance the conventional, level-of-service focused approach to TIA.

SafeTIA's practical basis

In a technical brief released March 2022, the ITE Safety Council encouraged the incorporation of Safe System Approach principles into TIA practice. The technical brief described several key components of a TIA that incorporated safety meaningfully and specifically recommended considering community needs and using an analytical framework based in Safe System elements and principles (e.g., safe speeds) (ITE Safety Council, 2022). Existing Safe System analytical frameworks, such as FHWA's Safe System for Intersections (SSI) methodology (Porter et al., 2021) and the Movement and Place framework (Corben, 2020) emphasize a shift away from reactive, crash-based safety analyses and toward conflict- and speed-based risk analysis frameworks. To this end, we adapted the concept of an "intersection risk envelope" from Cantisani et al. (2019) and expanded it to an entire development footprint to provide practitioners with an iterative, intuitive tool for identifying both existing and potential risks that exist at crossings adjacent to the footprint.

Implementation of SafeTIA is predicated on agencies having established a locally acceptable level of risk of roadway deaths and/or serious injuries and a timeline for meeting associated risk reduction goals. For example, a city may have adopted a Vision Zero plan that specifies a date by which local roadway fatalities and serious injuries are eliminated. SafeTIA could be implemented as a mechanism to support that the goal of Vision Zero through developer-provided risk mitigation.

Guidance for conducting SafeTIA

SafeTIA comprises ten steps that parallel and complement conventional TIA practices. Future demonstration projects will help refine and adjust the approach to improve efficacy and ease of use. The procedure is intended to be iterative to help developers and regulators understand and leverage the relationship between land development, traffic assignment, and road user safety.

Project scoping and background

Step 1: Specify a project scope and collect background information

As part of the initial development proposal, users will specify the project's geographic scope (the proposed development's area of impact) and collect safety-relevant background information.

Practitioners conducting a TIA are likely already collecting trip generation information to establish baseline (pre-development) traffic patterns. The purpose of this step in the SafeTIA framework is to ensure that practitioners also gather relevant safety information to illustrate how the proposed development will shape site- and impact area-specific safety concerns. Analysts must identify several pieces of information:

1) How large is the impact area?
2) When will development be completed?
3) Is the proposed project a new development or a modification to an existing development?
4) If the project is new, is this greenfield development or in-fill?
5) What is the surrounding existing land use context of the project site?
6) What is the likely future condition of the area based on local comprehensive plans and zoning ordinances?
7) What are the current travel patterns through the impact area?
8) What is the current modal activity of the parcel (i.e., can the site be accessed by pedestrians, bicyclists, and those using transit services)?
9) What is the known safety history of the area (including crash reports plus any available data on traffic enforcement efforts, 'near miss' reports, and/or resident-generated requests)

Some TIAs are limited to adjacent streets and short-term development periods, but new development can induce demand and reroute nearby traffic, changing traffic patterns within a wider area. Therefore, analysts should conduct an origin-destination (O-D) analysis and identify *any* affected streets, intersections, and crossings that will be used to access the development. Analysts should select the largest feasible analytical footprint, based on local contexts and standards.[6]

Table 1. Step 1 - Project scope and development context

Criterion	Information to record for context
Development footprint (in square feet)	-

[6] As yet there is no empirically tested guideline to establishing boundaries for a safe systems-informed analytical footprint. Future demonstration projects should attempt to develop a rigorous, defensible method for identifying an appropriately-sized analytical footprint.

Study period (in years)	-
New development?	-
If new, greenfield or in-fill?	-
Analytical footprint (in square feet)	-
Number of relevant intersections	-
Number of relevant midblock crossings	-

Step 2: Identify existing conflict points for all road users at the site

Identify all existing points of potential physical conflict for all people traveling in, to, or through the impact area. These number and nature of conflict points contribute to the impact area's risk envelope.

