Volume 1
Urban Driver Mental Frameworks
And Implications

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Project: Identifying Mental Frameworks Underlying Driver Behavior in Urban Contexts

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FOREWORD

Over the last 85 years, engineers and researchers have tweaked and analyzed every minute detail of roadway design with one goal: optimizing vehicular speed. Although the industry has been looking seriously at design for other modes since the late 1980's, the vast majority of the money and energy has been poured into examining every nuance and detail of roadway safety and design. Despite this, or maybe because of this, our pedestrian and bicycle fatalities have climbed steadily since 2008, and the trend is only accelerating.

For the last 4 years our team has run literally thousands of statistical tests and models to answer one question: **Why do people drive differently on a dense urban street than a suburban roadway or highway?** What is it about that context that captures our attention, engages our senses, and makes us better, saner drivers? Here, I'm not talking about the bumper-to-bumper congestion that we experience in vehicle dominated downtown cores. Those spaces may be dense and intense, but they are not necessarily urban. **For our purposes, urban space is defined as the type of environment where human scale interaction is common and a wide range of transportation options are a functioning reality.** These are the spaces that predate the automobile design standards of the last century. They are Jane Jacob's lively environments characterized by the unending dance of the street. Today, they feel like impossibly rare treasures. Crashes still occur in these spaces, but they are uncommon and have far less severe consequences when they do occur.

The research proposal for this project began with a far simpler question: What are the critical elements within the built environment that generate a different driving pattern? Our aim was to figure out how to build an environment where drivers would automatically behave well everywhere. Specifically, we wanted to know what design features would lead drivers to choose a low speed and high attention level without having to dictate that behavior directly with less than effective signage and regulatory systems. Many researchers have attempted to categorize the built environment in terms of speed and crash avoidance, but the results have been hit-or-miss. Features show up as critical in some studies but not in others. If you ask if a feature matters, the answer is usually, "It depends." I am tremendously grateful for the work of Dr. Peter Hancock and the human factors department at UCF. Without the example of their ongoing rigorous examination of the underlying human psychological and perceptual limitations, we would have stopped at this question and left with few real answers. Their work drove us beyond just characterizing the impacts to asking why that behavior is occurring.

What we found was stunningly unexpected but, in retrospect, completely unsurprising. Although it's easy to think of a vehicle's behavior as if the driver sheds their humanity when they step into a car, our human frame and neurology are not so easy to leave behind. Our neurological and perceptual systems were designed to function within face-to-face limits in scale and speed. The car gives us super-human capabilities but without the perceptual abilities to effectively use those powers. We need the eyes of a hawk, the reflexes of a cheetah, and the armoring of an insect to operate within a roadway environment unassisted. Thankfully, engineers are eager to learn from our many failures. Those last 85 years has been a tireless exercise in augmenting our human limitations to meet the everyday operational needs of this super-human assistive device.

Since the physics of the operation are super-human, engineers have treated the vehicle as if it were a simple point-mass that the driver could be trained to manage reflexively, while believing that their choices are conscious—simplifications that apply beautifully to a highway but not so readily to a busy urban street. Superelevation, curve radii, and vertical curves manage the inertial forces of an object in motion using the unyielding laws of physics. The size and uniformity in our signing and marking make up for vision and reflex limitations. Abundant spatial margins provide the forgiving cushion we need to manage our inevitable high-speed failures. The comfort of the driver and their human limitations were all observed and mitigated through extensive human factors studies that continue to this day. We have even come to anticipate the more common mistakes with forgiving design features. Few, if any, of these parameters have any impact on a driver as they navigate a space at an urban scale and pace. Even fewer of these controls can shape driver behavior sufficiently to make multimodal interaction safe in the chaotic environments that bridge between urban and highway spaces.

In this project, our goal is to identify the underlying psychological principles that govern the driver's behavior in socially dynamic urban spaces because physical laws are not able to control behavior at that scale and speed. These Mental Frameworks form the underlying structure of driver's automatic reactions and subtly impact their conscious thoughts. Because most of these systems operate below full awareness, they are difficult to impact through information, instruction, or regulation. Although these principles are not as inviolate as physical laws, they are statistically common enough to shape the behavior of the flow, similar to the way that three simple rules generate the flocking patterns of birds or the schooling patterns of fish (Dutta 2010)[1].

The pure-science psychological literature is replete with well-established cognitive, neurological, and mental patterns that have yet to be applied to real-world transportation situations. Although we document what the data is telling us about specific concrete interactions, it is the link between the hard psychological science and the behaviors we observe that is our primary target. It is within those linkages that we will identify the psychological and social principles that govern driver behavior in urban spaces. It will take several decades to pin down the nuances and implications of the principles we have identified so far, and there may be many more that have yet to be discovered. We are currently in the final weeks of a 4-year study and are still stumbling onto psychological concepts that explain what we see in the data. If we know why a behavior is happening and the physical limitations that govern that effect, we have a much better chance at understanding when a specific feature or an overall design choice has an impact and when it doesn't. This is the missing piece in designing a self-explaining road: decoding for ourselves what we are telling the driver with our design so we can provide the right messages, not an unintelligible chaos.

[1] The three rules are: 1. Don't get too close to avoid collisions, 2. Don't get too far away from the flock, 3. Fly in the same direction as your neighbors.

When I would tell people I was researching what drivers were thinking when they drive, the automatic response from nearly everyone was "they're not thinking at all." This observation is far more insightful than it appeared at first. Our initial research plans were to identify a set of cognitive schemata—the unwritten rules and contextual understanding that people consciously rely upon to make choices in social situations. For instance, the rules for a STOP sign require that drivers come to a full and complete stop, look around for a conflict, and proceed with caution. All drivers assent to that understanding or schema. However, even in this simple example, most drivers are more likely to pause or slow at the sign as they look for threats, proceeding as soon as they establish that the coast is clear whether they have stopped or not, (unless they remember that police officers are likely to be nearby.) This isn't a conscious behavioral choice but an unconscious slide into what is statistically safe based on their experience. On the contrary, the choice to obey the schema requires an intentional conscious override of the natural behavior that your less-conscious systems deem appropriate.

Driving is the most over-rehearsed skill most Americans possess. Over the first few years, drivers develop an unconscious sense of the speed and attention to detail that is required to provide them a statistically safe trip. This is a perfect example of what Nobel Laureate, Daniel Kahneman describes in his book, *Thinking, Fast and Slow* (Kahneman 2011)—our first mental framework. Thinking Fast (System 1) consists of reflexive responses to primal stimuli or largely unconscious, non-verbal responses to the probability of a previously experienced risk or reward. Thinking slow (System 2) is the verbally experienced, sequential, logical flow of conscious thought. The vast rehearsal time we give to driving is an ideal example of priming System 1 thinking with experience. As engineers, we have believed that drivers choose their behaviors, but the truth is that they stop making merely conscious choices about driving behavior after about 6 months of driving. Anyone who has taught their child to drive is grateful when that System 1 automaticity finally kicks in. Conscious choice takes a lot more time than a driver has available to respond.

This is where the problem develops for multimodal systems. In typical roadway contexts, the risks to a vulnerable road user (VRU) are entirely external to the driver so they don't automatically engage the System 1 processes that guard our own personal survival. In our native habitat, we have vast reflexive abilities that engage System 1 automatically when they see a human being. People are the primary source of our most critical threats and valued rewards. Human identification systems have been developed over multiple millennia of evolutionary design and ecological threat assessment. When we are observing environments at face-to-face scale and near humanly attainable speeds, we have neurological pre-programming to deal with other human beings and animals at that scale. Move out of that scale and speed and we need a lot of help for our own survival, much less the safety of people we may not be able to see.

Although the principles we have identified provide the ability to understand the consequences of our design choices, they cannot make those choices for us. Designing a roadway or street is a multidisciplinary effort with many competing interests and financial constraints. It is fundamentally a political question, not a technical one, though few of us, technical or political, fully comprehend the consequences of our individual choices. The mental frameworks we have identified are intended to fill in that gap with strategic principles that can guide our big-picture choices.

This final report is broken up into two volumes. **Volume I** focuses on the critical mental frameworks that impact urban, multimodal space and the resulting design and safety implications. Some of these frameworks were newly identified within this research effort. Others are well established in the driving theory and human factors literature, but may have different implications within an urban environment. Specifically, Volume 1 covers the following major topics:

- **Chapter 1: A Brief History of Human Factors in Roadway Design.** It is critical to understand what the previous psychological research has identified as critical for roadway systems in order to appropriately contrast them with the mental frameworks that control operational behavior within urban settings. Some of our urban mental frameworks emerge from well-established scientific exploration within roadway or highway contexts but may function differently in urban streets. Others are uniquely applicable to urban space. It is important to acknowledge the differences between the aims and applications of the immeasurably valuable research that has shaped roadway design in order to recognize the different application approaches that are required in urban street design.

- **Chapter 2: The Mental Frameworks**. This is intended to be a high-level overview of the mental frameworks themselves. It contains a technical description of each of the mental frameworks and the research that they are based upon as well as the indications in our data or other research that support them.

- **Chapter 3: Speed-based Design Paradigm.** This chapter describes the Integrated, Transitional, and Sheltered design paradigm for surface roadways. This concept recognizes that within every context classification, a mix of roadway types will be needed to support operations at different speeds. The proportion of that mix may vary dramatically in different contexts, but every context includes a few of each type. Each of these categories are tied to the operational speeds and multimodal features that the facility needs to provide.
    - **Integrated** blocks are capable of integrating a wide range of multimodal users safely throughout the right of way because the operational speeds are low—below 25 mph—and the driver's level of attentiveness is high due to human presence in the corridor.
    - **Sheltered** segments have few, if any, access points at pedestrian or bicycle scale and often include only one major land use type. Corridors are typically much wider and are optimized for throughput, which communicates that speeds are intended to be much higher. As a result, 85th percentile speeds are typically measured at 40 mph or more.
    - **Transitional** spaces operate between 25 and 45 mph, which makes them uncomfortable for all users: pedestrians, bicyclists, and drivers. Although these spaces may exist for decades to come, they should be considered a lose-lose

solution that ultimately requires a better long-term strategy to serve each of those populations. As these facilities are modified or adjacent land is redeveloped, they should be examined by local policy makers and technical experts to determine whether they should be transitioned to an integrated space or a sheltered space.

- **Chapter 4: Overview.** The concluding section of this volume provides a concrete linkage between each mental framework and its implications for integrated, transitional, and sheltered space in a tabular fashion. The strategic concepts and guidance included in this section are intended to support practitioners and decision makers in their roadway design and policy in an easily accessible fashion.

Volume 2 includes the research analysis from the seven individual task reports, reorganized topically into seven chapters. These chapters provide additional technical detail and analysis that supports the principles in detailed in Volume 1.

- **Chapter 1: Introduction.** This section describes the motivation behind the study in terms of being able to design a roadway that is safe for all users where drivers choose an appropriate level of speed and attentiveness automatically.
- **Chapter 2: Driver Behavior and Design Literature.** This discussion provides an overview of the literature regarding the impact of the contextual environment on driving behavior, particularly speed choice. It summarizes the 4 domains that have generally been the topic of driver behavior research: within the street, near the road, dynamic elements, and conceptual or cognitive schemata.
- **Chapter 3: Quantitative Methodologies.** This chapter describes the features that were tabulated for each study site using Google Earth and other data sources. It also covers the methodology for the SHRP2 NDS data tabulation, crash data tabulations, and the speed validation data used throughout the report. It concludes with a summary of the primary statistical methods employed for analyzing the available data.
- **Chapter 4: Attentiveness Assessment.** Several of the initial models for time on task and multitasking are described as well as assessments that evaluate the differences between the presence of a vulnerable user and the perception of that user. Since vulnerable user presence and perception are so critical to driver behavior, this section also touches on the environmental factors that predict whether a vulnerable user is likely to be in the space. The chapter concludes with an effort to understand driver vigilance patterns using acceleration and jerk.
- **Chapter 5: Speed impacts and Prediction.** This chapter provides several speed prediction formulas that can be used to estimate the operating speeds on a roadway based on the roadway's design and visual characteristics. It includes detailed information on the processes used to tabulate the data and how each individual variable impacts the roadway's speed profile. The two types of speed data tabulated within the SHRP2 data set were used

to generate these prediction formulas. Speed count data from Orange County, Florida was then used to test how transferrable the speed prediction equations were.

- **Chapter 6: Safety Analysis.** There were two primary crash analyses that were performed within this project. The first documented the historic crash rates in the NDS study locations and how the contextual features and our mental frameworks impacted crash rates. This analysis frames the paradigm of a pedestrian integrated space in contrast to a sheltered design. Then, a Pre/Post complete streets analysis was performed that was structured around 17 Florida locations that had multimodal improvements over the last 12 years. These were analyzed along with similar and parallel roadways, some of which had changes and others that did not. Killed, Serious, and Injury crash data for segments and intersections were tabulated for vehicle only, pedestrian, and bicycle crashes. This data was analyzed to identify how specific contextual and design features impacted crash occurrence.
- **Chapter 7: Visual Preference Surveys.** The purpose of this task was to identify which context features typical drivers and roadway experts believe are critical to attention, caution, and speed. This was measured both in terms of their overall impressions of different spaces and their individual feature selections. The experts in our survey included roadway designers, urban designers and police officers.
- **Chapter 8: Additional Public Comment.** A total of 14 presentations have been delivered over the last 2 years that covered a wide range of topics that emerged from this research. The last two presentations, a presentation to the SHRP2 community and a webinar hosted by FDOT Central Office were widely advertised and well attended. This chapter summarizes the feedback we had received by April of 2023. These presentations did not include the overall mental frameworks as we have formulated them for this analysis, or the pre/post crash analysis.

Many of these topical reports include extensive appendices including specific survey comment details, a description of the 17 projects evaluated in the pre/post crash analysis, a brief history of the PPM/FDM, and the slides and transcripts for several of the presentations given on this research effort.

The concepts and recommendations we are making are intended to be implemented over time as roadway projects are constructed and reconstructed. Many of them require a realistic evaluation of the adjacent land uses and their relationship to the community and regional context. A mentor of mine, Brent Lacy, once told me that you only get the chance to reconfigure a community once a generation. That is largely true. Major changes happen rarely and often at great cost. However, incremental changes on a project by project or parcel by parcel basis can add up. They are still likely to take a generation or more to transform our communities, but the sooner that transition begins, the sooner we will be able to reap the benefits.

VOLUME 1 EXECUTIVE SUMMARY

In typical roadway operations, the car is essentially an assistive device that allows the driver and his passengers to move at super-human speed. This requires the driver to see farther and react faster than their bodies are designed to operate. The strategy to address these limitations has been to understand and employ the principles of physics to govern vehicle operations. For 85 years, human factors research has been used to delineate the limitations of human comfort, perception, and reaction capabilities that can be managed by a minimally capable driver as they navigate environments at speeds that are ecologically foreign to our native human capacities. The goal of the roadway system was to allow drivers to take full advantage of these super-human abilities and optimize the throughput in our network. Because we were functioning in a biologically alien environment, mistakes are common and our designs were required to adjust to those realities. The additional speed these adjustments allowed was an unspoken bonus, theatrically decried by safety experts and lauded by popular culture in songs like "I can't drive 55," or "Fast Car."

However, when gas prices skyrocketed in the 1970's and bicycling advocates began pushing for universal access, a new safety concern emerged that has only been amplified since the introduction of the personal smart phone. Pedestrian and bicycle fatalities have risen exponentially since the introduction of the smart phone in late 2007 and that passing safety complaint has become a plaintive cry. However, that time period also corresponds to the emergence of the Complete Streets movement, hinting that completing a street by merely tacking on pedestrian and bicycle accommodations may introduce new hazards to vulnerable users.

Since 2015, the Florida Department of Transportation (FDOT) has embarked on a plan to implement complete streets elements into all projects. This supports state and FDOT policies that have been in place since the mid 1980's. The implementation process includes identifying how each potential travel mode can be appropriately supported within or around each project in a way that is sensitive to the context of the surrounding environment and community. To safely support this initiative, road designers must not only include features to support non-motorized travel modes, but must also design the facility so that drivers use appropriate speed, attentiveness, and caution automatically. This is not an impossible task. Dense urban settings have elicited this type of behavior for centuries yet despite vast numbers of vulnerable users, their crash rates are remarkably low. The advantage that these environments have over most typical roadways is that we are back in native territory. Conflicts are negotiated eye to eye, speeds are closer to our human capacities, and those slower speeds allow for more time to react. The slower speeds also generate much less inertia, making it easier to stop and less dangerous when collisions occur.

We entered this project searching for the physical features that generate this type of behavior. What we rapidly discovered was that it is far more important to understand why that behavior happens before we can understand what we can use to make it happen. Many an urban designer or project developer has shaped a beautiful space only to find that drivers summarily disregard all of their effort for no obvious reason. The concept of a self-explaining road is the Holy Grail of urban roadway design. It acknowledges the reality that the roadway environment is continuously communicating a set of expectations that are translated into a fairly uniform set of driver behaviors. What the environment tells the driver holds far more influence than the signs or laws that we naively assume will change their behavior. We just don't recognize what we have been saying.

Within this project, a wide range of information sources were mined and analyzed including data from the second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS), Google Earth measurements, crash data from Signal4 and Washington DOT, as well as driver and expert visual preference surveys. The purpose of this work was to uncover the mental frameworks that impact attention, caution (vigilance), and speed within a complete street environment. For our purpose, the **driver mental frameworks are defined as the social and psychological principles that uniquely apply to face-to-face urban transportation systems that can be extrapolated from well-established pure science research in neurology, psychology and sociology.** These concepts are the underlying structure behind drivers' automatic reactions. They are the psychological laws that produce the outcomes we see, no different than the laws of physics govern the trajectories of the high-speed vehicles on our roadways. If we can understand the reasons why people behave the way they do, we have a better chance of changing that behavior.

The primary mental frameworks include:

1. **Driving Means Thinking Fast, Not Thinking Slow.** The Nobel Laureate, Daniel Kahneman, coined the terms System 1 and System 2 thinking to describe the difference between intuitive (thinking fast) and intentional (thinking slow) thought patterns

(Kahneman 2011). Once a person has learned to drive effectively, nearly all driving activities emerge from System 1, though they can be accessed with System 2 resources. System 1 resources are often utilized on the edges of conscious thought. They are not subliminal because they can be queried in the moment, but they are not processed using words or logical sequences. The System 1 monitoring that drivers utilize is related to a hypnotic state in which the person is highly attentive to the cued stimulus but without engaging their higher-level metacognitive faculties. System 1 resources are typically targeted towards personal survival, operational efficiency, and conservation of mental resources. This makes them a less than optimal master for environments where the risks are external to the driver's System 1 programming.

2. **People see People.** Faces and bodies are seen prior to conscious thought and are prioritized in a visual scene above nearly everything else. These are System 1 resources that are engaged when human interaction could generate risk or reward and are impacted by the emotional tone of the human beings that are perceived.
3. **Perceptual Limitations.** Although human perception is prioritized, it is subject to concrete perceptual and processing limitations.:
   a. **Corridor Width.** To perceive a target as a human, it must be within roughly 90-135 feet in face-to-face distance based on the visual limitations of emotional facial recognition (Hager and Ekman 1979) and the systems that monitor emotional body language. To the driver, this translates into a corridor roughly 60 to 90 feet in width. A 60 foot wide corridor can be passively surveilled by the System 1 resources instead of active monitoring that must be managed by System 2.
   b. **Speed.** The vehicle must be travelling slowly enough for the driver to have sufficient time to find them in the field of view and process the person's expression and body language. Based on our research, the upper limits of this effect are between 20 and 40 mph.
   c. **Chaos.** Competing information makes it more difficult for even a person to be seen, despite the priority that human presence exerts on our attention.

4. **Conditioned Anticipation of People.** In urban environments, drivers' attention is reflexively elevated when they expect to see the human face or form (Tice, Hancock et al.

2022). Because dopamine reward systems and adrenaline threat recognition systems are activated by seeing people and moving human bodies, Pavlovian conditioning applies. Drivers are far less likely to pre-emptively search for human presence in locations where human presence is rare or where there are few reasons for a person to be in that location, in conflict with the vehicle.

5. **Novelty along the Path.** Along the length of the roadway, the rhythm of changing salient information the driver receives reorients the driver to the environment. Frequent changes in land use type, short blocks, close driveway spacing, the corridor aspect ratio, and the sense of enclosure maintain interest as the driver proceeds through the space.
6. **Workload and Speed Choice.** Workload is generated by processing human presence in the space, conflicts with other vehicles and users, and the flow of information. Speed choice manages this workload demand, which means it is most dramatically reduced when all three of these conditions are present. When only some of these conditions are met, speed is still reduced, but not as much. Where we have minimized the workload demand from the environment, a high level of automaticity can be expected which will result in minimal levels of attention, cursory vigilance, and high speeds.
7. **Spatial Event Memory Structure.** Memory is encoded as discrete events bounded by horizons in space and/or time. When an event horizon is crossed, information in working memory is retained and stored within both events while information currently stored in short term memory is purged. Within driving, these event horizons occur at the thresholds where change is salient to the driver. These include locations where there is a major threshold or a disruption to the visual flow, like visual offsets, major curves, or major stops, particularly when those changes engage the driver's 60' surveillance window. Physically stopping at a signalized intersection for an extended period may also generate several event horizons due to the physical pause and task changes that naturally occur as a driver waits for the signal to change.

Although we have identified the markers for each of these mental frameworks within our data, there are likely many more that have yet to be mined from the existing psychological and social literature, and many questions remain unanswered within these concepts. It took us 85 years to gain a firm grasp on the physics and human limitations that govern operations within the highway environment, and it is likely to take several decades to examine the nuances and parameters inherent in these mental frameworks.

Based on this information, a shift in our overall design paradigm is in order. A clear distinction should be made between spaces that can safely integrate vulnerable road users into its operations and those that will not elicit an adequately attentive driver response. The design of an individual facility should be divided into three conceptual categories:

1. **Integrated Design (operating at 25 mph or less)** is appropriate for narrow corridors with high levels of human activity, short blocks, frequent functional doorways, a high resolution in land use mix, significant roadway side friction, and very low speed profiles. Integrated design may be appropriate for corridors with pavement widths less than 60 feet and building to building face widths less than 90 feet. Within these spaces, on street bike lanes, shared bicycle operations, frequent street crossings, and pedestrian prioritization is appropriate. Most residential streets should support integrated design, but may struggle to provide adequate driver responsiveness when the building setbacks are wide. The geographic extent of an Integrated Design area should be at a walkable scale (1/4 to 1/3 mile diameter). Multiple integrated areas may abut each other but should each have a center of activity in order to facilitate transit accessibility and the area's cohesiveness. High volume access points to the remaining roadway network should be created at ¼ to 1/3 mile spacing but may require additional protection for vulnerable users. The psychology, perception, and affective/aesthetic support of the users in the space should govern design decisions as these are the factors that will elicit sufficient attention and vigilance to protect them.
2. **Sheltered Design (operating at 40 mph or more)** is appropriate for higher speed surface streets. These streets should be optimized for vehicle flow and congestion management. Sheltered Design areas should include visual and spatial buffering for all users incorporated into the roadway cross section and on-road bicycle facilities should be discouraged. When considering complete streets implementation, a network level strategy allowing secondary roadway network to provide access for vulnerable users is more appropriate. Ideally, facilities to serve bicyclists, pedestrians and transit should be relocated out of sheltered corridors and repositioned adjacent to the doorways and frontages of the land uses they are attempting to access. Multi-use paths and vertical

visual markers within wide roadway buffers are the most appropriate accommodations for most bicycle users. Roadway design should be governed by principles that address the high inertia movement of vehicles with substantial protection for any vulnerable users. Visual access of the land uses adjacent to the roadway should be optimized but connectivity to integrated design areas should only be sufficient to allow drivers to move out of the low speed areas at ¼ to 1/3 mile spacing. These access points should be treated with special care in order to protect vulnerable users that may interface at that location.

3. **Transitional Design (operating between 25-40 mph)** addresses the strategies that will shift mid-speed roadways into a sheltered or integrated design strategy.

Volume I of this report covers the mental frameworks themselves and the overall strategy for implementing them into roadway design practice. It provides an overview of the critical findings from the entire 4-year research effort. Volume II includes the detailed research studies and analyses, reframed into easily accessible topics.

