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RESILIENCE FINDINGS

Integration of Resilient and Complete Streets in Geometric and Roadway Design Guides

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Findings

This research explores the state of resilience and Complete Streets topics in current geometric and roadway design guides in North America. We conducted a content analysis of twenty-two provincial, state, and general design guides, and a topical examination of the relationship of Complete Streets elements to resilience goals. While Complete Streets topics are well integrated into guides, resilience topics are rarely present, leading to possible missed opportunities to achieve co-benefits or manage tensions. Implications from this research can begin discussions that embed safety *and* resilience into roadway design that also furthers multi-modal and sustainable transportation.

1. Questions

Transportation networks across North America, particularly in urban environments, have slowly begun shifting away from auto-centric infrastructure towards multimodal, sustainable, and safe transportation for all road users. This is often accomplished through a Complete Streets design philosophy and redesigning roadways (LaPlante and McCann 2008; Burden and Litman 2011; Jordan and Ivey 2021). Alongside this emergence, transportation resilience, which we define as the ability and capacity of transportation systems and associated infrastructure to mitigate, prepare for, respond to, and recover from acute shocks and chronic disruptions, is gaining priority to manage ongoing disruptions from climate change and human-caused disasters (Markolf et al. 2019; Sharifi 2019; Wong 2020; Fields and Renne 2021). However, priorities and designs for Complete Streets might not readily align with some transportation responses in disasters, such as evacuations. Moreover, it is unclear how resilience is currently considered in road design manuals, especially those that incorporate Complete Streets designs. Building off Fields and Renne (2021), which investigated resilient streets, we ask two questions in this research:

1. How is resilience embedded in geometric and roadway design?
2. What Complete Streets designs produce co-benefits of safety and resilience?

2. Methods

Focusing on North America, the data was sourced from geometric design guides and roadway design manuals from nine provinces in Canada, nine disaster-prone states in the United States, and four leading transportation

Table 1. Design documents (n=22) used for content analysis through a keyword and content search

Geometric and Roadway Design Documents		
Jurisdiction	**Document Title**	**Year Published / Revised**
Canada		
British Columbia	B.C. Supplement to TAC Geometric Design Guide for Canadian Roads	2021
Alberta	Highway Geometric Design Guide	2023
Saskatchewan	Design Manual	1990
Manitoba	MIT "Blue Sheets" Supplements to 1999 TAC	2002
Ontario	MTO Design Supplement for TAC Geometric Design Guide for Canadian Roads	2020
Nova Scotia	Standard Specifications - Highway Construction and Maintenance	2023
Newfoundland and Labrador	Highway Specification Book	2023
New Brunswick	Standard Specifications for Highway Construction	2023
Prince Edward Island	General Provisions and Contract Specifications for Highway Construction	2023
United States		
Oregon	Highway Design Manual	2023
Washington	Design Manual	2022
California	Highway Design Manual	2022
Florida	Florida Greenbook (MUTCD)	2021
Louisiana	Roadway Design Procedures and Details	2021
South Carolina	Roadway Design Manual	2021
Alabama	Performance-Based, Practical Design Guide	2020
Texas	Roadway Design Manual	2010
Mississippi	Roadway Design Manual	2020
Leading Transportation Organizations[a]		
ITE	Urban Street Geometric Design Handbook	2008
TAC	Geometric Design Guide for Canadian Roads	2020
NACTO	Urban Street Design Guide	2013
AASHTO	A Policy on Geometric Design of Highways and Streets - 7th Edition	2018

[a] Transportation Association of Canada (TAC), National Association of City Transportation Officials (NACTO), American Association of State Highway Transportation Officials (AASHTO) and the Institute of Transportation Engineers (ITE)

organizations in North America[1]. A content analysis of these design documents was conducted through a keyword and content search of Complete Streets topics (n=12) and resilience-based topics (n=11). The design manual for Quebec was not used since it was only available in French. Table 1 lists each design document analyzed while Table 2 lists and describes all keywords used.