The analyst should sum up all the merging, diverging, and crossing conflicts per access point within the impact area. This applies to both intersections (as illustrated in Figure 1 below and midblock crossings).

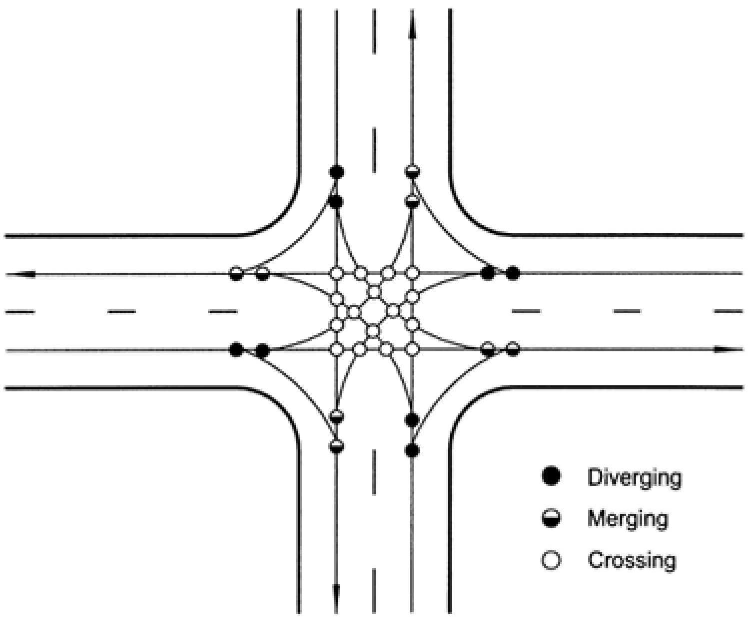

Figure 2. Schematic showing locations of diverging, merging, and crossing conflicts at a typical 4-way intersection. Image credit: FHWA[7]

Table 2. Step 2 - Identify existing conflict points

Criterion	Conflict Points		
	Merging	**Diverging**	**Crossing**

[7] FHWA Signalized Intersections: Informational Guide, Chapter 10

Access Point 1: Vehicular Trips	-	-	-
Access Point 1: Pedestrian Trips	-	-	-
Access Point 1: Bicyclist Trips			
Access Point 2: Vehicular Trips	-	-	-
Access Point 2: Pedestrian Trips	-	-	-
Access Point 2: Bicyclist Trips			
…	…	…	…
Access Point n: Vehicular Trips	-	-	-
Access Point n: Pedestrian Trips	-	-	-
Access Point n: Bicyclist Trips	-	-	-

Step 3: Identify existing challenges or barriers to accessibility

Analysts should identify challenges or barriers to universal access, as these increase the probability of fatal/severe injury in and around the project site. The SafeTIA framework assumes localities will already have a preferred approach to identifying accessibility limitations, although later versions of the framework should seek to define and integrate accessibility directly into the safe systems approach.

Table 3. Step 3 – Identify existing barriers to accessibility

Criterion	Existing Accessibility Limitations
Access Point 1	-
Access Point 2	-
…	…
Access Point n	-

Step 4: Calculate the existing risk envelope for all trips and all modes

Calculate the risk envelope for all existing trips in, to, or through the impact area (RE_0). The risk envelope is the probability of fatality or serious injury to individuals. It is calculated as the sum of the number of severe conflict points based on impact speed at each access point within the analytical footprint.

Analysts should identify the speed limits on adjacent streets at each access point to calculate the number of predicted severe or injury crashes. An alternative would be to note, simply, based on speed limits, how many severe (i.e., fatal or injury-based) conflicts occur during the peak hour or daily. Ideally, analysts would use measured speed data to determine likely impact speeds, but if these data are unavailable, speed limits can be used as surrogate impact speeds.