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CHAPTER 1: A BRIEF HISTORY OF DRIVING THEORY RESEARCH

To understand and identify the mental frameworks associated with urban space, a high-level review was performed to understand the history of driving theory within Human Factors research. To quickly compile an overall history, a Google Scholar search was performed to identify the major historical summaries for driving theory. Eight major summaries were identified that spanned from 1938 to 2017. Each literature review tended to focus on the underpinnings of whatever theory was currently debated at that moment. **Table 1** provides a summary of the major conceptual benchmarks documented within the most critical theoretical summaries, with highlights for the concepts that have critical implications for complete streets and our current analysis.

Table 1: A Summary of Driving Theory to 2017

Author	Year	Concepts
Gibson & Cooke	1938	Field: Life space containing the person and his psychological environment
		Car as a tool, vision defines the field
		Valences-positive attracts, negative repels
		Field of safe travel: perceived unimpeded potential paths
		Minimum stopping zone
Blumenthal	1968	Socio-technical problem; requires systems approach
		Accidents: Imbalance between system demands and driver capabilities
		Failures may be inevitable; plan for it
Shinar	1978	Individual differences
		Driver as information processor; Inattention/distraction
		Visual search vs. prediction failures
		Driver experience/education
		Intentional volitional errors
Michon	1985	Human as intelligent fallible problem solver
		Control Hierarchy: Strategic, tactical, operational levels
		Behavioral conditioning vs. Internal state models
		Taxonomic models: traits, task analysis
		Risk models: decreases in risk lead to riskier behavior. Several theories: Risk compensation, homeostasis, threshold, avoidance
		Distinction between performance (capability) and. behavior
Ranney	1994	Drivers compensate for limitations (behavioral adaptation)
		Attention switching within selective attention
		Mental workload; information processing speed
		Data driven vs. memory driven processing
		Speed selection motives: pleasure, risk, time, expense
		Risk taking as utility maximization, minimize attention paid
		Preattention and conspicuity
		Automaticity: active control vs automatic components
		Multiple resource theory: mental resources that don’t compete may happen simultaneously with minimal efficiency loss or stress

		Visual levels: Passive noticing, global search, specific scanning
		Behavior hierarchy: Skill-based, rule-based, knowledge-based
		Control hierarchy interaction with behavior hierarchy
		Drivers barely conscious of skill- and rule-based decisions
		Error production factors vs. error recovery factors
		Monitoring failures vs. problem-solving failures
		Consistency vs. novelty
Fuller	2005	Driving task difficulty, not risk shapes decision making
		Driver maintains safety margins from hazard, lane tube; automized control
		Task Capacity Interface Model: difficulty means demands exceed capacity
		Task demand is under driver control through speed selection
		Preferred level of arousal guides preferred task demand
Vaa	2014	Learning/operant conditioning: stimulus → response → reinforcing stimulus
		Driving is social interaction
		Survival motive develops the ability to avoid danger via biological monitoring
		Emotions vs. feelings (eg biological stress vs conscious affect)
		Cognitive span/chunking, 7+/-2: real limits in memory span
		Pre-cognitively limited alternatives chosen using "gut" (bounded rationality)
		Emotions/feelings guide the driver to handle most risks
		Driving Affordances
Shinar	2017	Information processing rate determines speed selection
		Attention; Long term and short term memory characteristics
		Schema: sets of experiences and relevant rules of behavior
		Situation awareness: perception, comprehension, anticipation
		Theory of planned behavior: norms → attitudes → intentions → behavior
		Information processing and motivation: slips, lapses, mistakes, violations

(Gibson and Crooks 1938, Blumenthal 1967, Shinar 1978, Michon 1985, Ranney 1994, Vaa 2014, Shinar 2017)

The first critical milestone in the psychological understanding of driving came in the way of a published conversation between the visual psychologist James Gibson and an early automotive engineer, Laurence Crooks (1938). Drawing from Kelwin's concept of "field theory" (Lewin 1937), the "field" is defined as the area containing the person and their psychological environment. In the case of driving, the car becomes a tool and the operating field is defined by the person's vision and the tool's capabilities. The car's capabilities include its speed, directional momentum, and braking. A subset of the driver's overall field is the 'field of safe travel,' which reflects the unimpeded paths of travel seen by the driver. Drivers are attentive to obstacles in the environment which impinge on this field of safe travel, creating a repulsive effect. Potential obstacles shape the speed and driving envelope (field of safe travel). In addition to what they see, drivers also anticipate obstacles, which also impinges on their driving field. For instance, drivers can and should maintain a tighter control on the speed and trajectory of their vehicle when approaching a crosswalk because they understand that vulnerable users may be there.

Blumenthal (1967) provided the next theoretical summary, describing driving as a complex socio-technical problem requiring a systems approach for safety analysis. He recognized that accidents may result from a mismatch between the driver's current capabilities and the system's design and viewed accidents as inevitable. Therefore, the potential for accidents must be anticipated within the design of the system.

David Shinar's first summary of the theory of driving (1978) referred to concepts such as individual differences in driver capabilities, the driver as a limited information processor subject to distraction, and driver education/experience. He recognized that a driver might not see a conflict because their visual scanning fails to pick up the threat, but they also could miss the threat because they had earlier failed to anticipate its presence. He also included the newly made recognition that drivers may intentionally choose to commit errors for their own reasons, like suicide or pleasure seeking (Treat, Tumbas et al. 1977).

Michon's (1985) influential summary highlighted the disconnection between information availability and behavior. He reiterated his earlier concept of a three-level control hierarchy including strategic, tactical, and operational levels of control (Michon 1971, Michon 1979). He also described the difference between modeling driving from a behavioral conditioning point of view where behavior emerges from the driver's traits or experiences and motivations with behavior resulting from the transient psychological state of the driver.

Michon went on to summarize several risk-based driving models which posited, in various ways, that drivers adjust to environmental risk via the allocation of psychological resources. The most important of these theories was posited by Wilde (1982), which states that drivers have a target risk and adjust their behavior to maintain their risk at that level. Therefore, environmental changes made to increase safety may reduce the attention given, potentially negating the anticipated benefits of the intervention (Treat, Tumbas et al. 1977). Several studies were subsequently performed in an attempt to refute this theory, but they only reinforced the concept that as the risk was reduced by a safety improvement, drivers compensated by increasing their speed or risky behavior.

In his conclusion, Michon made a clear distinction between what drivers are capable of doing and what they actually do in practice. Urban environments frequently suffer from issues related to these identified psychological forces. Safety improvements that reduce crashes, like wider lanes or conflict reduction designs ultimately communicate to the driver that their full attentional resources are not required. In turn, this results in behaviors that accommodate the driver's safety but are inadequate to protect vulnerable users.

Ranney's (1994) summary updates the range of risk theories being debated at the time to identify the nuances of risk-taking in terms of minimizing the attention required for driving (Janssen and Tenkink 1988). He brings together the concept of attention switching within selective attention as well as mental workload limitations (Hancock and Matthews 2019) to conclude that cognitive processing speed is directly related to collision propensity. He highlights the differences between data driven and memory driven processes, noting that pre-attention (priming for attention before entering a situation) and conspicuity assist drivers in identifying threats within three levels: passive noticing, global search, and specific scanning, an extension of Michon's operational control hierarchy (strategic, tactical, and operational control). The concepts of active control and automaticity are described along with Wickens' Multiple Resource Theory, a highly influential concept that describes how multitasking can occur when the mental resources used don't overlap while task performance degrades when the same mental resource is required to perform the tasks (Wickens 1984). For instance, a verbal and visual task can be performed simultaneously with few performance impacts, but reading and conversing consumes the same verbal processing resources and therefore compete. Ranney ties Michon's control hierarchy (strategic, tactical, operational) with a behavioral hierarchy (knowledge based, rule based, skills based) and through this synthesis recognized that drivers are barely conscious of skill- and rule-based decisions.

Fuller's (2005) summary focuses on the ways in which the difficulty of the driving task is mediated by the decisions and behaviors of the driver via two critical observations. First, task demand is under the driver's control via speed selection. Second, the preferred level of arousal guides the driver in selecting that preferred level of task demands.

Vaa's (2014) summary circles back to behavioral traditions, describing driving using the stimulus, response, reinforcement paradigm but from a neurophysiological perspective. He posited that the survival motive is communicated internally through the biophysiological affective response to stimuli like the heart rate acceleration that is later translated into the emotions of fear or excitement by the user. Using the concept of bounded rationality (Simon 1972), he concluded that because driving is a complex, time-sensitive process, drivers select sufficed (or "good enough") solutions from a limited subset of all alternatives that can be culled out of all possible alternatives, based on the driver's ability to maintain a pre-verbal, biophysiological feeling. Often, this state is equated to the pre-emotional state (or affect) of 'comfort.' Rather than a cost-benefit calculation made based on all alternatives, people automatically reduce the options they consider to an affectively critical and acceptable subset and choose the one that is "good enough" at maintaining a target feeling for the driver.

The final summary of driver theory is an update from Shinar (2017). In addition to recounting many of the concepts identified above, he highlighted the concept of mental schema: sets of experiences that generate relevant rules of behavior, like the rules for obeying a STOP sign. He also describes the three phases of situational awareness: perception, comprehension, and anticipation, as well as the theory of planned behavior, in which norms lead to attitudes, which lead to intentions, that work out into behaviors.

Current driving theory is exploring two main thrusts: incorporating the burgeoning field of neuropsychological research into operational systems, and understanding the human machine interactions required to implement autonomous vehicle systems. These are not mutually exclusive. Pre-emotional bio-physiological responses are frequently called upon to help understand stress and workload in the context of driving automation. As we begin to understand how our bodies and neurology respond to driving environments, these responses become both a model for automation systems and a potential cue for takeover when the driver is overloaded or under resourced.

CHAPTER 2:DRIVER MENTAL FRAMEWORKS

Many of the driving theory formulations identified in the previous chapter foreshadow or mirror the mental frameworks that are critical to an urban area. Others document the same principles, but have dramatically different implications between roadway and street applications. In a typical roadway style environment, human factors provide an input to the driver but are not the principal mechanism for managing their behavior—the laws of physics are. In an urban space, the laws of physics rarely provide sufficient input to the driver to change their behavior, so these mental frameworks must take on the primary role to shape driver behavior and physics becomes a supporting tool where it is needed. There will still be circumstances where a physics-based solution may be useful. Chicanes, raised intersections, or speed tables can be used to enforce an unavoidable consequence at specific locations that require more forceful intervention. However, for the most part, these physical interventions treat the symptom rather than the root cause. Speed may be reduced in those locations, but drivers will increase their speed around them in order to make up the lost time and they will bring only minimal attentiveness to the task, focusing only on the intervention, not the vulnerable users or context of the space. The mental frameworks we have identified allow us to diagnose the causes of our drivers' behaviors so that we can correct it if possible or understand that it cannot be corrected in that sub-context .

Speed and attention can be managed in nearly every situation, but competing interests and risk tradeoffs may mean it is not always wise to do so. Environments that demand full attentiveness from the driver will also fatigue them, which can ultimately generate real accidents—unintentional mistakes rather than the less conscious violations of the standard mental schema. They also give policy makers the ability to make informed choices about a host of transportation and land use issues. This foresight is rare today. The advice policy makers receive is often driven by competing interests with their own agendas, subject to the whims of the current season. The ability to understand the cause and effect relationships that generate the outcomes they see grounds those choices in reality.

As we described in the introduction, we are defining urban mental frameworks as **the social and psychological principles that uniquely apply to face-to-face urban transportation systems that can be extrapolated from well-established pure science research in neurology, psychology and sociology.** These principles are supported by the research findings within this project and others. Some of these frameworks are extensions of the psychological principles we have used for decades within roadway design, but may have a slightly different application in an urban setting. This chapter describes each framework in terms of the theoretical research that originally identified the concept and then provides highlights of the research findings within our report or within other research studies that support its application in urban space.

2.1 Thinking Fast and Hypnotically

Theoretical background. In Dr. Daniel Kahneman's landmark work, *Thinking Fast and Slow* (2011), he describes two modes of thinking, System 1 and System 2, as if they were two different people that operate within our psyche. System 1 responses are automatic, unconscious, gut-level emotional reactions to situations and stimuli and they occur far faster than our flow of language can capture it. System 2 thinking reflects the slow, effortful, logical, thought processes that we think of as rational thought. These thought patterns are theoretical, verbal, sequential, and reflective. System 1 responses may be understood by our System 2 metacognitive processes later (thinking about thinking), but do not require metacognition to occur. Driving is the ultimate over-rehearsed skill and the statistical rarity of vehicle incidents hints that drivers' System 1 resources are well trained at noticing salient information as it is needed.

However, urban driving straddles the boundaries between System 1 and System 2. Although many of the skill based interactions are deeply entrenched in the System 1 thought patterns, vibrant urban settings generate a much higher level of conscious and interactive attention than suburban or highway settings. The key to understanding this is in the hypnosis literature.

The initial description of highway hypnosis (Williams 1963) relied on an incomplete understanding of the distinction between a wide range of trance states and a hypnotic state. His descriptions included instances of hypnosis, even including the hypnotism of two students and their somewhat successful driving excursions. He reports that their response time was affected, but few errors or lapses occurred. However, most of what he described as highway hypnosis was associated with fatigue, drowsiness or microsleeps and the attention issues associated with those states (Hancock and Verwey 1997). Since then, neurological studies have identified one of the primary characteristics of hypnotism as an elevated level of focused attention to the target of the hypnotic state along with the suspension of the metacognition/self-monitoring systems in the brain's executive functioning centers in the frontal lobe (Rainville and Price 2003, Egner, Jamieson et al. 2005). Since driving requires significant mental resources, it is not surprising that the mental effort required to self-monitor would become less featured and therefore less involved as drivers gain experience. In essence, drivers train themselves to enter a semi-hypnotic state that reflects high alertness and awareness of the road and its statistically probable conflicts, but only minimal feedback from their metacognitive architecture unless it is necessitated by threat or reward. We find additional data supporting this idea in the relationship between response times and risk probability (Muttart 2004, Muttart, Dinakar et al. 2016). Higher risk threats generate shorter response time, which is another expression of System 1 processes.

Attention States in Driving. Attention plays a critical role in driver behavior, particularly in urban settings. A stimulus that fails to engage conscious attention (System 2 thinking) may be acted upon but is lost to subsequent processing and then, in turn, to memory. Much has been written about Driving Without Awareness (DWA) (Charlton and Starkey 2011). Recent research has found that when drivers are queried in the moment about the traffic situation, they exhibit complete recall of the details, however, that recall diminishes dramatically over time (Richards and Charlton 2020)[2]. Without elevating their thought patterns into System 2 or metacognitive

[2] This is likely an instance of the Zeigarnik effect (1938), a trained memory nuance first noticed in the ability of café waiters to retain complete details of an entire table's orders without any notes until that table leaves, at which point none of the details remain in their memory.

thinking, the memory is lost. Because most of driving is a System 1 type of thinking, it is quite good at predicting statistically common issues that pose an immediate threat, physically or emotionally. It is not as proficient at predicting statistically rare occurrences, like the presence of a pedestrian or bicycle in a suburban or highway setting.

These System 1 thinking patterns are fundamentally motivated by personal reward or risk. Without a personal motivation to maintain attention, mental resources will be conserved as Vaa documented (2014). However, the risks to the driver from a pedestrian or bicyclist are largely external. The vast majority of the risk of serious injury or fatality is borne by the vulnerable users. The increase in speed and risky driving behaviors identified during the COVID 19 lockdowns of 2020 could be attributed to the lessened expectation of seeing people in such spaces allowing for a level of automatic driving behavior that would not be possible under typical urban conditions (Katrakazas, Michelaraki et al. 2020). However, directly interacting with other human beings has always had an inherent risk/reward dynamic that activates System 1 operations if the conditions are right.

Urban driving, like all driving, is largely managed using System 1 resources. In our multitasking analysis, nearly 30% of the drivers were engaged in a second, third, or even 4^{th} tasks simultaneously as they drove, even in the densest environments. However, when vulnerable users are in the space, there appears to be a higher level of conscious engagement (System 2) because multitasking decreases and vulnerable users present in the space were observed at more than a chance rate, particularly when they were within human perceptual limits.

2.2 The Priority of Human Faces and Emotional Body Language (EBL)

Theoretical Background. The most critical difference between urban and non-urban spaces is that drivers are regularly in face-to-face contact with other people. In his landmark park study of New York City, William Whyte (1980) found that "*What attracts people most…is other people*." Our eyes are drawn to see people subconsciously and reflexively. In a fixation test with paired scenes with and without people, the first fixation was on the person in the picture 2/3 of the time (Fletcher-Watson, Findlay et al. 2008). Even in crowded assemblies of pictures and at eccentric angles up to 16°, a human face exerted a significant recognition advantage over non-faces, even clock-faces (Hershler, Golan et al. 2010).

Humans are preferentially hard-wired to recognize other human beings in nearly all conscious attentional states. We even see faces when they are not there: pareidolia is recognized as a nearly universal innate ability to perceive faces in everyday objects. Liu, Li et al. (2014) found that, when primed to do so, normal men were able to see faces or letters in images of completely random noise about 1/3 of the time. There is a specific portion of the brain activated when identifying a face (the face fusiform area) which is different than the areas that activate when identifying letters or shapes. In the somatosensory cortex of the temporal lobe, a stripe that runs vertically along the center of the brain, the face takes up the lower half of the space on both sides of the brain (Gleveckas-Martens 2016) and the entire area is accessed when visually processing Emotional Body Language (EBL) (De Gelder 2006).

Neuropsychologists have identified specific brain wave patterns and pathways that are activated when perceiving the human face and emotional body language (EBL) in the Face Fusiform Gyrus. EEG readings show a strong negative electrical wave at 170 ms (N170) that is reliably tied to face identification (Bentin, Allison et al. 1996). The P3 wave (a positive wave at 300 ms) that is a hallmark of conscious thought takes nearly twice as long to emerge (Salti, Bar-Haim et al. 2012). A similar wave also appears when faces are in peripheral vision, though slightly later due to the reaction time it takes to locate them in the scene (Rigoulot, D'Hondt et al. 2011).

EBL elicits the same neurological signatures at nearly the same point in time, around 190 ms (De Gelder 2006), and the amplitude of the brain waves is tied to the intensity of the emotion depicted in both facial recognition and EBL cases. Extreme emotions also registered in the brain as early as 100 ms, prior to the N170 facial recognition wave. One study that looked at mismatched facial expressions and body language found that the body language signal typically won out (Meeren, van Heijnsbergen et al. 2005). Spatial reasoning prioritizes bodies and heads, with much faster recognition times for these shapes (Yu and Zacks 2016).

These brain wave patterns are prioritized by the dopamine reward systems and the epinephrine threat detection systems (Schultz 1998, Skuse and Gallagher 2009, Rypma, Fischer et al. 2015, Cheyette and Cheyette 2019). As patients with Alzheimer's and Parkinson's Disease patients lose their dopamine reward systems, their ability to recognize specific faces, read body language, and finally the ability to recognize that an image is a face degrades with it (Nyman, Belcourt et al. 1988, Assogna, Pontieri et al. 2008, Lotze, Reimold et al. 2009). The amplitude of the N170 wave is linked to the intensity of the emotional state of the person viewed, so as this ability degrades and the wave forms lose their intensity, patients also become apathetic, losing their own emotional mirroring reactions to the faces and body language they see (Wei, Ruan et al. 2019, Akdeniz, Vural et al. 2020).

The evidence that the amplitude, or signal strength, of the N170 wave varies with facial expression and the emotional content of the body language means that we are not simply looking for people, but trying to decode their emotional state (Hinojosa, Mercado et al. 2015). The innate priority that the human brain places on the identification of other humans that are in direct proximity has an ecological survival foundation in terms of reward or threat recognition. This survival motive and the neurological timing places it squarely in System 1 thinking. Every personal, face-to-face interaction between people contains potential risks and rewards and the brain prioritizes these interactions above nearly all other stimuli.

The Priority of Human Perception in Driving. Throughout every test and analysis in our study, human presence and interaction was the primary overriding theme. Human presence, the probability of human presence, and/or various proxies for human presence in the space consistently had the most intense impacts on driver behaviors, whether that was time on task, multitasking, acceleration, jerk, speed, and crash history. Once a vulnerable user was perceived in the space, multitasking rates dropped from 32% to 25%. The only limitations on this effect were the limitations for perceiving the emotional state of the a human beings in the space through reading facial expressions or emotional body language.

2.3 Limitations for Perceiving Humans in Time and Space

Theoretical Background. There are concrete temporal and spatial human limitations for locating a person within the field of view. In terms of static capacity, strong facial expressions can be reliably identified at up to 135 feet, including those showing happiness, surprise, and anger (Hager and Ekman 1979). Other, more extreme expressions including fear and sadness, could be reliably identified at distances of 90 feet--the width of a typical intersection. Humans exhibit preferential processing for faces in peripheral vision, although it requires a longer time to process. Although facial recognition can occur more quickly than conscious thought in the focal area, (300 ms), the typical reaction times for faces in peripheral vision (15° and 30° from focal center) were around ¾ of a second with fearful faces recognized slightly more quickly than neutral ones (Rigoulot et al., 2011). In free-viewing fixation tests where the person was not as prominent, the time to first fixation on the person was 3.5 seconds for cued respondents and around 4 seconds for un-cued respondents (Zwickel and Võ 2010). Viewing a scene for anything less than 250 ms precludes visual search (Cole and Jenkins 1980). Most glance durations in driving range between ½ second to 3 seconds, with the majority of the glances in the ¾ to 1.5 second range (Green 2002).

Perception of Human Presence in Driving. Most glance studies are performed in the laboratory while the individual is at rest in order to identify the person's performance limitations. However, the driving task occurs at high speed, in a cluttered visual environment, and at much farther distances than the biologically natural interactions that typically occur between people who are walking or riding. One of the most disturbing findings in this study was the infrequency with which vulnerable users are seen even when they are present. As a part of the NDS data tabulation, we asked whether the vulnerable users in the space were perceived by the driver. Up to around 25 mph, about 73% of the vulnerable users were observed but between 25 and 40 mph, this stabilized around 50% and then decreased again when speeds exceeded 40 mph.

Drivers tend to focus 1-2 seconds ahead of their vehicle (Underwood, Chapman et al. 2003) and at high speeds, this distance can outpace the driver's static ability to recognize faces or human movement patterns. The faster a person is driving, the less time any pedestrian or other road user in the scene can be observed.

Table 2 summarizes how speed and distance interact at the significant distance and time breakpoints. Studies of retroreflective markings at night show that a pedestrian can be identified at a distance of roughly 300 feet (100 m) (Sayer 1998), (dark gray areas). This represents the upper limit using the highest contrast condition possible: a `moving retroreflective shape on a dark background. As was mentioned earlier, facial expressions are discernable within a range of 90 (white) to 135 feet (light gray). Assuming a typical glance duration of 1.5 seconds, facial expressions cannot be consistently decoded at speeds any higher than 45 mph. As the table shows, even under ideal conditions, they may not be in the driver's field of vision long enough to be discerned.

Table 2: Time/Distance Relationship for Typical Driving Speeds & Glance Durations

						Distance travelled during typical glance types				
			Time elapsed (s)			N170	Min	Typical	alerted	unalerted
Mph	Kph	Fps	90 ft	135 ft	300 ft	0.17 s	0.5 s	1.5 s	3.5 s	4 s
20	32	29.3	3.1	4.6	10.2	5	15	44	103	132
25	40	36.7	2.5	3.7	8.2	6	18	55	128	165
30	48	44.0	2.0	3.1	6.8	7	22	66	154	198
35	56	51.3	1.8	2.6	5.8	9	26	77	180	231
40	64	58.7	1.5	2.3	5.1	10	29	88	205	264
45	72	66.0	1.4	2.0	4.5	11	33	99	231	297
50	80	73.3	1.2	1.8	4.1	12	37	110	257	330
55	89	80.7	1.1	1.7	3.7	14	40	121	282	363
60	97	88.0	1.0	1.5	3.4	15	44	132	308	396

Legend:
00 0-90 ft 00 90-135 ft 00 135-300 feet 00 300+ feet

The identification of a person in a cluttered field of vision will take much longer than the typical glance duration. In still photographs, it took roughly 3.5 seconds for an alerted respondent to identify the person in the picture. If the driver is traversing a location where a pedestrian is expected, both the biological movement of that person and the increasing prominence of the person with the approach of the vehicle could reduce this search time substantially. Assuming a worst case of 3.5 second search time, the presence of a person may be identifiable up to 30 mph, but their facial expressions and EBL are not likely to be discernable. If the driver does not expect to see a person, it is likely to take 4 seconds to identify them in a busy environment, which means that up to about 45 mph only the form of the person, but not their expression can be identified before the driver passes them. Beyond 45 mph, an unalerted person may not even see the pedestrian before they have passed them by. It is likely that when the driver loses the ability to decode the meaning of the faces and body language they are seeing, System 2 processes have no hope of assessing their impacts and System 1 thinking processes are likely to disregard them as irrelevant.