To answer the second question, we conducted a simple analysis of common Complete Streets design measures (e.g., horizontal deflection, roundabouts, etc.) and their interaction with resilient transportation goals. The effects of each Complete Streets measure were brainstormed and listed, helping us

1 Transportation Association of Canada (TAC), National Association of City Transportation Officials (NACTO), American Association of State Highway Transportation Officials (AASHTO) and the Institute of Transportation Engineers (ITE)

Table 2. Keywords (n=23) with a short description used for content analysis

Keywords and Description for Content Analysis	
Resilience Topics	**Short Description**
Resilience	Ability and capacity of transportation systems and their associated infrastructure to mitigate, prepare for, respond to, and recover from acute shocks and chronic disruptions
Evacuation (General)	The movement of people away from a hazard to protect lives
Wildfire	A hazard consisting of the spread of fire (often quickly and uncontrollably) through an environment
Flood	A hazard in which water rises beyond typical levels or confines, especially onto dry land
Earthquake / Seismic	A hazard most often caused by tectonic plate movement
Hurricane	A hazard characterized by a rotating storm that is often characterized by severe winds, storm surge, and heavy rainfall
Landslides / Rockfalls / Mudslides	A hazard in which a large amount of earth, soil, or other debris (sometimes in combination with water) slides away from a slope
Avalanche	A hazard in which a large amount of snow or ice rapidly moves down a slope
Hazard / Disaster / Emergency[a]	A possibly negative event to societies or people / an event that has a negative impact on people or communities / an urgent event that poses risks to people
Climate Change	Long and medium-term shifts of weather conditions at various scales (local, regional, and global) that have been driven recently by human activity
Evacuation Route	Routes identified, designed, or improved to facilitate an evacuation during a hazard
Complete Streets Topics for Content Analysis	
Complete Streets Topics	**Short Description**
Complete Streets	Approach to street design with the intent of accommodating safe, convenient, and efficient travel for all users regardless of transportation mode
Sustainability	Transportation design with the intent to balance social, economic, and environmental needs
Air Pollution	Spread of (or related control of) contaminants with harmful effects that are released into the air by vehicles or other pollution sources.
Noise Pollution	Harmful or excessive noise that has a negative effect on humans or the environment.
Traffic Safety / Road Safety	Design measures or procedures that primarily reduce vehicle collisions
Traffic Calming Measures	Physical or other design measures with the intent to reduce vehicle speeds or other unsafe behaviours
Vision / Target / Road to Zero	Policies that aim to reduce traffic-related fatalities or serious injuries to zero, often by a specified deadline.
Bicycle Traffic Considerations	Design measures or policies that promote or accommodate the use of bicycles as an alternative mode of transportation.
Vulnerable / All Users	Transportation designed for the accommodation of all road users regardless of age, ability, mode of transportation, or other characteristics
Target Speed = Design Speed	Design practice of setting the design speed of a road to be equal to a determined target speed (as opposed to being based on operating speeds)
Land Use Changes / Traditional Neighborhood Development (TND)	Alternative land use policies that promote the use of alternative modes beyond vehicles, increase density, and/or promote more sustainable living
Transit Oriented Design	Streets and land use that are designed with public transit options as primary transportation options

[a] These words have slight variations in description but are categorized together for this content analysis.

identify co-benefits, neutral points, and tensions. While rudimentary, this simple methodology of document review, topical analysis, and goal-comparing can be easily replicated for other geographies to establish a current state for resilient and safe roadway design.