Not all conflict types will contribute equally to a risk envelope. Most problematic are conflicts involving pedestrians and bicyclists and crossing conflicts for motor vehicles. For the purpose of this analysis, all conflicts with pedestrians or bicyclists where the posted speed limit is 25 mph or higher should be considered severe. For conflicts between motor vehicles, severity is based on a combination of the speed and angle of collision. For motor vehicle conflicts, refer to Table 4, adapted from Candappa et al. (2015, Table 1) to identify potential severe conflicts.

Table 4. Speed and angle combinations that produce Safe Systems compatible levels of kinetic energy for occupants of motor vehicles, in kilojoules

		Impact Angle (degrees)							
		90	80	70	60	50	40	30	20
Speed (mph)	62	385.8	374.2	340.7	289.4	225.4	159.4	96.5	45.1
	56	312.5	303.1	275.9	234.4	183.4	129.1	78.1	36.6
	50	236.9	239.5	218.0	185.2	144.9	102.0	61.7	28.9
	43	189.0	183.3	166.9	141.8	110.9	78.1	47.3	22.1
	37	128.9	134.7	122.6	104.2	81.5	57.4	34.7	16.2
	31	96.5	93.5	85.2	72.3	56.6	39.9	24.1	11.3

Shaded cells represent Safe Systems compatible levels of kinetic energy; if a conflict's speed and angle combination are not shaded then mitigations should be considered

Reproduced from Candappa et al (2015), Table 1 (converted from kph to mph)

Table 5. Step 4 - Calculate existing risk envelope RE_0

Criterion	**Speed Limits**		**Severe Conflicts**			
	Road 1	**Road 2**	**Merging**	**Diverging**	**Crossing**	**Sum**
Access Point 1: Vehicular Trips	-	-	-	-	-	-
Access Point 1: Pedestrian Trips	-	-	-	-	-	-
Access Point 1: Bicyclist Trips	-	-	-	-	-	-
Access Point 2: Vehicular Trips	-	-	-	-	-	-
Access Point 2: Pedestrian Trips	-	-	-	-	-	-
Access Point 2: Bicyclist Trips	-	-	-	-	-	-
…	…	…	…	…	…	…
Access Point n: Vehicular Trips	-	-	-	-	-	-
Access Point n: Pedestrian Trips	-	-	-	-	-	-
Access Point n: Bicyclist Trips	-	-	-	-	-	-

Evaluate impacts of proposed changes

Step 5: Identify access changes required for development

Identify modifications in access points or crossings, including removal, relocation, or reconfiguration of existing access points or addition of new access points required by the development for all anticipated travel modes within the analytical footprint.

Table 6. Step 5 - Identify modifications or additions to access points

Criterion	Information to record for context
Number of new intersections	-
Number of new midblock crossings	-

Step 6: Identify all potential conflict points based on new access points

Identify potential conflict points for all people traveling in, to, or through the impact area after development, based on the modifications to the access points identified in Step 5 and the projected new trips generated by the development (based on local estimation methods).

This step follows the same process as Step 2 for all trips after development.

Table 7. Step 6 - Identify all new and/or modified conflict points

Criterion	Conflict Points		
	Merging	Diverging	Crossing
Access Point 1: Vehicular Trips	-	-	-
Access Point 1: Pedestrian Trips	-	-	-
Access Point 1: Bicyclist Trips			
Access Point 2: Vehicular Trips	-	-	-
Access Point 2: Pedestrian Trips	-	-	-
Access Point 2: Bicyclist Trips			
…	…	…	…
Access Point n: Vehicular Trips	-	-	-
Access Point n: Pedestrian Trips	-	-	-
Access Point n: Bicyclist Trips	-	-	-

Step 7: Identify new challenges or barriers to accessibility for all users

Following the same procedure as in Step 3, the analyst should identify all barriers to challenges to access presented by the proposed site plan.