It has been well documented that a perceptual narrowing effect occurs at higher speeds (Rogers, Kadar et al. 2005). This is due to two factors: i) increased visual workload (Jo, Lee et al. 2014), and ii) focus on the roadway at a farther distance with higher speeds, generally 1-2 seconds in advance of the vehicle (Underwood, Chapman et al. 2003). This cognitive tunnelling effect is particularly prominent for inexperienced drivers. As drivers increase in experience, the variance in their glance behaviors widen horizontally, particularly for rural and suburban roadways (Robbins and Chapman 2019) but the higher the speed, the more tightly the glance clustering remains around the center of the horizon line and the intermediate distance along the roadway environment. One often disregarded result of the perceptual narrowing study was that during braking, the typical 20° cone of vision collapses to around 5° as the driver focuses on the bumper of the car in front of him or the stop bar, making perception of vulnerable users in the space far less likely.

It can also be argued that the perceptual narrowing that occurs at higher speeds is related to the decreased likelihood of human scale interactions because drivers are going too fast to interact and the people are too far away to interact with. Based on the perceptual limitations we see in the literature, a Facial Field of View can be constructed as shown in **Figure 1**. As was identified earlier, all facial expressions can be decoded consistently at 90 feet and extreme expressions can be decoded at 135 feet (Hager & Ekman, 1979) as shown in the vertical axis. Horizontally, the field of view may extend as far as 30° left and right due to the potential for head movements (Underwood, Crundall, & Chapman, 2011) but is more likely to reflect the 20° Useful Field of View (UFOV) width identified by Ball and Owsley (1993). Underwood, Chapman et al. (2003) found the anchor point for most visual driving sequences was in the 1 to 2 second range ahead of the vehicle at its travelling speed. Scaling off figures from Rogers et al (2005), yields a perceptual narrowing decrease to 60% of the UFOV when speed increased from 18 mph to 68 mph[3]. Assuming that this narrowing occurs linearly between those speeds, a visual anchor oval can be generated for each speed, centered around 1.5 seconds in advance of the driver, with the near and forward edges set at the 1 and 2 second distances, respectively. Using these dimensions, the maximum static corridor width for face-to-face interaction is 60 to 90 feet when the driver is sitting still or proceeding at walking speed, although they may be focusing much closer than this. The surprising result was that the combination of the longer focal length with the narrowing of the visual field at higher speeds ultimately preserves this 60 foot wide corridor regardless of the speed. Perceptual narrowing happens in an angular sense, not an absolute sense. This has been confirmed recently in a simulator study evaluating pedestrian eye contact and safety to cross. Full eye contact was identifiable in the data at the 60-75 foot range (Onkhar, Bazilinskyy et al. 2022).

It may also be important to note that the longest distance typical of the driver's oval-shaped viewshed reaches the 90 feet boundary at 35 mph and reaches the 135 foot boundary at 45 mph. Above 35 mph, a driver that chooses a focal length 2 seconds in front of the vehicle is already looking farther ahead than they can see detailed facial expressions or emotional body language. Drivers trained to scan a longer distance by defensive driving techniques may be better equipped to see vehicles ahead but are less likely to see vulnerable users at speeds above 25 mph.

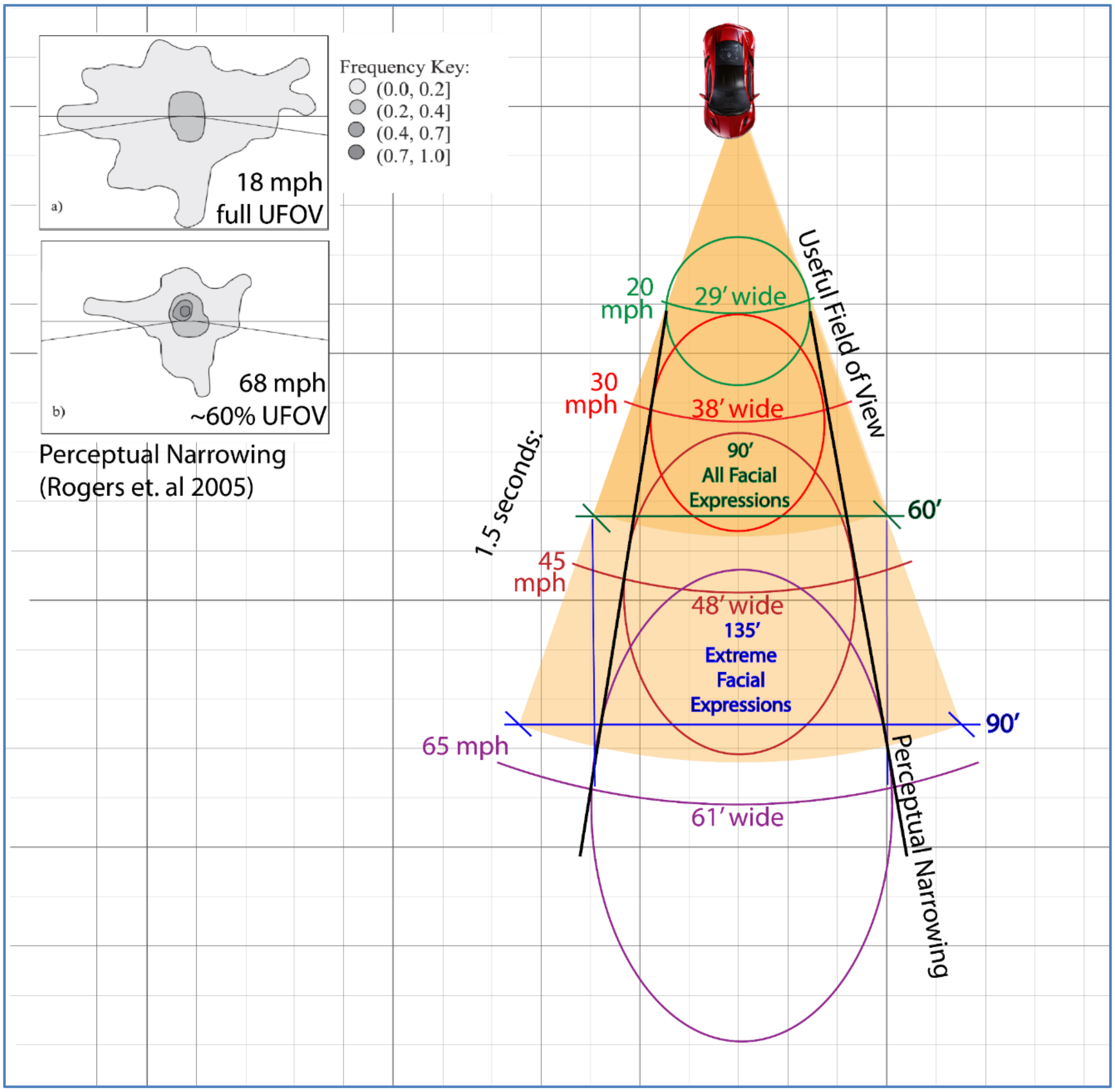
This is not generally an issue for highway driving because pedestrians are rarely within 30 feet of the driver laterally, and when they are, they are often quite conspicuous because of the wide recovery zones. However, stroads (high-speed corridors with multiple commercial uses) pose a particularly difficult problem since pedestrians may use these corridors, or even try to cross them while drivers are moving at speeds that make both recognition and reaction difficult if not impossible (Marohn Jr 2019). These locations prove to be the most dangerous for pedestrians. This effect may also explain why highly conspicuous workers in construction zones are still at significant risk when working on high-speed highways (Whitmire II, Morgan et al. 2011). A

[3] The Rogers, Kadar, & Costall team were consulted to confirm that the angular width of their figure reflects the typical 20 degree UFOV.

detailed discussion of the results within our study that confirm these limitations is provided in the next section.

From an anthropological standpoint, a cursory evaluation of historic city centers around the world yields an equally interesting observation. Within the areas constructed before the automobile, arterial streets are rarely wider than 60 feet from building face to building face. The only exceptions are in market squares which can extend to around 140 feet in width and around 300 feet in length. This may be a reflection of a pedestrian's inability to passively surveil the corridor beyond this width, requiring the engagement of System 2 resources rather than the more effective System 1 monitoring.

Figure 1: Facial Field of View



2.4 The Conditioned Anticipation of People (CAP) Psychological Model

Theoretical Background. Building on the previous three mental frameworks, the concept of operant conditioning adds another nuance to driver behavior. System 1 is trained in a probabilistic fashion through experience. In a landmark experiment, Bechara, Damasio et al. (1997) found that when faced with a rigged card decks, normal participants began to prefer the more favorable deck long before they were conscious that there was any difference between them. This means that System 1 resources have the ability to recognize reward or threat states based on their probabilistic experience long before we are conscious of even the most subtle of distinctions. As human presence is neurologically prioritized in terms of both threat and reward, there is no reason to believe that drivers would fail to anticipate their presence if that presence were regularly close enough to the vehicle to generate that type of neurological response.

The CAP Model of Urban Driving is one of the primary contributions of this research effort. As we identified in the previous section, speed and distance can reduce the probability of the neurological reward and gut-level threats inherent in human interaction, lowering the level of active attention required and generated by the environment. The Conditioned Anticipation of People (CAP) model posits that attention is preemptively elevated when drivers anticipate that face to face interaction is possible based on their experience both in terms of human presence and human proximity. This causes drivers to move from "driving without awareness" states into perceptual metacognition—a mental state where the driver recognizes that they see something critical that requires a more engaged level of monitoring.

This type of thinking sits at the boundary between System 1 and System 2. As Starkey and Charlton identified, this type of monitoring is not subliminal because it can be queried in real time, though rarely arises to the level of System 2 logical or verbal thought. The trigger to reengage these human surveillance systems is developed based on the dimensions of the space (ability) and the driver's previous experience within it and other similar spaces that contain features that imply that human beings are likely to be present (conditioning). It is important to note that the metacognition required may still remain below a cognitive/logical level, at the social perception stage not the social cognition stage (Pineda and Hecht 2009). In essence, this means drivers are able to recognize that they saw something important but does not necessarily rise to the level of verbal expressions within their thoughts.

It may be feasible for drivers with extensive experience in densely populated CAP environments (like delivery drivers[4]) to operate with more automaticity, possibly by disregarding or automatizing all but the most critical of personal interactions, but the vast majority of the driving public experiences these contexts as a small subset of their overall driving profile and therefore must retain less automatic situational awareness. It is important to recognize that this elevated

[4] Interestingly, taxi drivers are unusually attuned to human presence. Taxi drivers are doubly rewarded when they see many of the faces in their environment due to the rewards associated with picking up a fare. Borowsky, A., et al. (2010). The role of driving experience in hazard perception and categorization: a traffic-scene paradigm. Proceedings of World Academy of Science, Engineering and Technology, Citeseer.

level of attention is engaged based on primal neurological mechanisms but is highly contingent on experiential conditioning. This is reflected in our data in that the probability of a vulnerable user in the space, the typical group size, and features like doorway density that imply human presence were some of the most critical factors in terms of time on task, multitasking, and whether a pedestrian was perceived when they were present.

When faces interact, there is an affective impact due to the dopamine reward systems and the involvement of the amygdala and the norepinephrine and noradrenaline neurotransmitter systems. This affective response is the underlying precursor to a fully experienced emotional reaction made up of the biophysiological responses that the body generates before the conscious mind can register an emotional state. In colloquial terms, it is our "gut" reactions. These pre-emotions imprint on the driver and reinforce those locations as CAP contexts. A CAP-type location that shows no human presence over multiple visits, or a consistently neutral affect, may subsequently be down-graded to a non-CAP context by the driver. In familiar, non-CAP contexts, drivers operate largely without metacognitive monitoring, relying on low-level System 1 resources which includes frequent mind wandering (Burdett, Charlton et al. 2019). This continues until a situation of uncertainty arises and metacognitive monitoring activity is recruited to sit in judgement over an affect-level ("gut") set of choices (bounded rationality). Incidents of high affective or fully emotional involvement further cement the incident in memory, in addition to the memorial imprint caused by the metacognitive processes. This leads to post-trip and subsequent trip recall, like remembering where you were pulled over for speeding, for example. A single person in a previously identified non-CAP context may fail to be perceived due to a mismatch between the driver's speed and their perceptual capacity, but if it is recognized, it is likely to be flagged as a potential outlier that brings full cognition to the surface momentarily, only to recede quickly into an automatic state. However, if the human interaction is repeated, if they are a familiar person, or if there is a strong emotional expression from that person, the area may be flagged immediately as a CAP-type location, with the driver actively looking for people over the next few trips, either confirming it as a CAP location, or non-CAP place based on that driver's subsequent experience.

The human limitations on the perception of faces described in the previous section, particularly the affective impact of the people in the environment, form the geographic boundaries of the CAP and dictate the operating speeds within the CAP. This is shown in **Figure 1**, the Facial Field of View, laid out in the last section. In our research, when the visual corridor width exceeded 60 feet, 85^{th} percentile speeds below 30 mph disappear. Past 90 feet in visual width, 85^{th} percentile speeds below 40 mph also disappear. That doesn't mean that a visually narrow corridor will assure slow speeds, but uncongested speeds will be high when the corridor appears wider than 60 feet. To maintain lower speeds on a regular basis, the driver also must anticipate that they will directly interact with vulnerable users in the space. When a roadway width fits within this scale and there are pedestrian-active uses like shops with doorways, on-street parking, driveways, crosswalks, and/or plazas, then CAP behavior occurs automatically, even if people are only present intermittently. Where people are rare or there are few contextual markers of CAP activity within this impact zone, driving behavior is likely to revert to a baseline, unmonitored state.

This poses significant issues for nighttime operations in two ways. First, it is far more difficult to see a vulnerable user in the dark and decoding their emotional pattern (i.e. friend or foe) in those conditions is far more difficult. They are also less likely to be in that environment during that time, usually for those very reasons. When we reviewed the effectiveness of the speed prediction formulas in dense areas with high levels of human activity, the predictions worked quite well for the overall speeds, but when the doorway density term was dropped, the predicted speed conformed quite well to the speeds observed overnight when people were no longer present.

In addition to our own research findings. One recent study has provided supporting evidence for this concept. It was found that a smiling pedestrian increased the percentage of drivers that would stop for them to cross ($p<0.001$), both at a marked crosswalk and at other locations on the road (Guéguen, Eyssartier et al. 2016). In addition, drivers proceeded at a lower speed after this smile-based interaction. The persistence of the behavioral change after the affective interaction supports the idea that it is not just the interaction itself, but the affective component of the interaction that more rapidly cements in the driver's mind that a different level of attention is indicated.

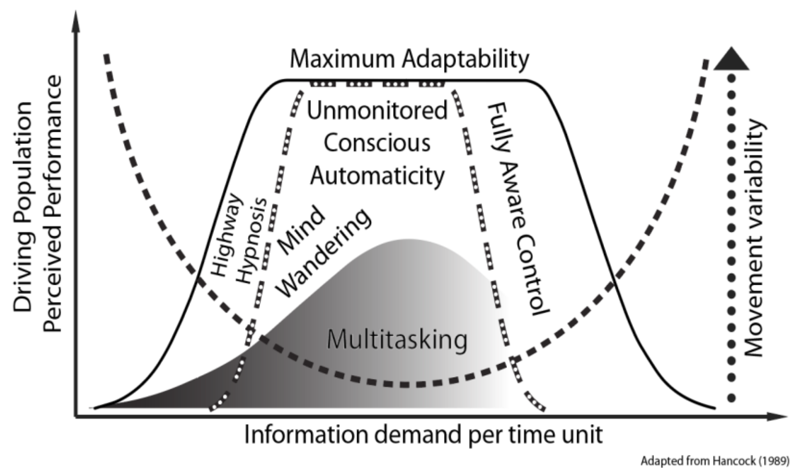
There is strong support for the CAP model in the relationship between the two attention variables and the available proxies for expecting to see VRU's in the context. The attention analysis in Volume 2 includes a canonical correlation analysis that shows two main impacts: workload and human presence, with nearly equal impacts. Human presence was not significant in these models, but the percentage of time that a human was seen by the driver and the ratio of times that they were seen if they were present were, as well as factors like the Walkscore, the visual width of the corridor and the typical group size.

2.5 Salient Novelty to Maintain Vigilance

Theoretical Background. While attention is especially critical in urban environments where the hazards may not be readily perceived, ultimately it is not just the observation of an individual hazard that is crucial, but the readiness to respond to a stream of expected and unexpected hazards over time and across a large field of view. In psychological literature this type of caution is referred to in terms of vigilance. Warm and Parasuraman (1984) defined "vigilance" as a state of alertness in which an appropriate response is made to a stimulus. Vigilance is hard work and performance tends to decline over time (Warm, Parasuraman et al. 2008, Dillard, Warm et al. 2013). Regardless of the vigilance task, humans are intrinsically motivated to minimize the use of mental resources, especially when the task is perceived as boring or uneventful (Rothengatter and Bruin 1987). One of the fundamental findings in Warm's work is that the frequency of the salient novelty helps to maintain vigilance over time. Video game makers have elevated this to a fine art, attuning and addicting players based on the most subtle management of challenge difficulty, timing, and reward. Social presence can improve vigilance performance without imposing additional stress, a finding that is critical for urban driving conditions (Claypoole, Neigel et al. 2019). This implies that adding a human being to the visual environment may be less stressful than adding a sign. Human presence can not only increase driver attention, but can potentially reengage drivers and their readiness to respond to the environment. However, within an urban setting, driver caution is not usually an issue of boredom, but an issue of overload.

Vigilance vs. Attentiveness in Urban Driving. Vigilance is a two-tailed phenomenon, with problems occurring in both underload and overload conditions as shown in **Figure 2**. Vigilance research has largely been focused on the left side of the figure, where reduction in the task ability over time results from underload (boredom) in highway or arterial type roadway conditions. Usually, the driver is motivated to minimize the mental resources allocated to the driving task, especially when it is perceived as boring or uneventful (Rothengatter and Bruin 1987), but in urban space responses are required at frequent intervals, the task is more difficult, and the environment is more engaging so the driver enlists a higher level of mental resources.

Figure 2: Sustained Attention in Driving



Lane position maintenance has been shown as a strong indicator of both inattentive and aggressive driving (Hicks and Wierwille 1979, Li, Merat et al. 2018). Aggressive driving (Murphey, Milton et al. 2009) and distracted driving (Choi, Kim et al. 2013) are both characterized by high variability in these factors as well as high variability in lane position (Wang, Li et al. 2019), while calm, attentive driving demonstrated lower averages and standard deviations for acceleration and jerk. In these highway (underload) situations, both texting and navigation tasks also increased jerk (Choi, Kim et al. 2013). These studies tie increases in jerk to aggressive or inattentive driving. The difficulty in those contexts lies in maintaining attention in low stimulus, large scale environments. This corresponds to the left side of the diagram where information demands are minimal and mind wandering can slip into highway hypnosis or fatigue states due to the lack of arousal needed to function.

However, in urban contexts, a similar change in the accuracy and adaptability inevitably arises due to increased demands on the driver. To distinguish between the typical analysis of vigilance performed in underload conditions, we are calling the ability to manage the high-information states on the right side of **Figure 2** "attentiveness." As drivers move from System 1 automaticity through perceptual metacognition to full conscious control, increasing movement variability signals that the driver is employing ever larger attentiveness resources.

In our acceleration, jerk and speed analysis, we were looking for the conditions where drivers manage their overload by engaging higher levels of conscious executive control on the vehicle position. This increased level of consciousness pulls drivers out of smoother automatic operations into higher levels of acceleration and jerk that we can measure in their driving patterns. Within driving, skill-based operations benefit greatly from System I automaticity. One study that looked at drivers specially trained to maintain conscious attention on the driving task showed a marked decrement in operational effectiveness in terms of lane keeping, car following, and speed modulation even with substantial driving automation (Young and Stanton 2007). When drivers use their full conscious attention on the task, they move around more within the space. This increased attentiveness has impacts on speed, acceleration, jerk, and lane position.

Acceleration, and jerk (speed's first and second derivatives) provide clues to driver attentiveness because they are closely aligned with what researchers call "driving style" (Guyonvarch, Hermitte et al. 2018). Consider the difference between a "sporty" driver that amply uses the brake and gas vs. an "eco-friendly" driver or a driver breaking in a new car. Both may attain the same speed, but the experience will be very different in terms of comfort and physical impacts. Some of the increases in jerkiness and the pattern of acceleration can be a result of congestion alone. However, the selection of drivers that were at or near the 85^{th} percentile speed should minimize these stop-and-go impacts.

When acceleration and jerk within the study epochs were compared to overall street-level driving, contextual variables that generated changes as the driver travels along the length of the street generated the most critical impacts, with doorway density hiving the highest effect. A high doorway density is a proxy for human activity but also reflects a rapid change in the businesses and land use along the corridor. The next most important was the UFOV sight distance, which measures enclosure, the sense in which a driving environment feels more like a room than an unending tunnel or field. It is defined as the distance to the nearest visual obstacle within the driver's 20° cone of vision. Block length also played a part as did Walkscore and the aspect ratio. Walkscore measures how frequently land use changes to generate complementary combinations within an area. Areas with a high Walkscore often have smaller businesses that change frequenty along the length of the blocks. When a corridor has a high aspect ratio, there's a dramatic break in the vertical walls that surround the driver at every intersection, especially near the edges of the day. The rhythm of open to closed space as the driver proceeds down the street provides another layer of interruptions.

2.6 Workload and Speed Choice

Speed choice has long been recognized as the primary means by which drivers manage the workload demands of a space (De Waard and Brookhuis 1996). Workload is the common thread that links each of the preceding mental frameworks. Workload has been analyzed in the human factors of roadway design for at least 40 years, but only in one direction. The design goal was to reduce workload in order to eliminate crashes and reduce driver fatigue. Even the forgiving road design concepts were intended to address when drivers were so unengaged that they left the roadway. However, in an urban space, workload is the primary control on speed and engagement. As was seen in the section on vigilance and attentiveness, both underload and overload conditions cause problems for drivers. Without sufficient engagement and arousal, drivers remain detached, using the highest levels of automaticity that System 1 can generate and protective of their own interests rather than those of the vulnerable users in the space. Therefore, rather than trying to unilaterally reduce workload, the goal in a walkable urban space should be to manage workload in terms of both quantity and quality. The desire to reduce the driver's stress is good, but a neutral impact only reinforces system 1 mindlessness. Environments that are pleasant and include people are more likely to operate at appropriate speeds and engage the driver in the context in positive ways.

Speed maintenance is the most obvious input and output in driving vigilance. Engineers often treat regulatory speed management as an input control on the driver's attention, assuming that a lower speed limit will automatically increase their level of attention. It is true that at higher speeds, drivers are less able to respond to unexpected threats. However, even if drivers abide by that lower limit, their information flow reduces, reducing the mental resources needed to navigate the space, which reduces the attention they give to the task accordingly. As the information load increases in quantity and attractiveness, attention is reoriented to the environment and away from mind wandering and distractions. A slower speed is the natural outcome, further allowing the driver to manage the information flow.

Throughout our research, two main concepts generate the most critical demands on the driver: the potential to interact with another human being and the rhythm of information that the driver processes as they move through the space. Drivers use speed choice to manage these demands. Therefore, speed is most dramatically reduced when all both of these conditions are present. When only one of the two conditions are met, speed is still reduced, but not as much. Where roadway designs have minimized the workload demand from the environment, a high level of automaticity can be expected which will result in minimal levels of attention, cursory vigilance, and high speeds. Unfortunately, spaces with high levels of congestion without human presence have a very high level of information demand, but no evolutionary ability to rally additional neurological resources to aid in that struggle. Congestion levels may be similar between a suburban arterial and an active urban street, but there are clear advantages in the quality of the workload and safety for environments that engage those resources.