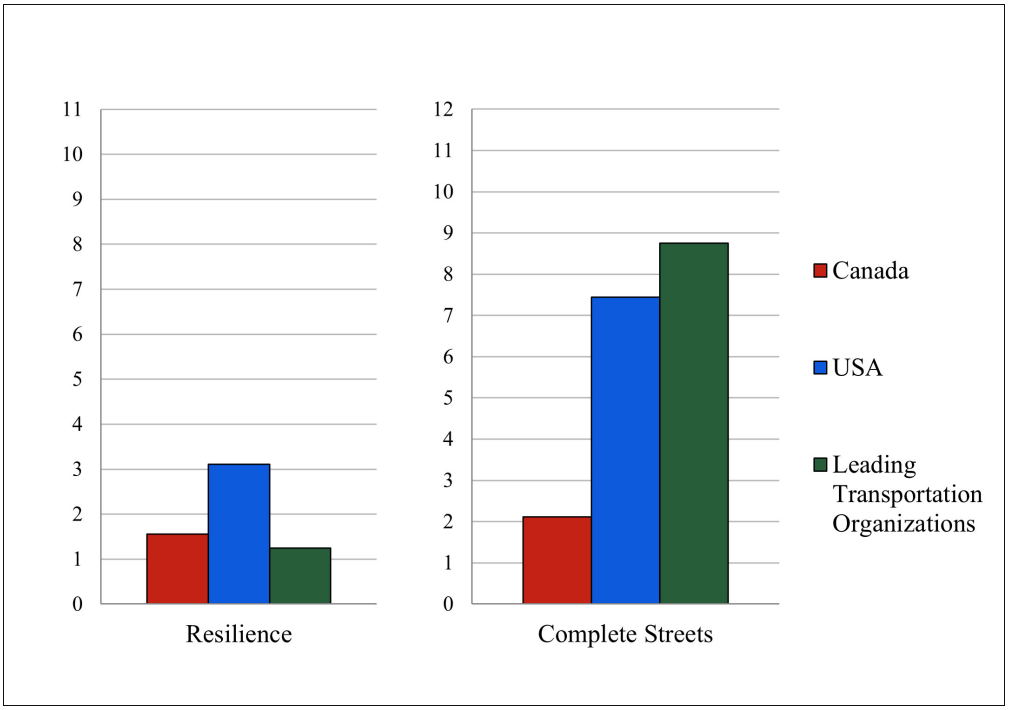

Figure 1. Average Topical Frequency for Resilience (n=11) and Complete Streets (n=12) across Jurisdictional Groups.

3. Findings

We first present the results of the keyword search and content analysis through average topic frequency for Complete Streets topics and resilience topics by jurisdictional group (Figure 1).

Across design documents, resilience topics were much less frequently mentioned than Complete Streets topics. For example, just 14% of all resilience topics were found on average in Canadian documents, while just 28% of all resilience topics were found on average in U.S. documents. We also found that the leading transportation organization design manuals on average had the highest Complete Streets topic frequency, but the lowest resilience topic frequency. Results presented in Figure 1 also suggest that Canadian provincial design documents lag behind disaster-prone states in the U.S. in both resilience and Complete Streets design. Ultimately, we find a lack of prioritization of simple resilience topics (mostly disaster types) across roadway design manuals across all jurisdictions.

We next analyzed topical frequency for Complete Streets and resilience across all design manuals (Figure 2). Despite the high frequency of Complete Streets and sustainability topics, multiple concepts were present in less than 40% of manuals. Under-represented topics included: transit-oriented design, Vision/Target/Road to Zero, land-use change, target vs. design speed, and the Complete Streets term itself. This appears to indicate that road design manuals still focus predominately on larger geographic areas, while more localized concerns and planning (e.g., land use, transit, Vision Zero) are left to individual