Table 8. Step 7 – Identify new barriers to accessibility

Criterion	Anticipated Accessibility Limitations
Access Point 1	-
Access Point 2	-
…	…
Access Point n	-

Step 8: Calculate the induced risk envelope for all post-development (existing and induced) trips and all modes

Calculate the induced risk envelope (RE_1) given the modified access points and total trips projected by all modes across the entire impact area once development is completed.

This step follows the same process as Step 4.

Table 9. Step 8 - Calculate the induced risk envelope RE_1

Criterion	Speed Limits		Severe Conflicts			
	Road 1	Road 2	Merging	Diverging	Crossing	Sum
Access Point 1: Vehicular Trips	-	-	-	-	-	-
Access Point 1: Pedestrian Trips	-	-	-	-	-	-
Access Point 1: Bicyclist Trips	-	-	-	-	-	-
Access Point 2: Vehicular Trips	-	-	-	-	-	-
Access Point 2: Pedestrian Trips	-	-	-	-	-	-
Access Point 2: Bicyclist Trips	-	-	-	-	-	-
…	…	…	…	…	…	…
Access Point n: Vehicular Trips	-	-	-	-	-	-
Access Point n: Pedestrian Trips	-	-	-	-	-	-
Access Point n: Bicyclist Trips	-	-	-	-	-	-

Step 9: Calculate the change in risk envelope due to the development

Analysts should compare the induced risk envelope RE_1 (i.e., after development) to the existing risk envelope RE_0 to identify changes in the number of fatal and severe injury conflicts induced by the development. This comparison can be done in aggregate at this step, and then accommodations can be prioritized by ranking and weighting in subsequent steps.

Table 10. Step 9 - Calculate change in risk envelope

Criterion	Existing Conditions	Projected Conditions	Difference
Total Conflicts	-	-	-
Severe Conflicts	-	-	-

Iteration and mitigation

Step 10: Repeat Steps 5-9 until risks are mitigated.

Repeat steps 5-9, adjusting the site plan as necessary to mitigate risks, until the difference between RE_0 and RE_n reaches a pre-determined acceptable level of unmitigable risk of injury or death to road users.

If RE_1 minus RE_0 exceeds pre-determined acceptable levels, the developer must modify the site plan and/or design of access points to reduce the induced risk envelope. This reduction may come through further modification to or relocation of proposed access points, speed limit and design speed reductions, installation of crossing treatments, and/or improvements to accessibility limitations.

Reporting

Once these steps are complete, provide the resultant site plan and description of remaining (unmitigated) safety and accessibility impacts to the local agency.

Conclusion & recommendations

The conclusions from this research are in alignment with the nascent guidance from professional groups such as ITE, to integrate safety considerations into TIA practices. Our research examines practical barriers to understanding the safety implications of current TIA practices and identifies leverage points for reimagining TIA as a mechanism for improving road safety for all users through the land development process. Our work uses those leverage points to develop the creation of a guide for practitioners seeking to incorporate safety and safe systems objectives into current TIA practices.

Our analyses suggest that contemporary TIA procedures often seek the goal of mitigating traffic congestion yet end up creating conditions under which congestion resumes and road user safety deteriorates over time. Based on the evident structure of the TIA/traffic safety system, we identified that transportation professionals were leaning into two system archetypes: “Seeking the Wrong Goal” and the “Fixes that Fail.”

This research shows a clear gap in the guidance on relationships between land development and road safety and identifies feedback loops within contemporary TIA practice that can undermine road user safety. By interrogating these feedbacks, practitioners and researchers can uncover and dismantle barriers to safer land development patterns. Given the complexities, ubiquity, and ‘messiness’ of contemporary TIA practices, there are no elegant solutions to centering safety yet. Increasing awareness among practitioners of the traps of “seeking the wrong goal” or “fixes that fail” would represent a substantial step toward development review practices with outcomes that balance safety, congestion, and development.