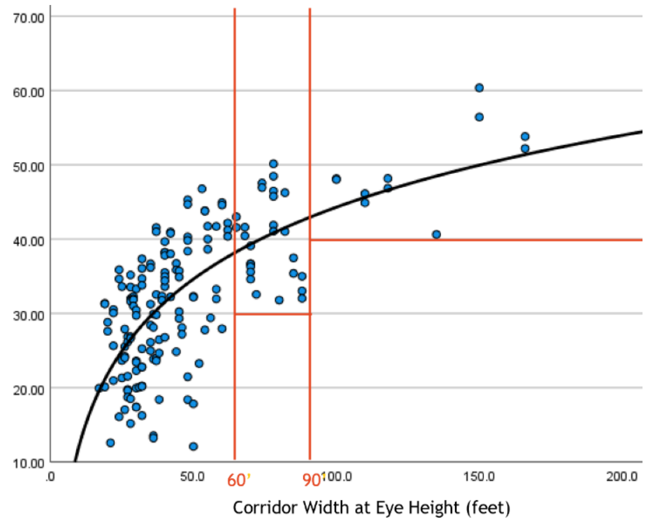
One of the most useful tools generated by this research effort is the ability to predict a roadway's 85th percentile speed. These prediction formulas are constructed directly from the mental frameworks and generally include variables that relate to whether a person will be in the space, the dimensions of the space horizontally, and the interruptions that the driver will experience along their path.

The initial motivation for this study was to identify what roadway designers could do to ensure that drivers would comply with lower speed limits, especially in areas that include high levels of active transportation. As **Figure 3** shows, there is a logarithmic relationship between the visual width of the corridor and the roadway's 85th percentile speed (r^2=0.491). Having a prediction formula that provides the ability to identify the speed outcome of a specific design is an invaluable tool that can be used to guide planning and policy decisions. A more precise model

(r^2=0.615) can be used if the block length and doorway density (doorways per 100 feet) are included:

85th %ile speed (mph) = -5.26
+ 9.90 Ln (eye)
– 1.58 (doors/100')
+ 0.0068 (block length)

Figure 3: Speed vs. Width at Eye Height



This formula appears to be quite transferrable across urban and suburban contexts. More accurate formulations can be generated for a specific community, but our field tests have found this to be accurate within about 3-5 mph for most situations. Unfortunately, when the visual corridor width (width at eye height) gets above 60 feet, no speeds are observed below 30 mph. An artificial depression of the 85th percentile speeds did occur occasionally, but only where the segment had a substantial proportion of the day in jam conditions. This skews the 85th percentile speed away from the behavior of the 85th percentile driver and the typical normal distribution of speeds that free flowing conditions generate. Above 90 feet, speeds below 40 mph no longer occur.

One unexpected outcome of the present investigation is the implication for wide roads within dense urban cores, where drivers appear to be just as inattentive as they are on the highway or in "stroad" environments. Density alone cannot create a space that is pedestrian focused and driver attention adjusts to this dynamic influence with great consistency. A vehicle-oriented city, typical of many of the suburban cities in the southern United State for example, can generate surprisingly low levels of driver attention. A major highway does not cease being a major highway because it goes through a downtown core, particularly when it does so with more than four lanes in width.

2.7 Event Segmentation Model

Theoretical Background. The Event Segmentation Model posits that "The stream of action in life, virtual environments, film, and narratives is parsed into events (which have) consequences for memory (Radvansky 2012)". These events are organized spatially and constitute a fundamental building block within our memory and mental processing structures. They are separated by horizons: boundaries or thresholds across which the mind resets. Researchers have noted that as we transition across the event horizon, our minds recognize the change and update our short-term memory, an phenomena called the location updating effect (Lawrence and Peterson 2016). Our ability to remember is directly tied to our ability to segment a sequence of information into discrete events (Kurby and Zacks 2008). As we cross an event horizon, our focus is on the transition itself and it is much easier to miss individual visual targets (Huff, Papenmeier et al. 2012). During the horizon transition, our visual processing resets to a wide scan of the environment and focal processing is delayed (Eisenberg and Zacks 2016). Our mental representations of the space in long term memory are bounded by these event horizons. Crossing the event horizon requires us to create or access our previous mental models of the new space and relinquish the mental model from the previous space, while scanning for unexpected differences. This effect is most well recognized in terms of forgetting things as you cross from one room to another.

Event Theory in Driving. Although the mechanical reorientation to the environment along the length of the path generated by blocks, stops, or potential conflicts has a clear impact on the speed and attentiveness the driver provides, the crash analysis hints that the spatial nature of event memory has an impact on behavior at intersections.

In the pre/post complete street analysis, we found a very different pattern for intersection and segment crashes that hints at this underlying psychological effect. Both for drivers and pedestrians, the context of the area, the roadway geometry, and the building configuration along the segment (during the event) are dominant factors for segment crashes but noticeably absent in terms of intersection crashes. What we think of as contextual features have an impact on segment-type crashes, but intersection-type crashes are driven almost exclusively by the scale of the intersection traversed, regardless of the mode. Drivers appear to be mentally resetting their attention and focus at the intersections, looking broadly at the overall space rather than looking out for individual targets or remembering the context that the driver just left. In one extreme example, the researcher, Gabriel Radvansky, related that he had received a letter from someone who regularly navigated a school zone that was interrupted by a roundabout. They found they often forgot that they were in a school zone during the roundabout navigation and had to abruptly put on the brakes not long after emerging from it when they remembered the reduced speed limit and noticed the students in the area[5].

A similar but less pronounced distinction is also seen for bike intersection crashes in terms of the building width and the painted intersection treatments. Paradoxically, painted intersection treatments had a positive impact in the segments but a negative or negligible impact in the intersections where they are located. If these treatments impact safety in the intersections, where they are located, this should improve intersection safety, but we see the opposite effect. We know in individual intersections where conflicts have been severe, the painted treatment and keyhole design is quite effective for reducing specific bicycle crash types, however the presence of green painted sections overall impacts segment safety not intersection safety. This can be partially attributed to exposure, in that cyclists may believe it to be safer to engage in conflicts with vehicles because the painted sections are there, but it is also a wider context-related issue. These painted sections occur both in the major intersections where event horizons more naturally occur and at minor conflict points that are swept up into the overall event rather than generating an event horizon. As they traverse the event horizon, drivers are focused on the big picture, not individual targets within it. The driver recognizes the lane painting in terms of an overall context where

[5] Personal Correspondence with the author dated 7/13/2023.

cyclists are more likely to be seen while in the segment but are not looking for individual cyclists during the transition.

This concept complements the longitudinal vigilance mental framework related to driver speed and attention. Block length, uninterrupted length, sight distance, and visual disruptions either contribute to the mental model for the event that we could label as the "segment" or generate an event horizon at an "intersection" due to the nature of the transition. Traversing the event horizon increases mental processing slightly, encoding the memory from the previous event, segregating it, updating it for the current event, and absorbing sensory information or accessing mental recall for the subsequent event (Swallow, Zacks et al. 2009, Swallow, Zacks et al. 2011). Therefore, these disruptions are not merely a mechanical impact on driving due to the stops or movement changes required to navigate them, but generate a recurring shift in cognition due to the recurrence of horizons between events. Any perceptibly significant change in the visual presentation based on jogs, a change in direction, or a dramatic change in context may also generate an event horizon. A full stop that takes a non-trivial amount of time spent in a different thought process at a signal could potentially even generate a separate memory event for the waiting period, distinct from the events approaching and leaving the intersection.

Conceptually, this can be tested with our own memory. If you were to mentally traverse a path that you drive regularly, it would be easy to parse that trip into unique spatial representations for events that are contained within distinct viewsheds or environmental types. For instance, I (Patricia) can readily identify 10 sequential event spaces along the 1.4 mile trip from my home to the local downtown area. Each of the events represents a unique mental model of a space divided by a change in view or a physical stop. I don't remember every single house or landmark, though I could find the most unique or familiar ones in my memory if I actively searched. For each event space along that trip, I have a distinct mental map that contains the typical environmental features, memory of past occurrences within that location, and typical behavioral expectations. Because that trip traverses a visually rich historic downtown network, the spaces are unique, compact, and easy to remember. There is one event space along that route that is broken up by a simple visual jog in the segment, but I find I am unable to think of the two spaces on either side of the jog in a unified way. In contrast, in my memory, a trip to a large commercial center located 17 miles away only contains roughly 20 unique event spaces, most of which are clustered at the ends of the trip, since the majority of the trip occurs along suburban multilane roadways and a limited access highway. That trip typically contains a substantial amount of mind-wandering where I am monitoring but not remembering the details of the path or the interactions between vehicles. This may have to do with whether the contextual change happens within the 60 foot corridor that is passively monitored by System 1. The areas that have much fewer event horizons all have large viewsheds both longitudinally and in terms of visual corridor width. When the configuration within the passively viewed window remains static, outside landmarks do not appear to disrupt the event memory structure.

The rate at which I am required to traverse event horizons is dramatically different: roughly 12 times per mile for the local neighborhood trip compared to one event every 0.87 miles on the longer trip, which includes at least one event that traverses roughly 4 miles along which I remember very little. Here the scale also appears to make a difference in my memory. Areas with a compact scale have more physical stops, but the changes in the visual flow in close proximity to the vehicle generate event horizons even where stops do not occur. On the contrary, in the limited access environment, even major changes in the vistas or available exit ramps do not generate memorable event horizons or distinct event spaces within my memory.

Every event horizon requires the driver to reorient their attention to the environment and mentally engage in order to traverse the event horizon's threshold. It is also possible that mind wandering or repetitive exposure may obliterate the event horizons entirely, allowing the driver to traverse large sections of their daily path without any memory of what occurred along the path, even at the transition points that were event horizons at one time. As event horizons fade into the overall trip after repetitive use, it becomes more difficult to go to a different destination along a familiar path, causing drivers to continue on "auto pilot" to their most common destination, even when they had planned to deviate from that path.

Event horizon theory may provide a useful way to approximate workload per unit of time. If we can understand what in the environment generates an event horizon and measure the frequency of horizons over time, this could provide a general approximation of the workload demands in the environment or at least should be considered as a portion of a workload estimation.

CHAPTER 3:SPEED-BASED DESIGN PARADIGM

In order to understand the design issues that are impacted by this research, a history of the non-motorized design standard evolution and detailed critique was prepared covering the Florida GreenBook, the AASHTO GreenBook, and the Florida Design Manual (see Appendix A.) From this critique, a new strategic approach has been crafted to address the regional needs of our communities and the safety of our vulnerable users. This strategy begins each project with an explicitly political discussion of the mobility needs that each roadway project meets within the overall network. This process is similar to the "right plant, right place" strategy that the Florida Department of Agriculture has successfully implemented to address xeriscape issues and water conservation. Just as there are no inherently bad plants, there are few inherently bad roads. Unfortunately, we have many roads that are attempting to perform more mobility functions than a single facility can support within a single right of way. The financial partnership that the FDOT provides to local communities for state-level facilities slants their policy decisions to vehicularly oriented roadways. To counter this, FDOT should consider policies that reinforce the role that local jurisdictions have in creating land use and transportation systems that provide balanced access for all modes on all facilities, not just the state system. The speed prediction formulas can be an invaluable tool in this process. When the land use and facility design are projected to generate speeds that are inconsistent with the community's long term multimodal vision, then a reassessment of the community's strategy to achieve that vision is the rational next step in their process to justify a specific design outcome, now and in the future.

In the past, we have framed this discussion around the concept of target speed, which is ideal from an operational perspective but fails to address land use accessibility questions. Of course, policy makers are quick to universally adopt a low target speed because they believe that it will facilitate multimodal operations and increase vulnerable user safety. Streets with low speeds are much safer for vulnerable users and roadways with high speeds drive them away. However, if a community desires a walkable, integrated space, the current and future land use are inescapable realities that are far more important than the facility design. A multimodal facility with ample multimodal amenities will continue to experience high speeds and low safety profiles for vulnerable users if the resolution of the land use mix, the proximity to individual businesses, and the dimensions of the corridor are not at a human scale. It's not possible to design a corridor that looks like a freeway where drivers will behave as if it is anything else. Add a transit dependent or non-driving population to the mix and the need to navigate high-speed systems on foot will inevitably lead to disaster. This is not just a problem of equity. It is also a long-term problem with aging in place and livability.

The choice to optimize throughput is incompatible with the choice to prioritize vulnerable users in the same space. A "choice" to balance between them on a single facility is a lose-lose proposition that accomplishes neither and endangers both. Once a realistic multimodal network assessment is performed, designers can determine the appropriate level of integration or sheltering that vulnerable populations require at each location based on the modal function that road performs within the overall network. The ability to predict the operating speed of the facility generates a feedback discussion about the modal purpose of the facility. If the design will not achieve a target speed that aligns with the level of integration or sheltering envisioned by the community, then there is likely to be a conflict in the needs and land use that the community desires to accommodate.

Giving the decision makers the ability and responsibility to recognize the function that each facility fills within their overall network allows them to make choices based on a clear understanding of the consequences of that choice. Not every roadway should be suitable for unregulated, close proximity interaction between motorized and non-motorized traffic. However, every network should provide complete connectivity for all modes. If a community is serious about mode shift, then land use mix, multimodal network connectivity, and flexibility are inescapable necessities. For multimodal travel to succeed, the community's goal should be increasingly smaller resolution between complementary land uses, at least for the modes that have a shorter geographic range and a ubiquitous network of interconnected facilities to support those modes.

3.1 The Benefits of Walkable Design

Walkability has always been framed in terms of serving pedestrians. We have assumed that there were few, if any, benefits to other user groups outside of the obvious aesthetic advantages. Our research findings indicate that the design characteristics of a walkable space have a cascade effect on drivers that provides a wide array of side-benefits in terms of driver behavior and engagement. Therefore, a fundamental design shift is required that distinguishes walkable urban spaces from roadway type environments based on the driver's limitations for recognizing pedestrians and bicyclists in that space and at the speed anticipated for that facility.

Should it be all that surprising that human beings are designed to manage the additional effort to be safe around vulnerable users if, and only if, they expect to be close enough to interact with them? Of course, we hope that to be the case and recognize that drivers should be more cautious from a cognitive point of view. No one intends to harm others and drivers are no exception. The surprise is that the response to human faces and movement are primal and therefore need not rely on cognitive mechanisms, which are frequently subject to distraction, motivational override, or forgetfulness.

We now know that elevated attention is only guaranteed when the environment is not just walkable but there are also people regularly walking in it that can be seen and anticipated by the driver. Therefore, the close-knit integration of vulnerable users within the cross section must be reserved for the spaces that are designed to take advantage of this primal, hard-wired capacity. Although individual drivers may safely operate in less alerting spaces, the statistical propensity for less attention and more multitasking makes multimodal interaction in these areas dangerous, particularly as distractions continue to increase.

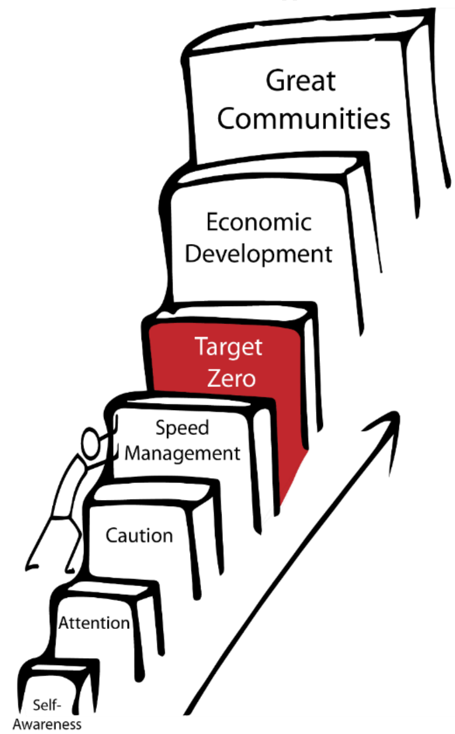
3.2 Integrating the Mental Frameworks into Design.

Shaping driver behavior for safe multimodal operations can be described as a domino effect as shown in **Figure 4**. As a profession, we have been working on speed management as our primary strategy for accomplishing target zero. This is not a bad approach. Reducing speed increases the time available for the driver to respond and decreases the inertia that kills. However, it requires more effort than is often necessary and by itself, may not address all of the issues that lead to crashes. For instance, a slow, inattentive driver may have more margin for error, but can still cause problems. In contrast, increasing self-awareness through human presence has a much less obvious impact in terms of the driver's perception but has a cascading impact on attention, caution, speed, and target zero, in addition to a host of other community benefits.

3.2.1 Reflexive Self-Awareness

The first step in the behavioral cascade is the anticipation of human presence in the environment as the driver enters or moves through the space. Drivers that know they are being watched or expect interaction monitor their own behavior more closely (self-awareness). This is most naturally built up over time through the driver's experience of interacting with human faces and movement. Spaces that have regular human presence are characterized by high levels of mixed land use, frequent active doorways, and short blocks. While the overall density of an area reflected in the building height or an enclosed space may suggest that human presence should be there, if that driver experiences that space without people in it regularly, they will eventually disregard it, no matter how beautifully it is designed. **In short, reflexive self-awareness comes from the learned expectation that human interaction is eminent.**

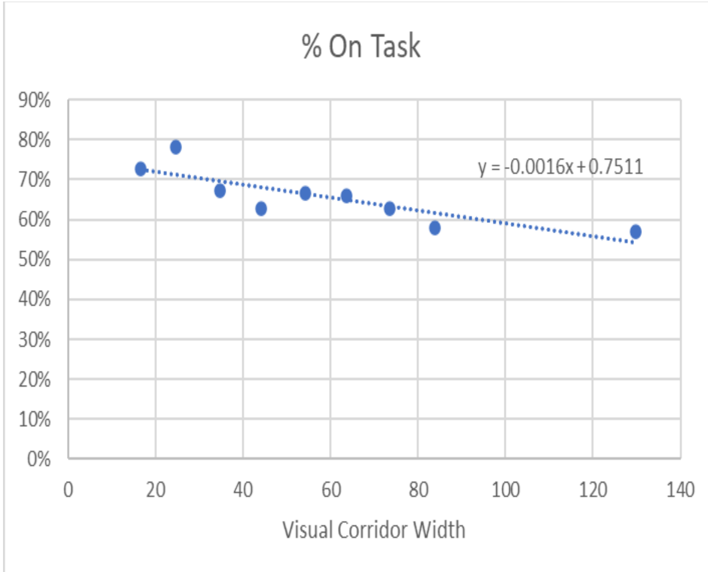
Figure 4: The Driver Behavior Domino Effect



3.2.1 Attention

Statistically, **how wide the corridor appears to the driver is the most critical factor for increasing driver attention and reducing multitasking.** This effect is strongest with the width of the corridor at eye-height, but is also strongly impacted by the curb-to-curb width. As the corridor width increases, on-task driving declines as a percentage of the population (**Figure 5**). This is due to the driver's limitations in terms of being able to see and decode facial expressions or recognize biological movement as described in Section 2.3 and **Figure 1**.

Figure 5: Percent of On-task Driving



The features that are typical in walkable urban spaces can directly contribute to elevated attention level even without priming due to the driver's experience with other similar features, but this effect will quickly fade if it is not reinforced with real human interaction. Gateway features can initiate an elevated attention level as can an active streetscape, engaging wayfinding, or surprising (not shocking) features like the addition of painted intersections. This novelty is important in the strategic or decorative components of the environment, but it is critical to maintain the consistency that the driver expects with respect to their skill-based operations, like turning, stopping, or maintaining their lane position. Trying to decode a novel left-turn sign or signal treatment while in a visually exciting environment adds unnecessary workload without any compensating dopamine (rewarding) or oxytocin (emotionally connecting) benefits.

3.2.2 Caution (Vigilance)

Capturing driver attention requires a corridor narrow enough to see and interact with people. **Maintaining driver attention in a sustained cautious pattern requires a repetition of interruptions.** The best interruptions for urban drivers are people, but other interruptions can also generate an event horizon that requires the driver to reevaluate the environment or access their memory of it. Corridor width remains critical, but not sufficient for maintaining this vigilance. The driver must also interact with repeating conflicts, frequent doorways, short blocks, enclosed spaces (which open up at intersections), overhanging lines of trees, and terminated vistas.

Although access management has been wildly successful in terms of vehicle-on-vehicle crashes, eliminating a cross street doubles the block length, which can increase the 85th percentile speed 5 mph or more. Because crossing maneuvers are limited to controlled locations, the geometric design of the remaining intersections also increase in scale, which shifts bicycle and pedestrian crashes to intersections rather than segments. These strategies often trade low-speed, rear-end crashes for higher speed angle crashes. They also increase the spacing between non-motorized crossings, often beyond the comfort of the pedestrians in the space, encouraging them to cross at unmarked mid-block locations rather than at the intersections where active control measures are typically located. Access management strategies are beneficial in flow optimized corridors like arterials and major collectors. However, in lower level streets and integrated spaces, they may not be appropriate.

3.2.3 Speed management

Our research confirms that speed management is a symptom of increased workload. **Speed management occurs naturally when there is adequate side-friction, which results from a combination of narrow corridors, with obstacles in close proximity to the vehicle, and frequent interruptions along the direction of travel.** Again, this effect is most pronounced when it is human presence that is close to the vehicle and repeatedly seen. Because of the dopamine and oxytocin impacts that are tied to seeing people, this type of additional workload may not be as stressful to drivers as workload induced by visual clutter or congestion.

A physics approach to speed management has a long history of undeniable success and can complement the context-based speed management strategies just described. Vertical and horizontal deflection are nearly impossible to circumvent, but the effect is generally limited to the area in the immediate proximity of the deflection. Between the treatments, drivers often attempt to make up for lost time unless there is a consistent reason to do otherwise. Traffic calming devices like speed tables/humps or chicanes are quite effective as gateway treatments around areas that are likely to have pedestrians or bicycles in the roadway, like around a park or at the ends of a street market.

3.2.4 Crashes

In urban environments, overall crash experience is directly tied to how rushed or vigilant the population is. Spaces that elicit high levels of speed management because the driver is required to be more vigilant have lower crash histories. Drivers in flow optimized corridors are far more likely to be in all types of vehicle incidents. **There is a tradeoff in walkable urban spaces. There are more crashes overall but they tend to be low-speed, low-impact collisions, and pedestrian and bicycle crashes are significantly less common.** This is the goal within a safe systems approach: wherever possible shift crashes toward lower inertia, lower consequence incidents. Workload does have an impact on crash density, but this effect only explains about 10% of the correlation between crashes and driver behavior.

In terms of environmental features, exposure effects dominate. Active corridors have more crashes. However, the features that support human perception from the driver's perspective decrease overall crashes. There is a slight increase in vulnerable user crashes due to exposure, as would be expected. Features like the visual width of the corridor, the roadway width from curb to curb, doorway density, and block length all have a significant impact on crashes, with more walkable environments having fewer crashes for both vehicles and vulnerable users.

The addition of complete streets features to a corridor often trades out segment crashes for intersection crashes. The additional space provided to non-motorized modes is beneficial along the segment, but adds to the scale of the intersection. These projects often include additional access management limitations which aggregate conflicts at the intersections and also increase their scale, which is the most critical predictive factor for crash rates.

3.2.5 Driver's Perceptual Limitations

If we want drivers to recognize, remember, and anticipate human presence in an urban space they must be close enough to the driver for them to see and decode facial expressions or at least close enough to decode the emotional tone of the body language that is occurring. Both typical low speed and high-speed glance behaviors indicate that drivers are viewing a corridor roughly 60 feet in width and although they may be able to see features or people outside of that corridor, there is far less frequency and reliability outside of that range.

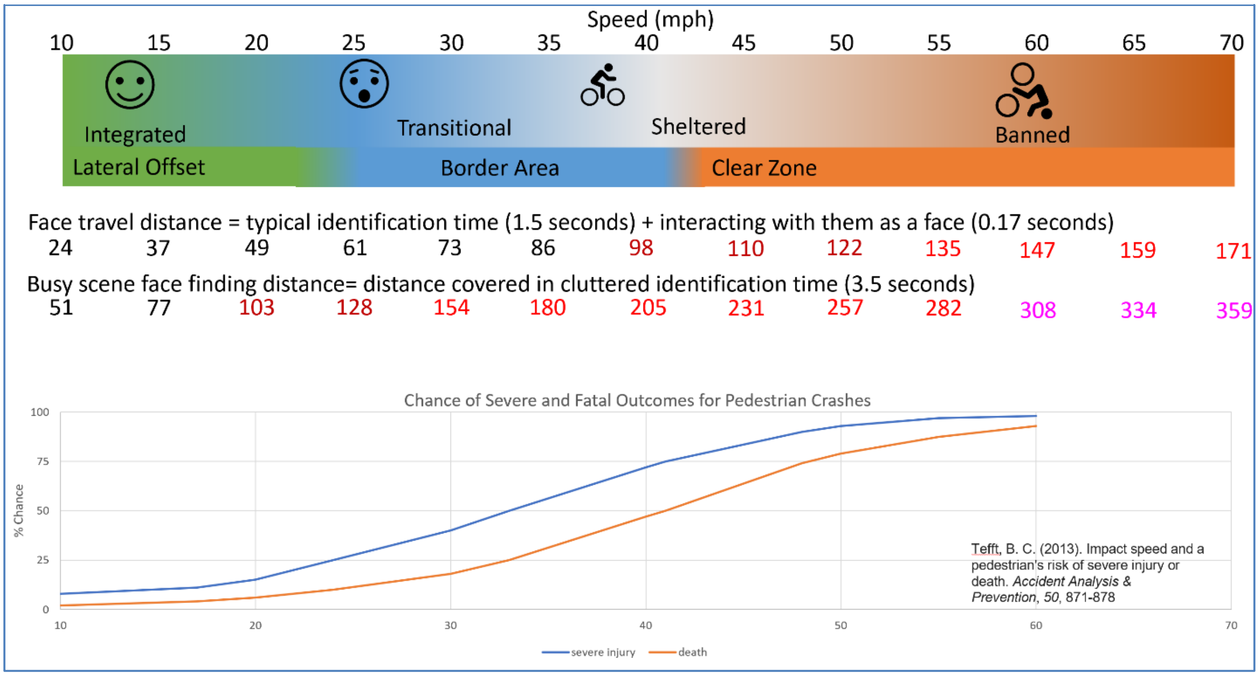
One of the most disturbing findings in this study was the infrequency with which vulnerable users are seen when they are present. At the slowest speeds, about 72% of the vulnerable users were observed but between 25 and 40 mph, this decreased to roughly 50% and decreased again when speeds exceeded 40 mph.

Our research provides a compelling explanation for the reason stroads are often so dangerous for pedestrians and are often held up as the primary examples of roadways that are "dangerous by design." A stroad is a wide roadway, often an arterial, that attempts to provide a high level of mobility and property access at the same time, which results in visual clutter, frequent driveways, retail strips, and high velocity capability (Marohn Jr 2019). Although the 'complete streets movement' has, with the best of intentions, attempted to retrofit walking and biking into these roadway configurations, neither drivers nor pedestrians feel safe enough to use them for modes other than driving. These areas, particularly C3 and C4 contexts, are typically where the majority of the non-motorized crashes occur in Florida (Abdel-Aty and Cai 2021).

3.3 Integrated, Sheltered, and Transitional Design Paradigm

The first critical step to address vulnerable user safety issues is to be explicit about the definitions and consistent use of the terms, "street", "road," and "highway". Streets should be clearly defined as very low speed facilities that function as destinations where human activity is regularly anticipated within and around the roadway. The term "highway" should be used for limited access facilities or high-speed surface-level roads that are intended to optimize throughput. It is the confusion of these terms and their underlying activity characteristics that give rise to high-conflict, high-inertia, high-crash facilities. Establishing which portions of a project are intended by the community as a destination and which are intended as a through-path is a critical first step toward Target Zero. **Figure 6** provides an overview of the speed-based design strategy for integrated, sheltered, and banned spaces.

Figure 6: Integrated, Transitional, and Sheltered Design Strategy



Our analysis also indicates that above 25 mph, the perception of vulnerable users in the space drops from roughly 73% to around 50%. Therefore, the primary assumption used in this strategy is that facial recognition and body language decoding are the critical perceptual limitations for shifting driver behavior. Perceiving a human form takes at least 1.67 seconds, but could take up to 3.5 seconds in visually busy environments. When speed is factored in, it becomes clear that between 40 and 55 mph (operating speed), it becomes perceptually impossible for a driver to perceive and process human-scale interaction and therefore, the interaction between vulnerable users and drivers should be severely restricted or banned.

In urban settings, where the environment is visually cluttered, it takes much longer for pedestrians to be located within the scene. Maintaining operational speeds below the 20-25 mph range allows the driver to have adequate space to identify a less obvious risk before they reach it, making integrated operations much easier to accommodate. This longer time-frame also balances the driver's perception/reaction time needs with the pedestrian's need to stay clear of any vehicles in the space.

Speeds between 25 and 40 mph constitute a gray area where there is significant inertia-based risk to vulnerable users while the limits of driver perception make their identification difficult, but not impossible. From a probabilistic standpoint, we cannot rely on the driver to perceive the risk in time to respond to it. There remains some risk to both pedestrians and drivers at this speed, and therefore designs that generate operational speeds in this range should be minimized, recognizing that congestion and network constraints make avoiding it nearly impossible. Therefore, adding visual cues or side-friction (door-scrape) risks to the driver can increase their desire to maintain their lane position with appropriate vigilance. To balance the risks to both drivers and non-motorized users, a border-area strategy is appropriate. Visual obstacles should be placed between the driver and the vulnerable users, but breakaway or small diameter trees should be considered to minimize the potential vehicle collision hazards in the middle of the night when speeds increase into dangerous ranges and pedestrians and bicycles are nearly non-existent.

This distinction is envisioned to sit above typical context classification but is informed and influenced by it. All contexts are likely to include integrated spaces in varying degrees. TND projects and C6 areas will include integrated spaces throughout most of the area but are likely to contain arterial or collector access roadways and ramp systems that should be designed in a more sheltered fashion. C2 and C2T spaces will be nearly all sheltered or limited access areas but will still contain downtown cores and neighborhoods that should be designed in an integrated layout. Even residential neighborhoods are often a mix of integrated and sheltered space. Although they should be designed as integrated spaces, many neighborhoods have such wide roadways, large setbacks, and infrequent pedestrian activity that their speeds cannot be managed at an integrated pace, no matter how low the speed limit is set.

3.3.1 The Scale of an Integrated Space

One of the most critical issues with designating integrated space is that even within C6 or TND projects, the scale of an integrated neighborhood cluster is typically very small—often only two or three blocks. This means that integrated spaces should usually be designated in terms of specific street stations rather than across an entire roadway project. The key to an integrated space is not just the geometrics of the design, but the street level daily activity that can be generated within that space. To function as an integrated space, drivers must see pedestrians and bicyclists in that space frequently enough to anticipate their presence. It may take a generation or more to grow integrated spaces into a wider scope within our networks. There are good reasons to make any shifts to integrated operations at a measured pace. Designing an integrated space that hasn't had time to generate human activity within it will frustrate drivers who can see that there is no purpose for the extreme design changes or draconian enforcement.

In most residential areas fifty years ago, teens regularly played in the street and the ideal was for neighbors to greet each other every evening from their front porches. This is the essence of a residential integrated space. The streets and alleys were designed for pedestrian and bicycle integration. Although COVID has brought back some of this type of activity, it remains to be seen whether it will be sustainable since the corridor widths of many residential streets are far larger than will support integration safe speeds. In commercial areas, integrated spaces are locations where people regularly walk in and out of storefronts with minimal parking lots or on-street parking. They are locations where transit can be productively used. Those spaces are becoming increasingly popular, but they have been out of fashion for a long time.

3.3.2 Critical Mass

Shifting driver behavior on a regional scale depends on a significant mode shift at a cultural level. It is an issue of critical mass. When there are sufficient pedestrians and bicyclists that drivers anticipate their presence, the driver's behavior shifts. Where drivers only experience conflicts from other vehicles, they move at speeds and attention levels consistent with that belief. When walking and bicycling is more common across the region, driver behavior will shift in general, as we saw in the contrast between driver behavior in Seattle and Tampa. Drivers in Seattle kept their eyes on the road about the same amount as those in Tampa, but engaged in less multitasking overall indicating that their engagement with the roadway environment was higher.

A regional strategy for growing sheltered systems that link up integrated spaces can provide great benefits. This is the key to mode shift, congestion management, and community livability. Unfortunately, this will have to happen incrementally. The Dutch system of frequently used cycle tracks took nearly 25 years (from around 1975 to 2000) to come into full maturity and their land use patterns were far more conducive to short-range trips. However, market pressures and roadway congestion are shifting our land use mix to a finer resolution, and the shift to work from home, even for a few days a week, makes discretionary trips far more critical in terms of congestion management than they were prior to 2020.

What set the Dutch experience apart from many other countries was the emphasis on functional cycling for all ages. Because their motivation was to make cycling safe for children due to the "Stop de Kindermoord" (stop the child-murder) campaign, cycling became functional and ubiquitous. This emphasis on all-age level cycling reduces the "last mile" pressure that stifles transit usage, allowing transit systems to space their stops at community-level hubs so they are more efficient. The evangelistic fervor of an elementary school child that has just learned that cycling benefits the environment cannot be discounted easily. Children and young teens that regularly cycle become adults that value multiple mode choices.

Some locations should, by definition, be an integrated space but poor design may limit its viability. For instance, it has become popular in newer developments to place on-street parking throughout the development regardless of the context immediately around it. Obviously, an area that has on-street parking means that the driver who has just parked there will come out of their vehicle in the immediate vicinity of the travel lane. This may or may not result in an integrated attention pattern. Areas along high-speed, 4-lane divided collectors are not likely see that type of behavioral shift.

3.3.3 Integrated Section Characteristics

Integrated streets are short sections that are specifically designed to support mixing of vehicles, pedestrians, and bicycles throughout the cross section, because those users can navigate the space safely and with high levels of driver engagement. The areas that functioned with minimal multitasking, low speeds, and low-inertia crashes had several features in common. First and foremost, they had consistent patterns of use by pedestrians and bicycles that were complemented by physical features that implied their ongoing presence, like high doorway densities or complementary land use mixes at the block level.

Narrow, enclosed corridor widths also meant that the eyes on the street were close enough to the driver to be seen in a meaningful way. Specifically, the corridor width measurement that is most critical is the width at the driver's eye-height, which can be used to estimate the corridor's 85th percentile speed. A lateral offset roadside strategy will best support maintaining a minimal corridor width and slow operational speeds. Integrated spaces will be most successful economically and from a safety standpoint when target and operational speeds are 20 mph or less, making a lateral offset roadside strategy a safe choice.

Short blocks and high aspect ratios provide visual interruptions to the driver's flow, regularly reorienting their attention to the driving task. This makes it easier for pedestrians to move throughout the space. On-street bicycle facilities should be designed in places where they will be heavily used or not included at all. On-street parking can be helpful, but only where use is continual and turnover is frequent. Placing on-street parking adjacent to a multilane divided facility with a wide visual presentation will reduce the attractiveness of the parking because of the obvious safety risks.

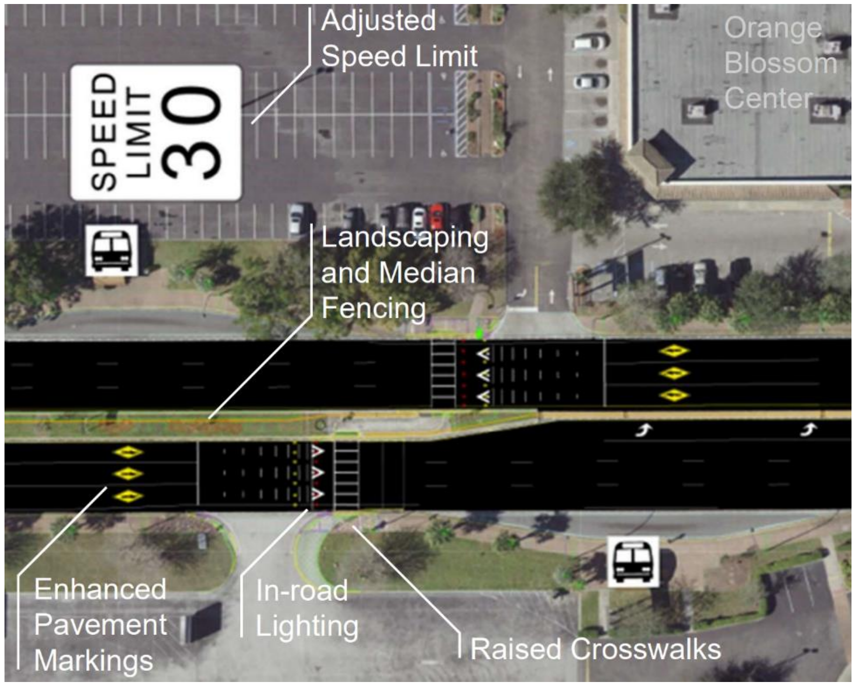
Outside of C6 and TND, integrated spaces should be designated in terms of specific stationing with plans for expansion based on the land use limitations surrounding it. Many of the large retail centers have struggled with the growth of e-commerce and are attempting to reinvent themselves into a more traditional community center style because their biggest advantage over their digital competitors is the human interaction that these downtown-style areas provide. This trend has often resulted in the generation of minor street networks parallel to the higher-volume, higher speed existing network. However, the ¼ mile diameter limitation for a neighborhood cluster appears too frequently in old-world, pre-automobile cities to be accidental and has parallels in suburban mall design. Developers rapidly found that if the distance between anchors exceeded 600 feet (1/8 mile), the areas between suffered and the distant anchor became functionally detached, creating its own new cluster (Garreau 2011). For an integrated space to grow, a new anchor will be needed for each cluster.

3.3.4 Sheltered Design

The surface-level roads that function above 40 mph operational speed should be designed according to standard engineering practice, optimizing vehicle flows for speed and minimizing delay. To reduce pedestrian and bicycle fatalities and support mode shift away from the passenger vehicle, they must be intentionally designed to shelter vulnerable users from these optimized flows. Where conflicts are anticipated within sheltered areas, intersections and mid-block crossings may be understood and designed as micro-integrations where driver attention is demanded, first by conspicuous signing, striping, and signaling, but also by subtle design changes like lane narrowing, elevated crosswalks, and curb extensions. In essence, a roadway in a sheltered area should be considered a fast-flowing river, too deep to wade across, and should therefore be provided with frequent locations for fording the river safely.

A good example of a micro-integration in a sheltered area is shown in **Figure 7**. The resurfacing and pedestrian improvement project that is currently planned for US 441 between Holden Avenue and 34th Street (FPID 447395-1) includes several high-volume pedestrian crossings within a 6-lane high-speed corridor. Each crossing is enhanced with additional pavement markings, raised crosswalks, in-road lighting, landscaped medians and pedestrian fencing, and narrowed lane widths.

Figure 7: US 441 Micro-integration Improvement



In areas dominated by a single land use, multi-use paths placed outside the clear zone are appropriate to provide longer distance connectivity, especially as the advent of the e-bike has increased demand for these types of connections. However, since these locations rarely have mid-block access or demand, draconian speed reduction is likely to be counter-productive. Drivers will disregard the speed limits and vulnerable users may be lulled into believing that those areas are safe for them to navigate carelessly. Crossings should be located at signals since mid-block demand is likely to be minimal or non-existent and protected intersection treatments should be the preferred standard. If necessary, fences or jersey barriers can provide protection where ROW constraints are tight.

3.3.5 Transitional Zones

Unfortunately, Florida has a vast quantity of roadway miles that operate between 25 mph and 40 mph. These facilities are uncomfortable for all users and generate far too many of the vulnerable user crashes within our systems. They are too slow and stressful for drivers and too fast and hazardous for non-motorized users. They also support a vast amount of our commercially developed land because their throughput is high but access remains readily available. Where these mid-speed roadways have been converted to higher speed facilities, small businesses struggle to retain sufficient visibility behind the vast parking lots that serve their anchors. The combination of through trips and local trips assures that the roadway remains highly congested and drivers remain continually frustrated. There is continual political pressure to widen these facilities. Typically, the first widening from two- to four-lanes is commercially successful, so the community often doubles down and widens it to six-lanes, finding out too late that the local businesses fail to survive the construction process and the land values around the road drop both in bulk and by the acre. Investments in nearby parallel facilities that can diversify the network demand are often far more productive and can provide an integrated facility to complement the sheltered one.

The strategy to address these facilities is to allow the community to determine whether it wants that facility to become an integrated street or a sheltered road. In most cases, this will be a foregone conclusion and the roadway should be allowed to transition to a sheltered facility since they have few other options to support their vehicle flows. In these cases, retail infill can turn its back to the high-speed facility and pedestrian and bicycle amenities will be transferred over time to the building sides of the parking lot. This transition can be supported with mid-block crossings away from the high-speed intersections that align with the building fronts. The second generation of commercial reconstruction will begin to generate a local street network within the former parking area. Ellen Dunham Jones and June Williamson (2011) have documented this process extensively in their book series on *Retrofitting Suburbia*. In some fortunate places, a parallel street network already exists that can be conscripted to serve the biking and walking needs, occasionally on neighborhood streets behind the commercial strip. One striking example of this is the Orlando Urban Trail that runs along Haven Drive, behind the shopping center that faces North Mills Avenue. This 12-foot, two-way path runs behind a local grocery store and several multifamily projects, linking downtown Orlando with the region's major cluster of parks, museums, and hospitals.

Where the community determines that it wants to create a section of integrated street, the land use should provide the support for this transition with street-fronting commercial or residential uses placed as close to the right of way as possible with doorways that front directly on the street behind no more than one lane of parking. An integrated street will not succeed where large parking lots are permitted to line much of the roadway. The parking becomes a barrier between the street activity and the human presence that will moderate its activity. A lane repurposing may provide some assistance, but the reconfiguration plan should consider reallocating pavement away from the roadway at the earliest opportunity.

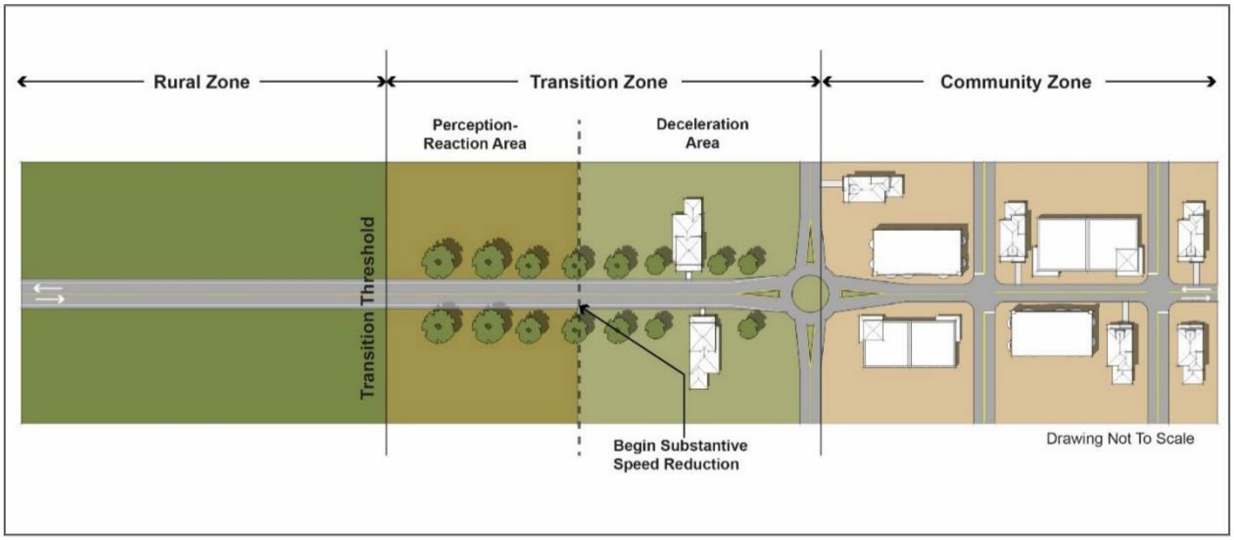
One of the critical limitations on a transition to an integrated space is the ability to reduce the visual corridor width below 60 feet in width. If this cannot be accomplished in the long term, a transition to an integrated space is not likely to be successful. It is possible to repair a roadway where the building faces would normally be too far apart, but it may require an extreme reconfiguration of the cross section and intersections. However, the payoff for a well-designed integrated street can be dramatic within only a few decades. For instance, Winter Garden, Florida originally had a 4-lane roadway with a rail line down the middle of the street, providing a curb-to-curb face width of nearly 100 feet and a building-to-building face width of 125 feet. The conversion of the old rail line to a heavily landscaped bicycle corridor lined with on-street and angle parking dropped the visual corridor width to about 20 feet and currently maintains speeds around 10 mph during the daytime. Construction on the project was completed just under 20 years ago and retail occupancy is reported to be over 95%. This type of experience is common in places that were originally designed prior to WWII where the grid network can ease this transition.

Building faces are often much closer to the street, if they haven't been previously demolished, and parcel sizes are typically small, making for a more interesting environment that will be regularly frequented by people.

Within the roadway, the transitional strategy for shifting to an integrated space is to minimize the area allocated to the roadway and incorporate vertical elements between the roadway and the pedestrian/bicycle infrastructure. Small diameter trees or light poles provide a sense of protection to the vulnerable users that might consider the pathway, even if they are temporary or designed as breakaway features. Drivers recognize that if they veer off the roadway, they will at least scratch their paint and the visual disruption within their cone of vision provides a motivation to slow down. FDM section 202.4 provides a useful description for a strategy for how to transition between context zones over the length of a facility. **Figure 8** summarizes this transitional strategy, in this case between C2 and C2T, which is quite effective and transferrable for transitions from sheltered to integrated space. Similar transitional concepts should be generated to support transitions between sheltered and integrated space. The goal is to provide a clear demarcation that the space that the driver is entering prioritizes users other than the passenger vehicle.

Transitions across time should also be thoughtfully considered and planned as a part of the

Figure 8: Transition Zone from C1/C2 to C2T Context Classification



development review process. Integrated spaces throughout the world often have a 1/8th mile radius limit, but can serve catchment areas over ½ mile in radius that are low speed, residential development. These support areas can be designed as integrated as well if the local corridors are visually narrow, have a short block structure, and have strong pedestrian amenities. Where multiple integrated commercial spaces are desired over the long, term, they can be chained together along the length of the street, but as each cluster is developed, they each need their own anchor point. This development pattern can be seen throughout the world and typically emerged organically because the clusters grew at different time frames. This is easiest to see in areas like Barcelona and New Orleans, where each cluster of 9 blocks is at this scale. The clusters are very active near their anchor point, and decrease in activity as the boundaries are reached. Seattle's clusters are typically in a 4x4 grid at the same scale. Portland's extraordinarily small blocks generate a 4x5 block cluster system in their downtown bounded by linear parks that round them out to ¼ mile. The older the city is, the smaller the clusters appear to be. Vancouver, BC has clusters that are as small as 1/6th mile diameter, but no clusters in their downtown any larger than ¼ mile between major boundaries. St. Augustine has clusters that are 1/5th mile in diameter, with the fort entrance located 1/8th of a mile from the center of the oldest cluster. This may be one of the issues with generating a walkable space in places like Miami, where the post-WWII block structure is slightly larger, making walking and biking uncomfortable.

When transitioning toward a sheltered or an integrated space, the costs will come in the transition itself rather than the materials or maintenance. Moving curb lines can be expensive, but the reallocation of pavement away from the road-bed and toward multi-use facilities may reduce overall costs since trails require much less in terms of underlayment and materials. Since the narrowness of the corridor is a priority, ROW costs may be minimized as well. There can be cost savings for transitions to sheltered space as well when pedestrian and bicycle facilities are shifted toward building faces, allowing the development community to directly serve their customers closer to their economic center, allowing for less ROW acquisition, and more space for their project.

3.3.6 Roadside Treatments: Clear Zones, Border Areas, and Lateral Offsets

The integration or sheltering strategy employed should be based on the vehicle speeds anticipated in the roadway. Integrated spaces (20 mph or less target/design speed) are appropriate for a lateral offset strategy, with minimal separation between the vehicle stream and vertical elements. This helps maintain a visually narrow corridor, reducing speeds while protecting vulnerable users.

For facilities with a low target speed (20-35 mph) that are transitioning to an integrated space, a border zone strategy provides an acceptable balance between buffering vulnerable users and providing for optimized vehicle flow. This strategy retains small diameter trees and vertical breakaway elements between the vehicles and a multi-use path to provide the perception of a barrier and give the driver motivation to minimize any damage to their own vehicle. As always, designers hope that drivers will be cognizant of the other users in the space, and the vertical elements provide a visual reminder to do so. However, driver attention and vigilance cannot be confidently expected from a large proportion of the driving public, so the additional buffering is provided in a way that minimizes the risk to both, particularly since the higher speed collisions are likely to occur at night when vulnerable users are less likely to be in the space. If the transition to an integrated space is to be successful, a narrow corridor is needed along with appropriate changes in land use mix and street fronting design. Large setbacks will interfere with the cohesiveness of the pedestrian environment and should be discouraged where a low target speed is desired.