To enhance TIA practices and center safety in the development review process, we have introduced a “SafeTIA” procedure, one that guides TIA practitioners through a series of steps to identify, measure, and integrated safety into existing TIA practices. Our team created this procedure with prospective developments in mind, though SafeTIA can be applied to existing developments in the interest of discerning, prioritizing, and incorporating safety retrofits. In this way, SafeTIA transcends more static procedures reliant upon crash histories via its capacity to detect risk distributions for different road user groups. Also, given its iterative nature, SafeTIA aligns with “adaptive” land use policies and regulations, ones which can be modified or changed in response to new realities—e.g., in travel mode preferences, migration patterns, adoption of intelligent speed assist technology, etc. (Agusdinata, Marchau, and Walker, 2007; Khabutdinov, 2019; van Duin, Marchau, and Walker, 2008).

Future research should build upon these findings through development of impact assessment procedures that center road user safety and conducting longitudinal studies of safety implication of development patterns shaped by contemporary vs. safety-oriented TIA procedures.

Executive summary

Introduction

Traffic impact analysis (TIA) is an important piece of how transportation systems are planned, designed, and built. Cities and states use TIAs to assess how road users currently use the transportation system and then predict how the system will operate if transportation patterns change through the addition of new buildings within an area or through new capacity added to the roadway. Many local and state governments view the TIA process as a critical means of generating needed infrastructure improvements, and its use has become ubiquitous among DOTs across the US. TIA can therefore exert a powerful influence on urban land use and transportation systems.

Reliance on the conventional approach to TIA, particularly in urban contexts, has been criticized for over-predicting automobile traffic, prioritizing congestion relief at the expense of other travel modes, undermining local efforts to shift travel onto non-auto modes, and encouraging peripheral and suburban development over infill or smart-growth projects. Previous research has shown that local and state agencies recognize these drawbacks and have been making substantial efforts to adapt the TIA process yet are hindered by a lack of guidance on how to use TIA to achieve contemporary demands for compact, livable projects that support walking, bicycling, and transit use.

Furthermore, little attention has been paid in research or in current practices to TIA's direct impacts on road safety or its potential role in shaping safe systems. This lack of attention is somewhat surprising, given TIA's conventional deployment as a means to minimize and mitigate the traffic congestion impacts of new development by tying roadway capacity improvements to land development permits. Furthermore, prior research on drivers of innovation in TIA practice strongly suggested that road user safety represents a tangential concern in contemporary development review procedures, superseded and subsumed by concerns over congestion mitigation.

Objectives

The overall aims of this research, of which this project is a foundational step, are to center road user safety in TIA and land development review practices. This project specifically sought to:

1) evaluate whether, how, and the extent to which current TIA practices incorporate road user safety into assessments of impacts of land development or into strategies to mitigate those impacts, and

2) identify opportunities to integrate safe systems concepts and metrics into the development review process, and

3) advance a new, safe systems approach to estimating and mitigating the safety impacts of new development

We achieved these objectives through analysis of interviews and focus groups with planners, engineers, and developers involved with local TIA practices in four states in the US southeast. We then developed a prototype "SafeTIA" framework, which capitalizes on leverage points identified in the analysis and lays out specific steps development review professionals can use to understand and mitigate potential road user safety issues in parallel with or instead of a conventional TIA.

Methods

The research team conducted 41 semi-structured interviews with planning and engineering professionals involved in TIA processes in Maryland, Virginia, and North Carolina. The research team supplemented the interviews with focus groups of 12 private developers representing firms headquartered in the southeast US and with direct experience working with local TIA processes. Data collection focused on eliciting perspectives on the role and limitations of TIA practices in influencing roadway safety. We used grounded theory analysis of interview and focus group data to explore transportation professionals' responses to questions on road safety. We used our findings from the grounded theory analysis to construct a causal loop diagram that allowed us to visualize interactions between components of the TIA/traffic safety system.

Findings

The research team discovered that conventional TIA practices typically fail to center road user safety. Furthermore, the analysis uncovered multiple self-defeating assumptions and narratives about the complex relationship between road user safety and congestion mitigation which hinder efforts to improve safety and lessen the impacts of congestion. In these ways, conventional TIA practice closely aligns with common and interrelated systems archetypes, i.e., "Seeking the Wrong Goal" and "Fixes that Fail."

The analysis also highlighted a near-universal recognition among developers that lack of safety for patrons is bad for business, as well as an openness to implementing evidence-based safe systems-oriented site designs. Developers expressed that *ad hoc* layering of safety-related countermeasures on top of congestion mitigation obligations is an unwelcome burden. Developing clear standards and processes for assessing safety issues in the site planning stage would costs for developers, reduce the outsize influence of developer/regulator relationship history on safety outcomes, and circumvent the subjectivity of professional judgment, all of which were identified in the analysis as barriers to prioritizing road user safety in development review.

Developing a new approach

Based on the above observations, the research team identified site plan review as well-situated entry point for bringing road user safety into the development review process. We developed the "Safe Systems Traffic Impact Analysis Framework," or SafeTIA, which guides practitioners through the process of identifying, measuring, and integrating safety into the project site plan, providing clear steps meant to complement, enhance, and ultimately replace, the conventional, level-of-service focused approach to TIA. SafeTIA comprises ten steps that parallel and are meant to complement conventional TIA practices. The procedure is intended to be iterative to help developers and regulators understand and leverage the relationship between land development, traffic assignment, and road user safety.

Next steps

This research lays the groundwork for a future demonstration effort that will aim to assess how the SafeTIA approach could be used to proactively prevent real-world road user safety problems. This will be achieved by identifying projects with a known crash history, and then applying the SafeTIA framework to identify the types of modifications to the design and configuration of the project would have been recommended. These will in turn be compared to the existing risk envelope (and crash history) for the site to understand the extent to which SafeTIA would have prevented the creation of the underlying conditions associated with these crashes.

Ultimately, we hope to partner with a municipality in order to test SafeTIA's performance with respect to a new development proposal. This *in situ* demonstration project would entail a full analysis of the SafeTIA framework, and hopefully demonstrate that safety can be achieved in addition to mobility benefits through the nexus between development review practices and Safe Systems, evaluate the shortcomings of existing procedures to demonstrate the gaps Safe Systems can fill, and partner developers and communities to find implementable solutions.

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Appendices

Appendix I: Data collection instruments

Interview instrument

Introduction

As I mentioned [in my email/on the phone], we are interested in understanding whether and how communities in the southeast are addressing issues safety of road users—including motorists, transit-users, and non-motorized travelers—in the TIA process. We know that you and your colleagues in (LOCALITY NAME) undoubtedly value safety for your residents through various mechanisms, but for the purposes of this interview we just want to hear about how safety does or does not intersect with your TIA processes.

All interviewees

1) Does your current TIA process quantify or measure road safety indicators such as crashes, vehicle speeds, or risk of multimodal conflicts when assessing existing conditions?

   If so, what indicators do you measure?

2) Is safety of road users considered in elsewhere in the TIA process (e.g., analysis of impacts, mitigation of impacts, or collection of follow-up data)?

   If yes, go to Q3
   If no, go to Q5

If response to Q2=yes

3) How is safety incorporated in the TIA process?

   Prompt for different modes, case by case?

4) Where do you look for guidance on incorporating safety into TIA practices?

   Go to Q6

If response to Q2=no

5) Do you (or others in [locality]) have any thoughts about ways safety could or should be incorporated into the TIA process?

   Go to Q6

All interviewees

6) To your knowledge, are any aspects of the way [locality] approaches TIA motivated by concerns over roadway safety?

   Prompt for ways in which safety has motivated TIA practices. We're looking for whether road safety is an explicit motivator.