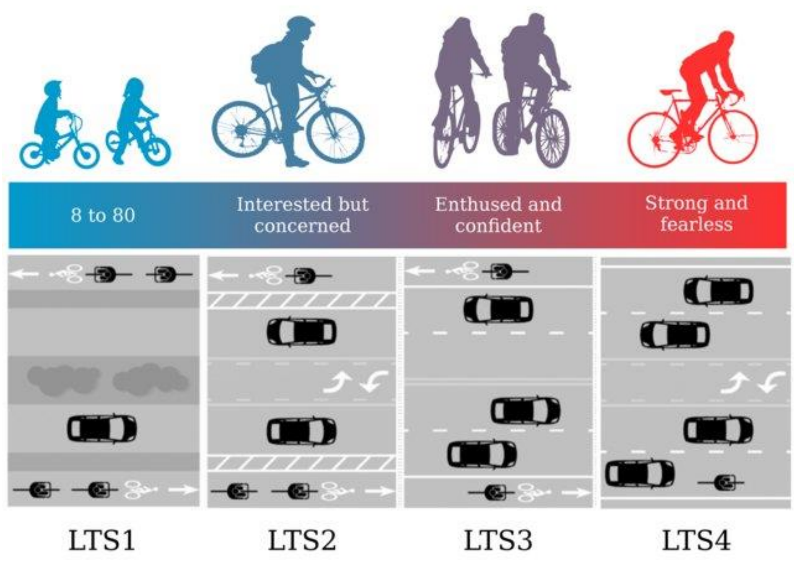
Moderate and high-speed facilities (40+ mph design speed) should continue the clear zone design strategy. The concept inherently assumes minimal or non-existent vulnerable populations within the clear zone, yet paths and sidewalks are routinely included within it. This is a self-fulfilling assumption. Because it does not feel safe to most vulnerable users, they will not use it in any quantity (Burmester 2020). If the roadside has been sufficiently cleared to allow a vehicle to leave the traveled way and cross over the bike path or sidewalk, the design choice has been made to sacrifice any vulnerable user in that space for the safety of the driver, who is already protected by an armor of metal and airbags. This is a dubious choice in light of Target Zero. Therefore, it is our opinion that the concept of a clear zone is incompatible with the provision of vulnerable user facilities within that zone. The only exception regards on-street bicycle facilities, whose users are assumed to consider themselves sufficiently conspicuous and experienced to manage such conflicts. This opinion may be a fallacy, but some communities may choose that option to support an avid local bicycling group. One Florida community recently recognized that many of its low wage construction workers have chosen to purchase e-bikes rather than cars and are regularly seen in their bike lanes alongside very high-speed vehicle traffic. They are currently struggling with how to meet the needs of that population in a time-sensitive way.

Facilities with mid-range design speeds (35-45 mph) will exist, but design speeds in this range should be a red flag that the community is attempting to accommodate incompatible traffic flows in the same space. Integrated spaces should be much slower and adequately sheltered spaces should operate at the top end of this range and above.

3.3.7 Cycling and User Type

The type of cyclist to be served should be carefully considered when selecting the appropriate cycling or shared-use facility. **Figure 9** summarizes the commonly accepted types of cyclists and the corresponding roadway design and level of traffic stress that each can be expected to navigate (Abad Crespo 2019). It is important to designate within the accepted design standards which user type the facility is designed to serve because this will dictate the design of the facility. At a minimum, collapsing the scheme to two groups, the "8-80" users and the "Enthused and Confident" cyclists, will cover a wide enough range of user types to address most circumstances common to roadway design and planning. The type of user served should be chosen strategically to support the overall transportation goals of the community. For cycling to become a viable mode, the "8 to 80" user type should be the preferred design standard unless there

Figure 9: Cycling User Types and Level of Traffic Stress



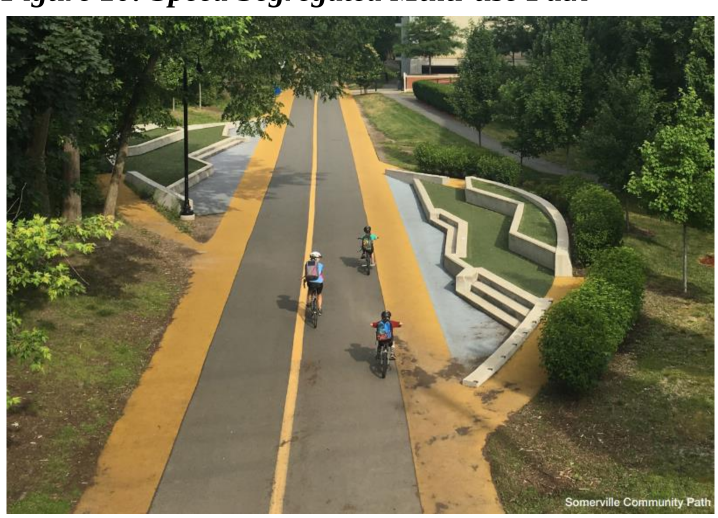
is a compelling reason to serve a more confident user group. Even in this case, additional width should be considered for supporting less experienced users in a more sheltered fashion.

There are places where the land uses are so monolithically single-use that it is difficult to envision functional bicycle use for the foreseeable future. Providing cycling facilities in those locations may still support employment trips or raise cycling awareness through recreational cycling. Therefore, the current population can be expected to consist of the "Experienced and Enthusiastic" or the "Strong and Fearless" style cyclists, who prefer a higher speed, typically on-street facility. However, these will likely be the only users even in standard 7' buffered bike lane, and this limits the potential for overall mode shift both within this facility and in the community due to minimal network connectivity. If we are serious about both target zero and mode shift goals, designing for the "8-80" user is the most likely path to success.

Where complementary uses are mixed at least at the mile scale (one mile travel distance around a grocery store, for example), functional cycling for all age groups should be the preferred option and the facilities should be designed for the "8-80" cyclist. We can ultimately serve a wider cross section of the population and have a better chance of shifting travel modes away from the automobile if designs are intentionally geared toward a less experienced cyclist.

Shared use paths intended for functional cycling should not follow the FHWA guidance that recommends designing for the highest possible speeds. This is a repetition of the roadway design mistake of equating safety with speed accommodation. The facility design will have a direct impact on the operating speeds. Designing the facility for lower speeds reduces the potential for fatal and serious cycle crashes by reducing the inertia of "strong and fearless" cyclists. Additionally, if the intent of the path is to support a wide range of cycling abilities, the high speeds used by recreational or highly experienced cyclists will discourage those who are attempting to incorporate cycling into their lifestyle, reducing the choices available to the public. Therefore, functional paths should be designed to encourage low to moderate cycle speeds and appropriate signage should be included on the path that indicates that high speed users should be courteous to less experienced users on the path. This can be coupled with marking designs that allocate space for different user types and speeds. The guidance that separates pedestrian facilities and multi-use paths in C4 and C5 contexts is appropriate since volume and capacity considerations can become an issue in the foreseeable future, particularly with the advent of higher-speed e-bikes and other motorized personal devices. FDOT should explore developing and ultimately standardizing share use path designs that provide

Figure 10: Speed Segregated Multi-use Path



guidance for coordinating multiple user types that function at different speeds. There are several potential strategies for accomplishing these goals within the Dutch CROW manual as well as Danish design standards. For instance, Striping patterns have been explored for shared use paths that provide guidance to users that lower speed users should stay in an appropriate location (either inside or outside). All shared use paths 10’ or wider should be striped with a centerline unless they are located on both sides of the roadway and a dominant travel direction is clearly identified. **Figure 10** shows a shared use path in Sommerville, Massachusetts (Lewis and Trepanier 2018) that has outside lanes marked for lower speed users and inside lanes for higher speed users.

CHAPTER 4: OVERVIEW

4.1 The Mental Frameworks

Driving behavior is only the visible outcome of internal mental states. The mental frameworks we have detailed build progressively to explain how the behaviors we observe in urban space differ from roadway driving. **Table 3** uses the mental frameworks to reframe our misunderstandings about urban driver behavior in ways that can have a concrete impact on our design practices.

Our conclusion, after reviewing the data, was that the situations (both in time and space) that can be driven with a high level of automaticity will allow for multitasking and mind wandering at a higher level than those that do not, but human presence enlists automatic resources that can help drivers reengage. This was amply demonstrated by the consistent connections between the contextual features, vulnerable user presence, acceleration, jerk, lane position, speed, and crash history.

In urban spaces, driving that generates safe outcomes starts with appropriate levels of attention. Thankfully, the attention that is needed to keep pedestrians and bicyclists safe is reflexively generated when the driver expects to see and interact with those users. The automaticity that allows drivers the freedom to drive without attention is only turned off when something salient, rewarding, or demanding is there to be seen. Increasing driver attention through increased levels of conflict or complexity increases workload and can push drivers into frustration. Human presence relies on a primal set of neurological reflexes, allowing the additional workload to be managed with less stress. In order for drivers to slow down and pay attention, three conditions are required:

- An active street environment with mixed use and frequent active doorways resulting in regular human presence
- A corridor narrow enough for drivers to see the people on the street, preferring that interaction over the thoughts in their own minds or the pictures on their device
- Salient interruptions that regularly reorient drivers to the environment and away from their own internal mental processes or chosen distractions.

Speed management and crash minimization then flows naturally from the combination of features that elevate attention and maintain vigilance. Paying attention at this higher level of engagement is costly to drivers in terms of mental resources and can generate fatigue and mistakes. Dense urban spaces typically form in clusters roughly ¼ mile in diameter. It is wise to limit vehicular activity within these high-workload environments to a similar scale, providing lower workload options for longer distance travel. Relocating vulnerable users away from these flow-optimized areas keeps them safe as well.

Table 3: Mental Frameworks and Design Misconceptions

Mental Framework	Myth	Reality	Design Implication
Thinking fast and hypnotically	Drivers respond to what we tell them in messages and signs.	System 1 automaticity is the dominant thought pattern in driving and is quite good at monitoring for personal threats and rewards. It does not think logically, sequentially, or verbally.	If drivers have to consciously think to change their behavior, they won't. Show them, don't tell them.
Prioritization of Human Perception	Everything that the driver sees matters.	Perception of the emotional state of other human beings is prioritized and occurs before conscious thought, making it a System 1 resource. The intensity of the response is tied to the emotional state observed. If the emotional state cannot be percieved, the vulnerable user may remain a part of the background.	If drivers can't see facial expressions or read emotional body language, System 1 will not recognize them as people and they will be disregarded as visual clutter.
Limits of Human Perception	If people are in the driver's sight lines, they will get seen.	Both speed and distance impact a driver's ability to emotionally interact with people in the space. Above 25 mph, vulnerable users are only seen about 50% of the time when they are there. Beyond 90 feet in linear distance (a 60 foot corridor around the driver), rapid emotional monitoring for threat or reward is no longer possible.	The scale of the environment matters. Corridors that look wider than 60 feet will not get slow speeds. Drivers increasingly lose the ability to see vulnerable users at 20 mph and 40 mph.
Conditioned Anticipation of People	Drivers will automatically be cautious in urban settings.	Without experience with regular human presence or at least environmental features that imply human presence, drivers will treat the area as if they are not going to be there.	Land use mix and street level human activity are key to maintaining driver awareness.
Salient novelty	Consistency is always critical to safety and conflicts cause crashes.	In an urban space, attentiveness is maintained at optimal levels by allowing the appropriate rhythm of salient change. Interruptions in the visual and mechanical flow reorient the driver to the environment and reduce mindlessness. Consistency is only needed for skill-based design features.	Short blocks and regular visual interruptions make the space more comfortable for vulnerable users and assure that drivers retain attentive caution.
Workload Speed Management	Speed is a conscious choice that can be controlled by regulatory systems.	Speed choice is the driver's main tool for managing workload, but is managed using System 1 automatic adjustments. Workload associated with human presence reduces speed, but adds biologically hardwired resources to the task, making it less stressful in comparison to congestion or clutter alone.	Drivers will go as fast as the workload demand of the environment allows. Interactive human presence reduces speed where it is needed. Where human interaction is out of range or unexpected, speed reductions are less likely.
Event Theory	Drivers recognize hazards in the same way in segments and intersections.	Intersections and major interruptions to the visual flow in the 60' corridor around the driver generate an interruption in the driver's memory processing. At these event horizons, short term memory for the previous context is updated and the driver shifts to a scanning mode that doesn't identify specific targets well.	Vulnerable users are particularly difficult to see when drivers are updating their memory at an intersection. Contextual cues must be carried over from the segments into the intersection. Large scale intersections require more scanning. Protected intersections reduce conflicts between bicycles and vehicles and move those conflicts to places that drivers can anticipate seeing them.

This can be addressed using three strategies. First, in locations where pedestrians and cyclists are likely to be common, an increase in the frequency of the interruptions that intersections provide will generate an added benefit in terms of driver attentiveness. Second, although the practice of placing 4-way stops in locations that do not currently warrant them has been discouraged, it may be time to strategically reconsider this practice for speed management and driver attentiveness.

Finally, there are several strategies that can pull the surrounding contextual features into the intersection, like painted intersections, gateway treatments, or a nuanced assessment of tree placement in and around an intersection as described in the FDM as the Clear Sight Window Concept (§212.11.6.1). These types of features may help to carry the contextual features through into an intersection where pedestrians and bicyclists are prioritized. They also reduce the visual scale of the intersection. When a thought is held in working memory as an event horizon is crossed, the memory of that thought is encoded within both the previous and the new event, doubling its impact and increasing the ability to recall the thought. Carrying the context through the intersection may have the same amplified effect on driver attentiveness and speed.

4.2 Broader Implications of the CAP Model

Since the CAP model is one of the critical contributions that this research effort has generated, this section provides a more complete discussion of the overall implications of this psychological model.

The issue of night-time conspicuity in light of the CAP model was raised as a question in our research outreach. Night-time pedestrian and bicycle crashes constitute 75% of the fatalities with many of the factors we have considered being statistically significant, including midblock crossings, 40-45 mph roads, and 5-lane urban arterials. If a pedestrian cannot be reasonably seen during the daytime at certain distances or speeds, they will be far more difficult to see at night. The addition of multimodal amenities to support this population may be disproportionately impacting cyclists that operate at night. Appropriate lighting may increase their conspicuity, but only if it is of very high quality and has thorough coverage. Most lighting includes dark areas between the lights that may further degrade the amount of time that the driver has available to see a non-motorized user during their visual scanning.

Driving without metacognition is a learned skill that appears to be acquired within the first few years of driving. Therefore, driver education and training regimens should recognize that the skills acquired in the early years of driving are differently applied as the individual becomes more experienced. More experienced drivers can be trained to identify locations where they need to reengage full metacognition, including recognizing specific locations or even transient events that can cue drivers to examine their behaviors at a more conscious level. These cues could be as simple as a public awareness campaign that highlights seeing faces as a cue to slow down and pay attention, augmenting the metacognitive elevation with intentionality.

It may be advantageous to explore how the inclusion of photographic faces or other pareidolic or abstract faces act to change driver behavior within driving simulations. However, any such ameliorative strategy runs the risk of the ‘crying wolf.’ effect. Over exposing drivers to non-rewarding stimuli may make them disregard input that is actually vital for their operational safety.

In terms of form-based codes, the number of functional, operational, active doorways or businesses per block has a more substantial impact on driver behavior than was previously anticipated or understood, as does the impact of building or landscaping setbacks. Therefore, consideration of this influence should be given a higher priority wherever possible. It should be cautioned that non-functioning doors may generate less response than is desired since System 1 resources are remarkably skilled at disregarding non-salient information. It is the resolution of the land use mix (how frequently the land use type changes), not the number of entryways that impacts driver behavior. This is an overlooked benefit that Dutch streets have over many other countries. In the Netherlands, property taxes were originally based on their linear canal frontage (Tabarrok 2018), providing an incentive for building tall, narrow buildings. This means that there are active, functional doorways for distinct homes or businesses at frequent intervals, making for a very interesting streetscape from the pedestrian’s point of view.

A less obvious implication of the CAP theory is the geographic scale of a CAP area. Driving with metacognition engaged represents a high mental workload task and may not be tolerated or maintained for long distances without significant driver fatigue. We saw in the models that workload has a much smaller impact on crash rates than speed optimization, however, these high-workload spaces are not typically very large. Driver fatigue becomes an increasing problem the larger the walkable area becomes. It is likely that the area that the driver can tolerate this level of attentiveness has a natural match with the geographic extents of a typical walkable area, which is usually a ¼ mile in diameter. Ancillary residential areas around these clusters may retain integrated operations, but require the same vigilance with regard to the visual width, pedestrian amenities, and block lengths. If the fundamental argument of the CAP model is sound, the number of faces encountered is likely to have a direct impact on the amount of workload required, not just the density of the faces. Therefore, the driver is likely to become fatigued far faster than a pedestrian because he is encountering those faces more frequently.

Walkable scale areas have always been scaled with human limitations in mind. The distance a person can recognize the shape of another human (300 feet) sets the limits of a successful pedestrian scale block to no more than double that (roughly $1/8^{th}$ of a mile). This distance is even used in mall design for the acceptable distance between anchor stores (Garreau, 2011). Large cities in the US often have either arterial corridors, freeway off-ramps into the core, or transit accessibility at roughly 1/3 to ½ mile spacing—3 to 5 blocks wide, or roughly 2 neighborhoods apart. As walkable areas connect within the overall urban fabric, interchange spacing should consider the limitations for driving within a walkable area as the same as the limitations for walking that area as a pedestrian. Travel demand models should evaluate the typical length of the driving trip within dense urban spaces. Assigning a different value of time to urban streets may help these models better replicate driver demand. Interchange justification or removal analyses should also consider how limiting or improving access to dense urban areas will impact crash and road rage effects on the surface network.

4.3 Policy Implementation

Our research results imply that transportation professionals need to think of complete street design in more of an "all or nothing" way with regard to non-motorized travel modes. In the places where the cross section and street rhythm make low speed, high vigilance behavior successful, integrated design protocols should favor vulnerable users while allowing for very low speed driving. In places where the cross section is too wide, parking lots are near the road, or optimal vehicle flow is desired, roadway designers cannot provide any assurance of safety to the vulnerable users in close proximity to the roadway. Therefore, a sheltered design strategy is more appropriate. At a neighborhood level, vulnerable users can and should be provided as fine-grained accessibility as possible, but not within the high-speed vehicle roadbed without physical or at least visual vertical barriers to draw attention to those users. Indeed, if our industry wants to serve bicyclists and pedestrians well, we need to consider how to shift those trips away from the roadway, closer to the commercial entrances they are attempting to access.

Ideally, multimodal travel will eventually require networked bicycle and pedestrian systems distinct from the vehicle network. Rather than thinking in terms of completing the street for all users within a single available right of way, approaching the problem from a network or off-street standpoint will be safer and more effective. Areas in the vicinity of these roadways can be retrofitted into more pedestrian friendly zones incrementally, as land use and transportation systems evolve.

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APPENDIX A: DESIGN HISTORY AND CRITIQUE

Year	Pedestrian	Travel Lanes	Multipurpose	Bicycle	Notes
1967	5'	12'	10' to curb face 8' for parking, 2' buffer		
1981	5'	12'	10'-11.5' to curb face Refuge lane		
1985	5' 6' to back of curb	11-12'	13.5' to curb face 15.5' where bicycle facility criteria are met		
1989	4-5'	10' rural 11' most 12' freeway/ arterials	14' to lip of gutter 15' w/o gutter	4' replaces Wide Curb Lane	Detailed narrative about the benefits of wide curb lanes, including benefits for turning vehicles and bicycle passing
1991					Access management introduced
1993	5'; Cycling on sidewalk acceptable for the inexperienced but inappropriate to sign it as such	11-12'	Urban Multipurpose lanes: 8'; 10-12' for transit	4'	Left turn lanes allowed as narrow as 10', desirable 12', maximum 15'; Narrative prioritizes shared bicycle facilities due to increased visibility and maneuverability. Policy to consider needs of cyclists on all facilities except limited access. Clear zone.
1994		10-12'	7' minmum parking lane		Added RRR chapter including direction to provide for pedestrian and bicyle needs, especially ADA, pedestrian refuges in medians, convert wide outside lanes to striped bike lane; lane width typically based on volume; 10' minimum urban width
1996					Access management classes defined
1998			Urban Multipurpose: 2.4 m; Wide curb lanes no longer meet FDOT requirements except in RRR;	1.2-1.5 m	Bicycle chapter quotes FAC 335.065(1)(a); Multiuse trails discussed
1999	Sidewalks should be outside the clear zone				
2000					Transporation Design for Livable Communities; Horizontal clearance exeptions to clear zone
2001			Shared use paths are not replacements for on-street bike lanes		Mid-block crosswalks, curb extensions
2003					Keyhole bike lanes at intersections; 4-lane high-speed suburban arterial highways: max design speed 55 mph, shall have bike lanes and sidewalks, 30' minimum median width; 35' border width;
2004			Shared use path typical cross section		Crashes must be addressed in RRR
2005					Context Sensitive Solutions
2006	As far away from the road as practical		5' between parking and travel lane, wider for high turnover	4' minimum bike lane; do not include curb;	Keyholes on bus bays; bike/transit interconnection details; midblock and marked crosswalk treatments and limitations; Figure 8.3, Bus stop categories;

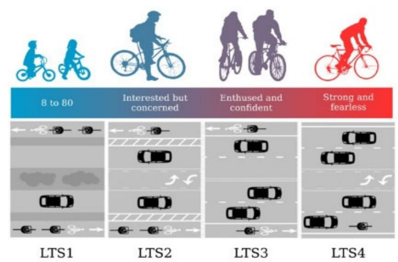
Year	Pedestrian	Travel Lanes	Multipurpose	Bicycle	Notes
2011			12' minimum shared use path width		Keyholes mentioned by name; Sharrows as a guide for positioning cyclists
2012			10-14' shared use path	Green colored bicycle lanes	Figures for green bicycle lanes at intersections
2015			8' minimum urban multi-purpose	7' buffered bike lane; provide as much as possible down to 4'	Lateral offset terminology used; keyhole minimum 5'; door zone buffer 3' for on-street parking included in buffered bike lane; Exclusive transit running ways
2016					Massive restructure of all roadside safety concerns into Chapter 4. Midblock crosswalks limited to 60' wide without refuge
2018	5-12' based on context	10-12' based on context and design speed	Parking restrictions at driveways and intersections	Bike boxes, 2-stage queue; separated bike facilities; bike lane exhibits 223	Context Classification Guide. On-street parking. Border width reduced; shadow diagrams and spacing for tree trunks. Lane elmination projects. Access management revisions.
2019					Speed management. Transition zones. Figure 222.2.3 Curb Extension. Shared use path within limited ROW.
2020			Shared use path may be substituted for a bicycle lane-design speed 35+	Separated bike lane details	Target Speed; Figure 223.2.1 Bike lane/Shared use path substitution
2021					Lane repurposing. Median island approach nose extension Fig210.3.3); refuge island details; hardened centerlines; tubular markers.
2022	Raised crosswalks		Urban side path	8' shoulder width for marked bike lane	Commentary added. Posted speed pavement marking; Recommended corner radii; Figure 212.12.2 Actual Curb Radius vs. Effective radius.