7) To your knowledge, have concerns over road safety been discussed or seen as either a motivator of or impediment to adoption of new or innovative TIA practices in [locality]?

Prompt for details on the perception of road safety as either a motivator or barrier to changing TIA practices.

8) Do you feel as if [locality's] current TIA practices adequately address safety for all road users (motorists, transit users, non-motorized travelers)? Why/why not?

9) Has [locality] adopted or considered adopting any formal roadway safety policies or signed on to any programs regarding multimodal safety (e.g., a ped safety action plan, signing on to VZ, etc)?

10) Do you have any additional comments or concerns over the way road safety is incorporated into transportation or land use planning in [locality]? Both in relation to the TIA process and more generally?

Focus group Instrument

Introduction

There are several things that developers must do to develop in a city. While cities may require a traffic impact analysis study, these studies generally overlook the issue of safety. Additionally, planners and planning in general tend to drive the discussion about traffic safety, with little to no insight or perspective from developers about the role of safety in development. The purpose of this focus group is to gain developer insight about safety in general and, in particular, the developer side of the conversation regarding interactions with city staff regarding requested or required changes to address safety.

Focus Group Questions (Shown on a PowerPoint Slide during Focus Group)

1) Do you consider road safety as an important consideration in project development, or is this principally a governmental responsibility?

2) Have local governments requested changes to the development to address safety concerns?

3) Have you received requests to address safety impacts, beyond those tied to traffic volumes before the development was built? If so, what types of requests?

4) Have you received requests to address safety impacts directly related to your development upon the completion of construction as a result of the new construction due to unintended consequences?

5) Was safety included as a consideration in traffic impact studies for a project. If so, how? Was it incorporated into the traffic impact studies?

6) Are local government requirements a help or a hindrance? In the absence of local government requirements, how would your approach to development in relation to traffic impacts be different?

7) Is there a market for safety in general? What about pedestrians and cyclists?

8) What could be changed to make traffic impact analysis most meaningful?

9) What might be the best mechanism(s) to better consider traffic impacts?

10) How would you improve the current policies related to traffic impact analysis?

Supporting/Follow-Up Question Options and Original Draft Questions

1) Questions about site planning and design

    - Developer perspectives on road safety
        - Do you consider road safety as an important consideration in project development, or is this principally a governmental responsibility?
        - Should you consider road safety in your developments?
        - Do you think there is a market for safe developments?

        - If so, how would you or do you market your development using safety perspectives?

- How do you incorporate safety into the site plan? Is your goal to meet or exceed regulations?
    - Street configuration/layout
    - Building configuration/layout
    - Parking
    - Intersections
    - Access to external street network

- How are background conditions and other external factors considered?
    - Traffic volumes
    - Crash history

2) State/Local Government Requirements

- Have local governments requested changes to the development to address safety concerns?
    - If so, which (ped/bike, access control, driveways, intersections, signals, etc).
    - Have you received requests to address safety impacts, beyond those tied to traffic volumes before the development was built? If so, what?
    - Have you received requests to address safety impacts directly related to your development upon the completion of construction as a result of the new construction? (To capture unintended consequences)
    - Was safety included as a consideration in traffic impact studies for a project. If so, how? Was it incorporated into the traffic impact studies? (consideration vs. incorporation)
        - Consider specifically: peds, bikes, motorists
- Are local government requirements a help or a hindrance? In the absence of local government requirements, how would your approach to development in relation to traffic impacts be different?

3) What could be changed to make traffic impact analysis most meaningful?
4) How do you feel about incorporating safety? Is there a market for safety?
5) Pedestrians and bicyclists – how is safety incorporated into the design for them? Is it incorporated into the design? If so, how so?
6) What might be the best mechanism(s) to better consider traffic impacts?
7) General → How would you improve the current policies related to traffic impact analysis?
8) Specific → where is the sweet spot between developers shouldering all of the costs to mitigate traffic impacts and cities shouldering all of the costs?

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