Citation	Notes
FDM, Volume I	
102.2 Definitions, Blended Transitions	Blended Transitions can be used as a gateway treatment to identify an integrated section, or as a micro-integration in a sheltered section
102.2 Definitions	Add integrated, sheltered, and micro-integration
102.2 Definitions, Design Speed	Need a section for "Street Speed" with a 10-25 mph max; consider 40-45 a problematic zone. Design speeds should be low for integrated sections, optimized for roadway sections and mid-range design speeds (35-45) should be considered a symptom of a problem: If the design speed is in that mid-range, we're probably trying to accomplish too much--too much access while maintaining too much
102.2 Definitions: Road	Define in contrast to street as a place where vehicle movement is prioritized and vulnerable users are protected; Include discussion regarding the safety and operational issues associated with street/road hybrids
102.2 Definitions, Streets	Interesting that this exists as a definition. No definition in AASHTO and it's sorely missing. Emphasize priority of non-vehicular movement and access, particularly for non-motorized modes; Define in terms of a single location with a small extent rather than a wide network. A street is a place. C4 and TND may have a network of streets, but that is (unfortunately) an abberation in the overall pattern in Florida
Form 126A	Add a list of integrated sections by stationing. Add a list of crosswalks or micro-integrations for sheltered sections.
104.3 Community Awareness Plan	Gain direction from stakeholders early on Integrated sections from local agency; identify ped/bike desire lines (attractions) across the corridor; Add designation of integrated sections and micro-integrations to (5) Traffic Control and Access Impacts
105.2 Aesthetic Design	Add a discussion of how aesthetic elements can highlight areas with high levels of pedestrian Integration
10.4.1 Project Design Controls and Standards	Add integrated/sheltered classifications
114.3.1.5(4) Design documentation	Identify stations that are designated as integrated or sheltered
114.3.4 Pedestrian Bicyclist, and transit	Add FDM sections for integrated/sheltered
120.2.2 Traffic Data	Need to collect and document ped/bike volumes
120.2.3 typical section package	Establish integrated and sheltered sections by stationing and get appropriate approvals
120.2.6 (3) Preliminary traffic control plan	What extra is needed to maintain ped/bike activity during construction?
122.2 Variations/Exceptions	Need to make sure that public involvement establishes local community consensus on Integrated sections during Phase I; Many strategies will require design exceptions or varitations until the standards are adopted in the Florida Greenbook or AASHTO
122.3 Justification for approval	Need to add a justification 9) Driver behavior management

Citation	Notes
FDM, Volume I	
122.4(2) Documentation for Approval	Add stationing for integrated and sheltered sections
122.5.1.1 Design speed AASHTO Criteria	I believe the most recent AASHTO has much lower minimum design speeds. Design speeds below 25 mph are desirable for integrated sections regardless of their functional classification
122.6.2 Roadside safety analysis program	Roadside hazards need to be deliberately included in integrated sections to minimize risk and increase awareness of ped/bike facilities

Citation	Notes
FDM, Volume II	
201 Design Controls	Consider two sections within design controls: LA/Roadway (preferrably grouped together with sections addressing the distinctions internally), and Street. Need to add design controls specific to integrated sections and design cyclists. Identify integrated space based on doorway density (2 per 100 feet or more), and land use mix (2-3 uses within 1/8th of a mile) with a note that high mid-block ped/bike crash volumes may indicate the need to choose an integrated or buffered micro-integration mitigation strategy. Design for target speed at or below 25 mph. Add integrated design conrols for corridor width and interruptions.For controls within integrated sections, Add corridor width at eye height (<60'), crossing distance (<50'), number of lanes (up to 5 at 10' through lanes, 11' center), sidewalk width (6'+) as controls for integrated. Address speed management with interruptions using minimum access management spacing for pedestrians within integrated stationing: Add block length or mid-block crossings (<600'), and block perimeter (<1320') to integrated.
201.1 General	This is where the distinction between a roadway and a street becomes critical, because the approach is different. Physics based controls are appropriate in both LA and Roadway, with differentiation in speed and scale rather than the nature of the facility. Behavioral and contextual features control the design in streets. Some design controls will be applicable to all facilities but have different issues. Others need to be added to specifically address the different strategic objectives involved in street design. In order to maintain the current numbering system, we recommend adding sub-sections within each topic to provide clear delineation regarding its applicability for roads and streets. Integrated objective: maintaining concious attention with full awareness of vulnerable users. Buffered objective: consistency and automatic response.
201.1,1 Capacity and LOS	Capacity and LOS are far less critical in integrated spaces, particularly if there are parallel buffered or LA spaces that can serve that population. Evaluating corridor level capacity reduces the chance of creating bottle-necks with integrated spaces on roadways with higher functional classifications. Ped/Bike QOS evaluations need to be added. Need to add a note regarding the economic implications of bypasses. We currently have few if any evaluation procedures for bike/ped capacity, but will eventually need them if we do our jobs right.
201.1.2 Design Consistency	In an integrated space, the goal is to maintain design consistency for skill-based oeprations and provide attention getting features for rul-balsed or strategic level operations. It is critical for the environment to capture the driver's attention without overloading them. The goal is surprise, not shock or confusion. Signing and striping may introduce novelty and community-based visual identifiers like pavement painting that does not disrupt standard MUTCD designs (i.e. painting sections between zebra lines, in the intersection, along the street, etc.) or themed wayfinding, commensurate with a destination type space. All designs should be evaluated for color-blindness issues. Painting can be included to visually narrow the operating space but must include a maintenance agreement as needed. Buffered or LA roadways maintain consistency to support automatic driving patterns as usual.

Citation	Notes
FDM, Volume II	
201.2 Context Classification	Provide a table detailing the percentage of integrated space likely to be observed in each context classification and discuss. Add TND footnote to the table indicating that nearly all of a TND's streets will be integrated.
201.3 Traffic and Design Year	In integrated stations, traffic projections should address vehicle capacity needs at multi-facility corridor level with facility specific capacity evaluated for non-motorized modes. Integrated facility design should prioritize bicycle/ped capacity needs and allow vehicle LOS to fail at the facility level. Buffered traffic estimated as usual but include a discussion of induced demand and network connectivity in this section. Design volumes should be projected for ped/bike by user type based on future land use designations wherever possible. We currently have few locations with sufficient ped/bike volume that a capacity analysis is necessary, however, we are increasingly seeing conflicts between different bicycle design users. This is an avenue that needs exploration.
201.4 Access Management	To be truly multimodal, the section needs to address access management connection maximums for ped/bike in addition to the spacing requirements for vehicles. Our rationale is that in a buffered section, vehicle operations are optimized, making mid-block crossings hazardous. Micro-integrations for long blocks with attractions on both sidees may be necessary. Integrated will always be category 6 or7 by definition. Driveway spacing should consider potential ped/bike conflicts and conspicuity detailing (green bike-lane paint across driveways, corner clearance visibility). Add block length, mid-block crossing, and block perimeter maximum limitations for pedestrian facilities. Consider adding text regarding micro-integrations for mid-block crossings and median fencing to limit ped/bike access in buffered sections with high crash history.
201.5 Design speed 201.5.1 Design speed selection	Integrated design/target speeds 10-25 mph. Target speed is inherently an integrated concept. It is critical to get local buy-in on integrated secont locations and their target speeds. Public involvement should emphasize that buffered sections should not be drastically restricted for speed becasue it increases speed variability. Buffering using BA with vertical elements reduces the need to artificially reduce target speeds. If possible, we need to consider discouraging design speeds in the 35-45 mph range unless capacity is driving the operational speed down. Designing for a free-flow speed of 40 mph means drivers are going too fast for vulnerable users and a lot slower than they want to go. This means VRU's are not safe and speed variability goes up, so drivers aren't safe either. Design speed ranges for C4-C6 have minimums that are too high. Consider 20 mph minimum for non-SIS. Add a table or sentence that recognizes that local streets and minor collectors may request design speeds that are substantially lower.

Citation	Notes
FDM, Volume II	
201.6 Design Vehicle	Maintain controls for turning radii based on WB62-FL, with exceptions allowing for a smaller control vehicle if step-down freight is available. Dense urban areas can maintain smaller cross section features if larger WB series vehicles are prohibited, but this poses serious issues with urban freight delivery. Step-down distribution (local distribution centers that step freight down from WB to van or bicycle delivery) can help communities maintain corridors that control driver behavior without sacrificing delivery needs. See Seattle Delivery Hub pilot.
201.6.1 Control Vehicle	Use Control Vehicle for Integrated and design vehicle for LA/Road. Consider strategies for protecting pedestrians from control vehicle encroachment in the corners.
201.7 (recommended) Design cyclist	Need to identify at least two cyclist types: 8-80 and Enthused/Confident or Interested/Concerned. Keeping it simple and adding bicycle facility limitations may avoid conflicts. If we design for 8-80, we have a fighting chance of generating functional mode-shift. If we only design for I/C or E/C, we will never get the mode shift we need for congestion management. Integrated should be designed for 8-80. Buffered can include designs for E/C in the street and 8-80 in buffered off-road accommodations. 
201.8 (recommended) Corridor width	Add corridor width at eye height (<60'), crossing distance (<50'), number of lanes (up to 5 at 10' through lanes, 11' center), sidewalk width (6'+) as controls for integrated.
202 Speed Management	Overall, this chapter covers the mitigations that address speed from a physics point of view well. Needs discussions on how faces and moving bodies impact speed and attention.
202.1 General	This chapter will be so much simpler if it focuses on integrated sections and micro-integrations at intersections and highly conspicuous mid-block crossings. It goes back to the concept that we are optimizing for human presence in integrated sections and optimizing for high speeds in buffered sections.
202.1 Lane Repurposing	We now understand why repurposing alone doesn't have as much of an impact on speed. Without visual changes to the corridor width in the vertical dimension, speeds are unlikely to change. Adding a discussion on what can be done to incorporate this type of change into a lane repurposing project will be helpful.

Citation	Notes
FDM, Volume II	
202.2 Speed management concepts	Need to add discussions about the impact of faces and human movement on attention and speed, emphasizing that it is the expectation of human interatction in close proximity to the vehicle that has the biggest impact on speed. Discuss geometric limitations for visual impact and how the overall corridor dimensions relate to these dimensions. It is critical to show the driver the reason for the desired speed. Without a visually obvious reason to moderate their speed, drivers will percieve lower speed limits as a typical government overreach and compliance will be low. Speed is directly tied to workload. Emphasize a how the uncertainty supports a safe-systems approach, reducing speeds and inertia. The additional uncertainty and workload may increase low-speed vehicle crashes but does so by replacing higher speed and ped/bike crashes. Uncertainty discussion in engagement is good and needs to highlight that non-traditional features may provide visual cues that signal human presence to be likely. Make the distinction between non-traditional elements that are tied to higher-level decision making while features that are tied to vehicle manuvers should remain consistent--be strategic about how you incorporate uncertainty or novelty.
202.2.1 Target Speed	Target speed is an integrated section concept. Incorporate why target speed and how it aligns with integrated/buffered paradigm
202.3 Speed Management Strategies	Add pedestrian/bicyclist integration to the list
202.3.1 Roundabouts	You almost mention roundabouts as a gateway feature. Gateway features are likely to have a direct impact on speed because it signals that human presence is more likely.
202.3.2 Onstreet Parking	Because OSP always involves a driver exiting the vehicle and becoming a pedestrian, OSP is a primary indicator and trigger for an integrated space. Wide roadways/corridors and OSP are incompatible because the vehicle speeds will be dangerous to the driver exiting the vehicle. Make sure pedestrians are still visible beyond the parked cars, especially at intersections. Dropping the visual corridor width with onstreet parking creates enclosure.
202.3.4 Lane Narrowing	The corridor narrowing effect described should be discussed as a visual cue for micro-integration spaces. The message is: "Pedestrians are not always in the corridor, but they could be right here!" Narrowing a single lane has little impact. Narrowing all of the lanes together changes the corridor width and can make a difference, particulrly in 4 and 5 lane sections.
202.3.6 Street Trees	Street trees have minimal or non-existant impact on speed when placed consistent with clear zone criteria. Trees aligned along the edge of the roadway in close proximity to the vehicles create a visual walll that will change the driver's perception of the corridor width. Urban street trees placed consistent with lateral offset critera manage speed, especially when drivers expect to see people. Trees placed consistent with clear zone requirements don't and people won't be there either because they feel exposed. Small diameter trees and breakaway signs/poles provide a warning to vehicles and the perception of safety to pedestrians and bicyclists in corridors with mid-range speeds. Street trees are an attractor of human presence--people like to walk where there is shade if there's somewhere to go. Without the people, the impact of the trees will be negligible. One of my favorite drives is down a 4-lane curb & gutter highway with the most beautiful mature oaks. Typical speeds are 50 mph and more even though they don't meet clear zone criteria at all.

Citation	Notes
FDM, Volume II	
202.3.7 Short Blocks	Short blocks impact drivers two ways: they signal a pedestrian area and they disrupt the driver's progression, helping to maintain attention in the space. Adding crosswalks at all intersections but will only be productive if they are actually used regularly.
202.3.8 Vertical Deflection	Vertical deflection is effective but doesn't impact the driver's perception of the area unless it is used as a gateway treatment for a visible pedestrian attractor like a park, school crossing, or integrated commercial area. Without the context, they are only effective in the specific location and drivers tend to speed up between them. Add discussion about EMS supportive speed cushions, speed peanuts;
202.3.9 Speed Feedback Signs	Without a logical reason for a reduced speed, feedback signs are likely to be ineffective except in their immediate vicinity. In other words, "you want me to go slowly--so what? I want to go as fast as the conditions show me I can." Show the driver why they are being asked to go slowly.
202.3.11 Islands	Street trees in islands are attractive and reduce the width at eye height but have minimal impact on speed without the presence of other contextual features. Excessively wide medians that run through dense urban areas can be retroffited to integrated sections with multi-use trails or park sections between the lanes (Paris-style islands). Street trees in buffered sections have minimal impact on speed. They may minimize the highest speeds, but the evidence is anecdotal.
202.3.12 Curb Extensions	Curb extensions visually reduce the corridor width and are an implicit signal that pedestrians will want to cross there. This must be backed up with actual human presence to provide significant speed reductions. Integrated sections should use curb extensions liberally. In buffered areas, where crosswalks exist, a short distance lane narrowing and curb extension can provide a visual cue to anticipate pedestrians crossing (a micro-integration). The need to navigate a narrower space has a small but measurable impact on speed.
202.3.13 RRFB/PHB	RRFB's/ and PHB's create micro-integrations within buffered areas and are a necessary part of making pedestrian crossings conspicuous.
202.3.14 Terminated Vista	Drivers focus their scanning on a location approximately 1.5 seconds in front of the vehicle. When their vision is limited, their speed moderates slightly to adjust. Terminated vistas create visual disruptions that help maintain driver caution across the length of their travel pathway. Assuminng SSD and DSD are maintained, streets should be designed with as short a visual horizon as possible.
202.4 Transition Zones	Gateway features should be implemented to signal a transition to an integrated section of roadway. Transitions between contexts within buffered sections should incorporate vertical visual elements on the higher context side. For instance, shifting from a clear zone approach to a boundary area approach when moving from C3 to C4/C5 should include vertical elements on the C4/C5 side. This sets up the transition to an integrated section later and provides addtitional percieved safety for pedestrians and cyclists.
210 Arterials and Collectors	Integrated sections will be rare and short. Their design will need to be dramatically different from the surrounding areas. Boundary areas and lateral offsets should be applied rather than clear zones.
210.3.2 Islands	When an integrated section occurs on an arterial or collector, islands and lane repurposing can and should be used to bring extra conspicuity to the pedestrians and bicyclists in the space. (Paris islands)

Citation	Notes
FDM, Volume II	
210.3.2.3 Refuge Islands	Refuge islands should have slightly different designs in integrated and buffered sections. In an integrated section, refuge islands are welcome, but less needeed where the corridor is narrow and pedestrian activity is common. Use trees where possible to further narrow the corridor visually. Trees can be used to further narrow the driver's visual corridor as long as they don't hide the pedestrians. In buffered sections, refuge islands should be kept clean and visually distinct so that any pedestrians can be seen based on biological movement, not just facial expressions. Refuge Islands are needed in buffered areas to signal that the crossing reflects a micro-integration. They should have low vegetation and it may be appropriate to have a mid-height fence around the median crosswalk areas as an additional visual indication to the driver that pedestrians will be there. A low-height fence through the median can prevent pedestrian crossings outside of the crosswalk.
215 Roadside Safety	This topic needs to be more intentional about balancing roadside safety between vulnerable users adjacent to the roadway and drivers. The Clear Zone concept is completely incompatible with integrated roadway sections. Lateral offsets are appropriate. Between 30 and 40 mph, the border area concept better balances the safety needs of vehicles and vulnerable users. Without vertical buffering between multi-use paths and the roadway, open corridors will repel the 8-80 bicyclists or pedestrians. In this speed zone, drivers need to be able to see the biological movement , but users should be buffered from any immediate threat. Above 45 mph, a clear zone is needed to protect the driver and pedestrians and bicyclists should be completely buffered from the traffic stream.
222 Pedestrian Facilities	The chapter needs to address the assumed inclusion of pedestrian activity strategically: are they going to be safely integrated into the street activities or buffered from roadway hazards? Pick one. It is critical to be up front about which strategic avenue is chosen. There are tradeoffs for each, and transitioning from one to the other over time needs to be discussed . If they are integrated, then the corridor needs to be narrowed enough to elicit lower speeds. If they are buffered, then the vehicle operating speed should dictate whether physical distance or barriers are used to "protect" them. Placing a pedestrian or bicycle facility in a clear zone implies, by definition, that the designer is more concerned about the safety of the driver than the vulnerable user they could hit. The implicit assumption may be that pedestrians and bicycles just won't be there, but that is a self-fulfilling feedback assumption. They won't be there because they don't feel safe. From a financial planning perspective, mode shift is one of the best ways to keep roadway construction costs down.

Citation	Notes
FDM, Volume II	
222.1 Pedestrian Facilities: General	This section is perfunctory in its approach. The strategic issues and choices as well as the limitations of the pedestrian need to be discussed in the introduction, similar to 201,202, 210 and other chapters. Since pedestrians are to be expected on all Florida state roadways, if they are not there in any quantity, the question needs to be raised about why they aren't there. Would a pedestrian percieve the location as safe, comfortable, or functional? Is the pedestrian path close to a high speed roadway without any barrier to protect them? Are there complementary land uses in close proximity? Are the pedestrian facilities placed poorly with respect to their access points? Should the pedestrian facility be placed outside of the corridor through an easment agreement and a mid-block crossing? Need to discuss the pedestrian perception that trees, onstreet parking, or other vertical elements provide protection. Need to comment on how the regular presence of pedestrians in a tight corridor changes driver behavior. Need to add a discussion of integrated and buffered design strategies in terms of logic, scale, and design. Need to add a discussion of the safe systems approach (prioritizing for lower inertia crashes) and target zero.
222.2.1 Sidewalk	Lack of existing connectivity should not, by itself, be a justification for not providing sidewalks. If there are no existing sidewalks or complementary uses that would generate pedestrian demand within a mile, their absence is justified. There should be a discussion about identifying whether the project location should be incoprorated into an overall network of pedestrian facilities? Local agencies should be encouraged to negotiate safe parallel pedestrian and bicycle accommodations outside of the ROW and close to the building entrances with mid-block crossing support as appropriate.
222.2.3 Crosswalks	Painting in crosswalks or intersections is a cue to the driver that the area has a different purpose than typical roadways (destination, not path) and that human presence is likely in that location. Consider approaching FHWA with guidelines and regulations to streamline review. Recommended requirements should include: 1.) integrated designation, 2) contrast conspicuity of standard MUTCD markings and 3.) color-blindness testing. Crosswalks marked at each minor street intersection can provide a visual disruption to the street flow, which could be beneficial in terms of speed management (see Figure 202.3.2). This could tip segment operations from a vehicle dominant to an integrated operation by increasing pedestrian use and reducing speed. This type of treatment should be accompanied by features that narrow the corridor visually. Corridors optimized for vehicle flow (buffered) should be intentional about selecting appropriate crosswalk locations that support walking desire lines while optimizing the conspicuity of any pedestrians that choose to cross.
222.2.3.2 Midblock	Recommend lane widths be narrowed and curb extentions be added at all midblock crosswalks as a matter of policy rather than as an optional treatment.

Citation	Notes
FDM, Volume II	
223 Bicycle Facilities	Address the incorporation of bicycle facilities from a strategic point of view. If the legal requirements were not present, what would be the rationale for providing them? What is the design user? What is the purpose of the activity? Does that purpose benefit the system as a whole or does it add risk without any transportation benefit? Is our intention to subsidize risk-taking behaviors or support mode shift? Facilities should be prioritized that support functional cycling for the majority of the public that could be willing to cycle, which means designing for the 8-80 cyclist or being intentional about providing separate facilities and training to support the Confident/Experienced cyclist. Our research findings leave us less confident that bicyclists are percieved within adequate time to adequately respond to their presence. User tracking and surveys indicate that most of the population feels far more safe with multi-use trails or side-paths. The only notable exception is the recreational and fearless cyclists who are bothered by the slower traffic on the trail and are often frightening to the rest of those users. Experience in the Netherlands and Denmark indicate that a wide range of users can be willing to shift modes if the paths are readily available, destinations are close, and the user demands are fairly low.
223.2.1 Bicycle lanes	I am not confident that on-road bike lanes can be safe at design speeds more than 35 mph due to the typical profile that experienced cyclists take and drivers' proclivity to travel far faster than the design speed. At design speeds of 25 mph or less, experienced cyclists are theoretically travelling at the same speeds as the vehicle flow and therefore are far more compatible with their operations. The introduction of e-bikes makes this even more likely than in previous years. Certainly, roadways with higher design speeds should be required to maintain the 7 foot buffered bike lane at a minimum. In integrated sections, bike lanes may add to the corridor width unless they are very frequently used. The addition of a bike lane (striped or not) to the cross section acted like additional roadway width in terms of attention and multitasking. Integrated sections should have design speeds at 25 mph or less, which matches the typical operating speed for experienced cyclists and sharrows that designate the appropriate location for cyclists are appropriate. In buffered sections, buffered bike lanes are appropriate for design speeds between 30 and 40 mph. However, off-road bicycle facilities should be preferred in order to support the 8-80 cyclist.
223.2.1.4 Green-colored pavement markings	Standard details and by-right approvals should be pursued with FHWA; consider requiring green pavement markings for driveways crossing multi-use paths to identify the potential conflict to both driver and cyclist
223.2.2.1 Marked Shoulders	A marked shoulder in an integrated area is likely (but not guaranteed) to widen the corridor in a way that disrupts the speed mangement. In a buffered area, consider reducing the maximum design speed for allowing marked shoulders to 35 mph.
223.2.3 Shared Use Paths	In theory, a shared use path is not needed in an integrated section, but if there is a shared use path in adjacent buffered areas, continuing it through the integrated section may be appropriate. In buffered areas, lower the threshold for considering a shared use path to 25 mph to support 8-80 cyclists
223.2.4 Separated bicycle lanes	This represents the ideal situation for a buffered condition. Green pavement markings should be considered for driveway conflict points.

Citation	Notes
FDM, Volume II	
223.2.4.3 Separated bicycle lane widths	Directional bike lanes are preferrable to bi-directional pathways because at high volumes the handlebars and pedals tend to conflict between oncoming cyclists. In buffered sections, it may be appropriate to consider 5 foot minimum width for RRR conversions from onstreet bike lane to separated lane. Designers should also consider vertical delineators for driver speed management and additional rider safety perception.
223.3 Shared lane markings (sharrows)	Sharrows have a chequered history, with inconsistent results in terms of safety and minimal impact on driver behavior. They can provide value in integrated sections in terms of maintaining a narrow cross section and positioning the cyclist appropriately within the lane, particularly next to onstreet parking. They also help manage driver expectations that bicycles are legally and practically appropriate in this area. Sharrows are not appropriate for buffered areas.
224 Shared use paths	Consider adding a design or standard plan for striping a shared use path for higher speeds in the center of the path to minimize conflicts and extend the applicability of a shared use path within C2T, C4, and C5 and to support the 8-80 cyclist.
224.1.4 Conflict points	Pursue FHWA approval for green striping across conflict points and generate a standard plan.
224.7 Horizontal Clearance	Trees provide additional buffering between the drivers and the vulnerable users in the path, increase the perception of safety for the SUP users, and reduce vehicle speeds due to the reduction in width at eye height. Add an exception within buffered areas for trees between the roadway and a shared use path allowing for a 2-foot clearance to the tree trunk, especially for RRR projects.
224.12 Separation from roadways	Clear zones imply that it is acceptable for drivers to leave the roadway and hit a vulnerable user in the path. At a minimum, Clear zones should only be applicable for design speeds 40 mph or higher. In a border area application, providing a buffer line of trees between the SUP and the roadway will add shade and protect vulnerable users.
226.1 Patterned Pavement and Architectural Pavers	As an indication of human presence their use is not mearly aesthetic but provides speed management benefits. Raised crosswalks and intersections add substantially to this effect.
228.1 Landscape design	A discussion of the impact that linearly aligned trees can contribute to driver attention is warranted here. In an integrated section, trees are used to reduce the width at eye height. In a buffered section, trees are used to provide a perception of safety for pedestrians and bicyclists.
228.2.2 Department maintained landscapes	It is noted that "rigid geometric designs focused on repetition should not be used as it is very noticeable if one or more of the trees fail." However, maintaining a visual line of trees creates a narrower visual corridor and is desirable from a speed management perspective. It might be better to recommend that geometric designs allow for interspersed age and species so that repetitive patterns may be maintained over time and specimens can be replaced when they become too large to maintain adequate visibility. Consider recommending structural soil to minimize sidewalk/path uplift.

Citation	Notes
FDM, Volume II	
230 Signing and marking	Consistent signing and marking is critical for roadways in general and for skill based operations within integrated sections. FHWA should be approached in order to provide more permanent guidance with regard to decorative treatments (both signing and marking) within integrated areas as the novelty cues the driver that there is likely to be human presence within close proximity to the roadway. Reducing higher-level automaticity is desirable in integrated environments to minimize mind-wandering and increase vigilance for vulnerable users.

Page	Citation	Notes
Florida Greenbook		
	Purpose	
vii	Policies and Objectives (H)	Add: Understand that experienced drivers use highly automatic attention patterns for most driving tasks to reduce their workload, resulting in efficient, effictive driving patterns and therefore engage in frequent distractions and mind-wandering as a normal part of their operations. This is generally safe as long as the driver maintains their eyes on the roadway since lane keeping and following is typically managed by the driver's peripheral vision. Fullly conscious, self-aware attention is most likely when drivers anticipate interaction with people in close proximity to their vehicle.
	Definitions:	
	sheltered section	A roadway section in which vehicle operations and flow are prioritized and optimized. Vulnerable users are sheltered from vehicle operations with active protections like buffered bicycle lanes, shared use paths, side paths, or parallel low-stress facilities outside of the corrior. Non-motorized crossings are designed for high levels of conspicuity and vulnerable user support.
x	Clear zone	The provision of onstreet bicycle lanes assumes that they will contain vulnerable users that are far less conspicuous than typical vehicles. The provision of a clear zone in an area where a bicycle lane exists is an intentional prioritization of the safety of the driver, who is already heavily protected by an entire armor of metal, over the safety of a bicyclist. It degrades the usability of the bicycle lane to less than 30% of the public (the Experienced and Confident or better), It communicates to the driver that maintaining attention on the driving task is not their responsibilty and lapses in their judgment or attention are low risk, not just to themselves but to everyone around them.
xi	Design User	Add definitions for at least two types of design bicyclists: the "8-80" year old cyclist, and the "Experienced & Confident (EC)"
new	Highway	A public right of way that allows for uninterrupted high-speed traffic flows. Highways are typically limited access facilities.
new	Integrated section	A street section in which pedestrians and bicyclists are given priority since they can be expected to move throughout the cross section on a regular basis. Integrated sections should be designed to operate below a community established target speed using contextual features like narrow cross sections, close building faces, and active land uses. Outside of C6 or TND envirnoments, integrated sections typically span roadway stations or blocks. Integrated sections are not synonymous with shared streets because they maintain the typical delineated cross section elements, but non-motorized users should be anticipated to be present in all cross section elements.
xii	Low Speed	I understand that AASHTO makes the break between low speed and high speed at 45 mph, but the psychological break is between 35 and 40 mph, so low speed should be categorized at 35 mph or less with very low speed tagged at 10-25 mph.
new	Micro-integration	An intersection or crosswalk located within a sheltered roadway section where vulnerable users are anticipated for 150 feet or less and therefore the potential for their presence is made highly conspicuous to motorized users.
new	Moderate Speed	40-45 mph design speeds
xiv	Recovery area	Add: the inclusion of pedestrian or bicycle facilities within the recovery area is strongly discouraged as it leaves them vulnerable to errant vehicles.

Page	Citation	Notes
Florida Greenbook		
xiv	Residential Streets	All residential streets should be designed as integrated spaces, but many are not due to the wide building setbacks and high through speeds.
new	Road	A public or private right of way that is primarily used for travelling from one destination to another. Roads prioritize the optimal flow of motor-vehicles over property access. Individual property access may be provided from roads, but are typically limited through access management criteria. Multimodal accommodations are provided according to statutory requirements, but vulnerable users should be sheltered from higher inertia motor-vehilce movement. Pedestrian and bicycle conflicts should be made highly conspicuous to assure their safety.
new	Street	A public or private right of way that is primarily used for access to businesses, residences, or institutional land uses in the immediate proximity of the corridor. Streets are destination spaces that typically span no more than 60 feet between curb faces or outside pavement edges and generally have building faces no more than 90 feet distant from each other. Streets prioritize access for vulnerable users over automobile flow and have typical operating speeds of 25 mph or less.
	Chapter 1: Planning	
1-3	B: Classification	Add a section describing integrated station identification and sheltered design between Context Classification and Design Speed
1-9	C.1 Safety	Add a discussion regarding integrated/sheltered sections
	Chapter 2: Land Development	
2-1	A. Introduction	Add in list at the bottom of the page: "Drivers have a clear understnading regarding when to expect interaction with vulnerable road users based on the characteristics of the street design and built form.
2-5	C.2 Network Design	Update bullets to use highways, roads, and streets according to their definitions.
	Chapter 3: Geometric Design	
3-2	A. Introduction	Incorporate integrated/sheltered as a concept into the existing text, particularly in the second paragraph
3-4	B. Objectives	Add a sentence at the end: Balance this protection with the need to assure pedestrians and bicyclists that they will be safe from vehicles that deviate from the travel path.
3-8	C.2 Design Vehicles	Rename the section to "Design Vehicles and Users" and add a table describing at least two of the 4 major bicycle user types ("8 to 80", "Interested but Concerned", "Enthused & Confident", "Strong & Fearless"). I prefer 8-80 and E&C.
3-17 new	C.3.e	Because we need drivers focused on the near-vehicle space, both for ped/bike recognition and speed management, best practices dictate that non-occluding focal distance obstructions should occur at least every 600 feet. This addition to the discussion should likely be placed somewhere other than the intersection section.
3-53	C.7.e Medians	In integrated spaces, tree filled medians can drop the width at eye height or be raised to provide pedestrian refuge spaces (that shouldn't be needed) but otherwise they should be discouraged because they add unnecessary width which encourages higher speeds.
3-54	C.7.e.1 Type of median	A wide, gently depressed median is the preferred design for LA and high speed roads. This type of median is detrimental in an integrated space

Page	Citation	Notes
Florida Greenbook		
3-71	C.7.h Parking	On-street parking, by definition, should tag the area as integrated since the driver will be in the roadway to enter and exit the vehicle. This description of OSP is unecessarily negative. There are substantial behavioral advantages to onstreet parking in terms of buffering pedestrians in integrated spaces and reducing multitasking. It should be balanced with the caveat that on-street parking without active street-front uses has minimial impact on speed and attention and therefore puts the person exiting the vehicle at an additional disadvantage in terms of the vehicles passing by. It's not a cure-all and has been abused.
3-73	C7.j.3 Preferential lanes	Add a note that the design bicyclist should be considered when designing a preferential lane for bicyclists. They can degrade corridor safety if they are not designed well. It may be better to have a shared space within an integrated section, although C6 applications will likely benefit from onstreet bike lanes where separate paths are not feasible. Increasing efficiency and vehicle type separation is the key to the sheltered strategy.
3-79	C.8.d Control of urban and rural streets and highways	This entire section is absolutely contrary to what we have learned in the last 30 years. Dendritic systems cause congestion at their trunk lines and cannot ultimately be served well. Highly interconnected patterns provide resiliency and automatic congestion management. Crossing and left turn movements in urban spaces are much easier to manage when they are dispersed through multiple opportunities and the systemic repitition of interruptions provides a consistent speed management and reorientation of the driver's attentional resources. Grid networks reduce the need for traffic signals by dispersing the demand across multiple, low volume intersections. Designing or redesigning commercial properties into more traditional grid systems minimizes the high-speed, high congestion access points and facilitate pedestrian access. Grid networks eliminate strip development. Dendritic systems are vulnerable to failures at key points that disable huge chunks of network. Take, for example, the Williamsburg neighborhood to the southeast of Sea World, which has 1600 homes served by one access roadway and one primary signal. A major accident at the primary signal (which is likely because of the congestion) can impede travel for the whole area. An accident south of the first minor intersection completely shuts off access to all of the properties to the south with no remedy.
3-120	Clear Zone	REplace guidance with a three-tier system tied to operating speed. Lateral offsets should be the only standard for integrated stations (0-25 mph). Clear zones should only be applied in high speed sheltered areas and are incompatible with pedestrian and bicycle facilities (45+ mph). Boundary areas are applicable where ped/bike features are placed. See Chapter 4, A
3-121	C.10.a.3 Sidewalks	Sidewalks 6 feet or wider will allow parents to hold hands and supervise two children.
3-123	Bicycle Facilities	This section needs to include a short discussion regarding the anticipated design user for the space.
3-126	C.11.c Reconstrcution Priorities	Clarify first bullet that sight distance obstructions at intersections are a priority. Sight distance setback lines should consider whether the section is integrated or sheltered since limited longitudinal sight lines are a proven speed management tool.
	Chapter 4: Roadside Design	

Page	Citation	Notes
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4-1	A. Introduction	There needs to be a clear delineation between two strategies: protect driver or protect the vulnerable user. You may not be able to do both simultaneously. Allowing the driver minimal observable consequences in terms of maintaining lane position fails to protect the pedestrian or bicycle that will be hit when the driver leaves the travelled way. This is far more common now that texting and driving is a more common occurrence. The socially unacceptable nature of drinking and driving hasn't stopped people from doing it. We must anticipate that lane excursions will continue to rise no matter how socially unacceptable it is deemed to be. Therefore, we must make the consequences of lane deviation in the proximity of vulnerable users as obvious and unavoidable as possible. Without this protection, we cannot achieve mode shift or target zero. Recommend a three-tier system for roadside hazard mitigation: Clear zones for high speed (45+ mph), boundary areas for low and moderate speed (30-45 mph) and lateral offset distances for very low speed (10-25 mph). Vertical elements in clear zones should be eliminated, including pedestrian and bicycle facilities. Ped/bike facilities should be allowed within boundary areas and buffered by highly visible vertical elements that are breakaway where possible. Lateral offsets should be used in very low speed areas with trees and other highly visible elements strongly recommended between vulnerable users and the vehicle flow except where they interfere with intersection sight distances.
4-33	E.6 Warrants for median barriers	Need both identification criteria for when median barriers are necessary (crash history) and mitigation strategies for providing appropriate mid-block and signalized crossings, which should be provdied at least within 300 feet of the desire lines. High pedestrian crash incidents may signal the need to convert the roadway section to an integrated cross section, if possible. Add inforrmation for warrants for median barriers to prevent median crossings by pedestrians and bicycles.
	Chapter 6: Lighting	
6-2	B. Objectives	add a bullet: Allow for drivers to recognize the presence of biological movement
6-3	C. Warranting Condtions	Integrated sections and micro-integrations within sheltered sections should always be lighted. Within sheltered bike/ped facllities, use the following criteria: Locations were pedestrians or bicyclists are present at least two nights out of a typical week.
6-16	N. Light poles	Light poles should be subject to clear zone regulations where they are appropriate (design speeds 50 mph or greater). Frangible poles should be permitted in border areas. Light poles in integrated sections or roadways with target speeds 25 mph or less should be located consistent with the appropriate lateral offset criteria.
	Chapter 8: Pedestrian Facilities	
8-1	A. Introduction	Add strategic discussion regarding Integrated/sheltered sections. Add discussion regarding pedestrian perception of safety when clear zone principles are applied and the placement of pedestrian facilities on the differet speed roadways
8-3	B.3 Shared Streets	Add a comment that all shared streets are integrated sections.

Page	Citation	Notes
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8-4	C. Minimizing Conflicts	Provide a full strategic discussion of integrated sections and default sheltering. Integrated sections are short sections of roadway in which vehicle, pedestrian, and bicycle activity are to be regularly expected within all parts of the cross section, including the roadway. Target and operational speeds are maintained at very low speeds (25 mph or less). All other low speed and moderate speed roadways (30-50 mph design speeds) should be designed as sheltered sections, with an intentional effort to shelter vulnerable users from vehicular flows.
8-6	C.2.c Vertical sheltering	This drops the width at eye height. In low and moderate speed sections, the incorporation of trees or breakaway posts will provide protection that will support more frequent use. Add a discussion of vertical delineation of sheltered pedestrian facilities to provide a visual cue that vulnerable users are in the space and a lower speed is appropriate.
	Chapter 8: Bicycle Facilities	
9-1	A. Introduction	Bicycle facility presence and design requires a nuanced handling that should begin with the identification of the purpose and user profile that the facility will serve. Level of traffic stress should be incorporated into the design of all bicycle facilities. Integrated should have LTS 3 or 4 in C4, C5, and C6. LTS 1 or 2 is acceptable for sheltered sections that are not transitioning.
9-34	C. Shared Use Paths	Modern shared use paths can be considered as an appropriate replacement for on-street facilities, particularly if they are striped for high-speed, low-speed segregation and the adjacent street has a target speed of 25 mph or less (sharable street).
9-38	C.7 Pavement Markings and Signage	Submit to FHWA requesting standard plan for striping shared use paths for high-speed center travel and permanent approval for green pavement markings at all SUP driveway crossings.
	Chapter 14: Design Exceptions and Variations	
14-1	A. General	Create an additional section for controlling design elements within very low speed streets (25 mph or less). Include target speed, corridor width, longitudinal visual distance.
	Chapter 16: Residential street design	
16-1	A. Introduction	Need to add a discussion about the impact of visual corridor width on speed management and traffic calming. Residential roads (those not functioning adequately as streets) should be targeted by local agencies for remediation. At a minimum, new residential streets should be designed with speed management as the primary aim.
	Chapter 19: Traditional Neighborhood Development	
19-1	A. Introduction	Nearly all roadways within TND's are designed specifically for integrated operation. This is a good chapter to refer back to any time an integrated design is needed.

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1-6	Figure 1-1	The table already recognizes that there are roads and streets at all levels except freeways. They never make a clear distinction between them.
1-22 new	1.5.4 Integrated or sheltered roadway sections	This is the appropriate location to add an initial description of the concept of an integrated or sheltered strategic choice is either before or after the context class discussion.
1-24	1.6.1.3 Pedestrians	Managing driver expectation is the key and that includes managing whether they anticipate being surprised. Transportation engineering has worked hard to make roadway design and operations very predictable, but it cannot succeed at making pedestrians, bicycles, or micromobility devices predictable in the same manner, so it is up to the transportation engineering profession to add clues and cues that allow the driver to expect surprises.
2-4	2.2.5 The Information System	Part of the information that must be communicated to the driver is that integrated spaces are not as predictable as typical roadway systems because they involve direct human interaction. Informal information sources should include contextually appropriate deviations from the typical formal information systems.
2-8	2.2.6.2 Primacy	If the goal is to focus the driver's attention on the critical design elements, then we need to be intentional about focusing drivers' attention closer to the vehicle in integrated spaces which will reduce their speed. This can be accomplished by providing visual disruptions between the decision sight distance and the horizon to generate a sense of enclosure.
2-8	2.2.6.3 Expectancy	Human presence is one of the most critical elements that drivers need to adequately anticipate. This element has a primal priority, neurologically, but the expectation of human presence can be easily lost if it is not adequately rewarded with actual human presence.
2-11	2.2.7.2 Errors due to situation demands	This section discusses overload and underload, but fails to discuss a third critical condition: the situation where the environment appears benign but requires more vigilance than is anticipated. In overload situations, the driver may be frustrated by their inability to keep up with the information flow, but they can adjust their speed to account for this. In underload situations, drivers are aware that they may become fatigued or distracted and have strategies to address the deficit. Many urban environments appear to require only minimal engagement based on the visual presentation of the cross section, but require much more conscious attention than typical automatic driving because the occasional presence of pedestrians and bicycles are not remembered or anticipated. The driver depends on the road designer to provide appropriate visual cues to alert them to the potential issue and the pedestrians and bicyclists rely on the designer to protect them from inattentive drivers.
2-22	2.3.6. Speed	The choice for the limits on low speed and high speed appears somewhat arbitrary and a more data-driven selection of breakpoints may be useful. We recommend 10-25 mph for very low speed, 30-45 mph for low speed, and 50+ for high speed. Additional data with regard to balancing driver attention, vigilance, and inertial consequences may be required to identify what the critical issues and boundaries are for each category.

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2-27	Design speed	This discussion would benefit greatly from a clearer distinction between roads and streets, and the subsequent incorporation of integrated and shelterd design strategies to align with these definitions.
2-54	2.7 Bicyclists	A discussion of the 4 primary types of bicyclists is appropriate in this section as the user type has a direct impact on the facility design in a way that is similar to how different vehicle operating characteristics dictate the facility's geometric design.
2-91	2.9.1.1 Roadway Design	This needs to be broken up into two sections: roadway design and street design with a description of the different strategic approaches needed for each.
2-92	2.9.1.2 Roadside design	Roadside design and speed management are intrinsically linked. Wide roadways generate high speeds which make obstacles dangerous. Narrow roadways with obstacles generate lower speeds because drivers recognize the danger that those obstacles pose. The appropriate strategy is to provide lateral offset for low speed multimodal environments in order to reinforce that vulnerable users are expected and a high level of vehicle position management is required. In moderate speed environments, the same message is needed in order to gain appropriate speed management and compliance from the driver and a measure of security for the vulnerable users. A boundary area strategy may be able to accommodate the need for breakaway roadside equipment and small diameter tree specimens. Clear zones are appropriate for high speed traffic but incompatible with pedestrian and bicycle accommodations since their intent is to make it "safe" for a vehicle to exit the roadway. It may be safe for the driver, but that excursion is deadly for a vulnerable user. Pedestrian and bicycle facilities should be relocated away from these corridors where possible.
3-53	3.3.6 Design for low speed urban streets	This section should address the active control of driver attention, vigilance, and speed mangement through design. Additional topics to be address include corridor width at eye height, street activity impacts, block length and mid-block crossings as a pedestrian safety and speed management strategy. and terminated vista distance to maintain driver focus in the near distance and reduce speed.
4-9	4.3 Lane Widths	Lane width on its own doesn't impact speed, but it cumulatively impacts the corridor width, which does impact speed. In integrated sections, travel lane widths should be kept to the minimum to maintain functional operations. Typically this means 10 foot wide travel lanes. Widths less than this adjacent to onstreet parking show frequent issues with side mirror collisions.
4-17	4.6.2 Lateral Offset	Lateral offset impacts operating speed. Minimizing lateral offset in urban spaces while keeping the sidewalk in clear view keeps drivers attentive due to the ability to see pedestrians. Incorporating vertical elements in view of the driver supports better lane-keeping.
4-39	4.11 Medians	Trees in the median have a positive impact on speed management. Use trees to narrow the width at eye height while maintaining adequate site distance at the intersections.

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4-57	4.15.4 Fencing	Consider median fencing to in high pedestrian crash areas to reduce unregulated crossings in sheltered sections. Make sure that there are still adequate crossing locations to support pedestrian desire lines. Pedestrians are likely to attempt to cross even with the fence if the crossing provided is too far.
4-77	4.18 Bicycle Facilities	This section needs a discussion of how the design bicyclist impacts the choices for facility type. If the goal is to provide functional connections within the community, designing for the 8-80 bicyclist will support mode shift in both integrated and sheltered sections. Consider whether accommodating the Strong and Fearless contributes negatively to Vision Zero outcomes and whether there are a sufficient contingent of ths cyclist type to be regularly anticipated by the driving public. In integrated sections, separate facilities are preferred but a sharrow may be appropriate to designate where the cyclist can avoid door issues from on-street parking. In a sheltered condition, multi-use paths may accommodate safer operations for most users and functional cycling. Striping the multi-use path for higher speed cyclists or instituting a speed limit for the Strong and Fearless may be required.
4-85	4.20 On-street parking	Any location with onstreet parking is, by definition, an integrated space. Add a discussion of where onstreet parking may be inappropriate due to high vehicle speeds, infrequent entryways, or inappropriate functional classification. Without the accompanying sidewalk and land use activity, the driver emerging from the vehicle may be at high risk from drivers in the travel lane that do not expect activity from the parked vehicles.
5-14	5.3.1.3 Levels of Service	Add a discussion regarding how providing an overly high level of service can induce additional demand and increase vehicle speeds, contributing to inatttentive driving and pedestrian or bicycle crashes.
5-16	5.3.2.1 Width of the travelled way	Lane width accumulates and together contributes to wider corridors which decrease driver attentiveness and increase corridor speeds. In integrated spaces, only use what is absolutely necessary and allocate any remaining space to vulnerable road users
5-18	5.3.2.8 Border Area	The border area concept is best applied when the operating and target speeds are 25-35 mph. Lane width accumulates and together contributes to wider corridors which decrease driver attentiveness and increase corridor speeds. In integrated spaces, only use what is absolutely necessary and allocate any remaining space to vulnerable road users. Lateral offsets are appropriate for sections with target speeds below this range, while clear zones and ped/bike relocation may be necessary at higher speeds.
5-19	5.3.2.10 Cul-de-sacs and Turnarounds	Add a discussion of how live-end streets impact pedestrian travel distance. When pedestrians are more common in the environment, speeds moderate and driver behavior is more attentive.
5-23	5.3.4.1 Clear Zones	The entire concept of a clear zone is incompatible with multimodal operations and should be strongly discouragd. We still have plenty of local engineers that point back to the AASHTO Greenbook to validate the incorporation of clear zones in residential neighborhoods, which directly contributes to high-speed, inattentive driving patterns. The exposed nature of these corridors is a significant impedement to pedestrian activity and contributes to neighborhood blight.

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6-13	6.3.1 General Design	Add a discussion regarding how cross sections can be designed to evolve with the development pattern over time.
6-13	Design Speed	Add the target speed concept. Integrated sections of collectors should be designed for speeds much lower than 30 mph, preferrably 10-20 mph.
6-16	6.3.2.1 Width of roadway	The width of the travel lanes should be tied to whether the section is integrated or sheltered. Integrated sections and micro-integrations at crossings or intersections may require narrowing of the lane widths to make the context change obvious. Sheltered sections can be designed for a wide range of speeds.
6-16	6.3.2.2 Number of lanes	A discussion regarding the negative impacts of design traffic over-estimation should be added.
6-21	6.3.4.1 Clear Zones	Either do a clear zone or don't. Incorporating elements of a clear zone will increase speed and decrease attentiveness. If the desired operating speed is high, then use a clear zone. If not, the openness generated by attempting to comply with clear-zone protections will leave pedestrians and bicyclists vulnerable to higher speed, inattentive vehicle flows.
6-21	6.3.4.2 Lateral Offset	Consider how to maintain minimal curb radii without large vehicle corner encroachment at intersections, particularly as they may impact the blind and wheelchair bound. Bulb-outs in urban areas can be used to improve turning radii and avoid encroachment while increasing the conspicuity of the pedestrians and bicyclists in the intersection and reducing crossing widths.
7-49	7.3.4 Roadside Design	Add recommedation to be intentional about the choice of a border area or clear zone for design. Choose one and apply it consistently. If pedestrians or bicycles are to be anywhere close to the roadway, then using a clear zone approach puts them at risk and subsequently decreases demand. If high speeds are anticipated on the corridor, rather than attempting to serve pedestrians and bicyclists within the right of way, consider alternate parallel locations and clear wayfinding that route users closer to their destinations, like doorways and building frontages.
7-66	7.3.19.1 Location of bus stops (midblock)	Add a discussion of how to bring additional conspicuity to midblock stops with narrowed midblock crossings, particularly on segments with long blocks. These are often high pedestrian crash locations and require additional conspicuity in sheltered sections to assure that their operations are functional while maintaining adequate safety for users. If the block is longer than 600 feet, use a narrowed mid-block crossing.
9-5	9.2.3.1 Human Factors	Pedestrian and bicycle visibility directly impacts driver attentiveness and speed.
9-7	9.2.4 Design Considerations for Intersection User Groups	Pedestrians: Add a bullet for the land use activity in terms of functional doorway access. When doorways are sparse or located away from the intersection, drivers are far less aware of pedestrian presence leading to poor safety outcomes.
9-8	Table 9-1 Key dimensions of Specific	Add block length to pedestrian, wheelchair users, and persons pushing strollers. Short blocks increase pedestrian conspicuity and keep travel paths short. Once block lengths exceed 600 feet without a midblock crossing, pedestrian activity decreases to negligible quantities.

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9-10	9.2.5 Intersection Capacity	Intersection and segment capacity for pedestrians and bicyclists are rarely an issue yet. However, we should anticipate that they can be in some locations today and there will be a need for evaluating capacity for non-motorized modes in the future as we increase network connectivity and these modes become viable for travel.