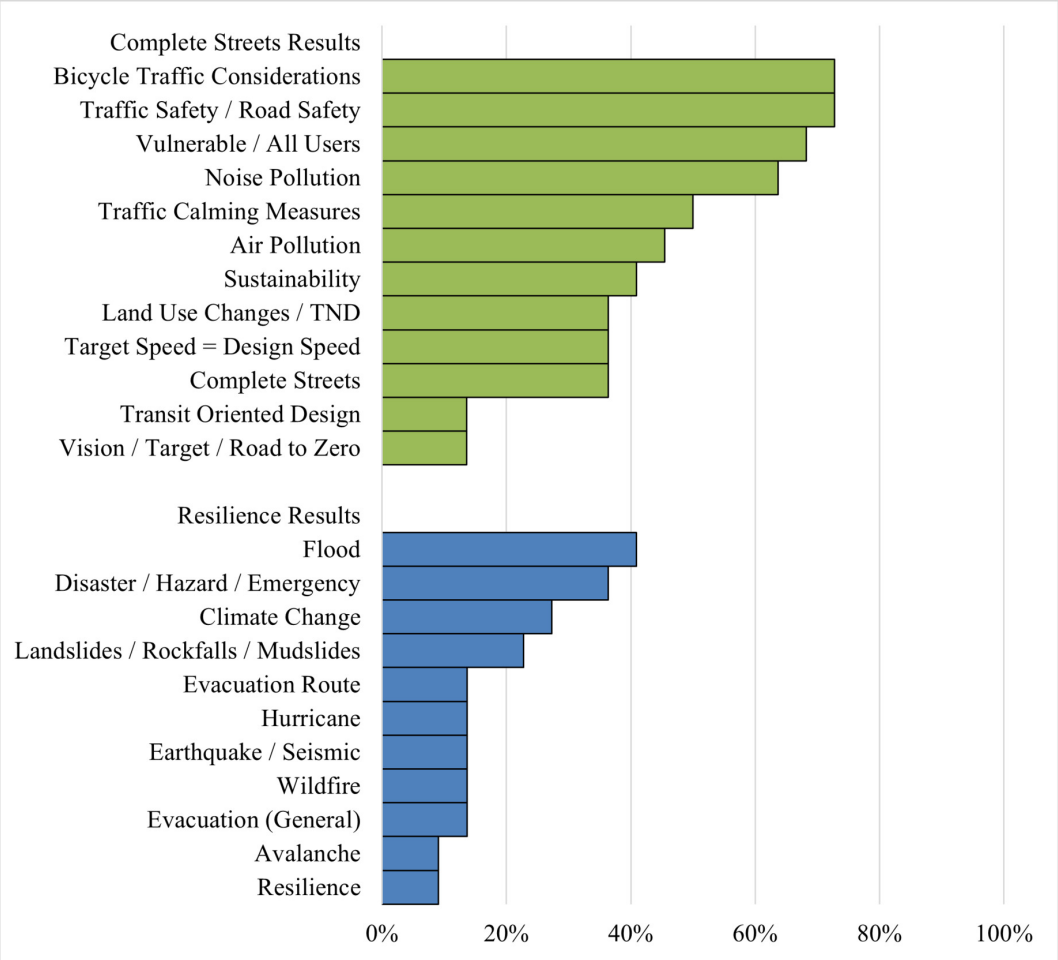

Figure 2. Overall Topic Frequency across 22 Road Design Documents

communities. Focusing on broad topics, over 70% of documents discussed bicycling, traffic/road safety, and vulnerable/all users, indicating a prioritization of alternative modes and equity.

Relative to Complete Streets topics, resilience topics were largely left out of design guides apart from a few exemplary documents (e.g., Oregon, Washington, California, and British Columbia). Though topics such as flooding, disasters / hazards / emergencies, and climate change were somewhat common, they appeared in less than 50% of all documents. A common disaster across most jurisdictions, flooding was often discussed in the context of drainage needs and its rapid effect on roadway functionality. Other hazards were more jurisdiction-dependent. Evacuation routes, evacuations (other than routes), and the concept of resilience itself were present in less than 15% of manuals.

Standout examples in the U.S. included Oregon's Highway Design Manual with 82% of resilience topics and 83% of Complete Streets topics, Washington State's Design Manual with 100% of Complete Streets topics and 36% of resilience topics mentioned, and California's Highway Design Manual with 82% of resilience topics and 75% of Complete Streets topics discussed. In Canada, British Columbia's Supplement to TAC Geometric Design Guide

mentioned 64% of resilience topics and combined with TAC, mentioned 75% of Complete Streets topics. These exemplars offer a template for effectively incorporating both resilience and Complete Streets topics within design documents for current and future roadways.

To conclude, we conducted a brief examination of the resilience of several Complete Streets design measures (Table 3) for future research purposes based on information provided by several design documents. Overall, few Complete Streets measures appear to directly conflict with resilience goals. Some potential co-benefits include:

- Using transit or bike lanes as flexible lanes during evacuations;
- Maintaining intersection throughput during a power outage via roundabouts; and
- Modal shift and improved safety conditions for walking or bicycling in a disaster.

Most tensions we found involve the reduction of roadway capacity, which could inhibit auto-based evacuations. Temporary infrastructure and operational strategies might be needed to overcome this specific tension, though more research and post-disaster assessments will be necessary.

Although a simple analysis, our study presents a first step into understanding the current state of Complete Streets, resilient roadway design, and the connection of these topics. Future research will be needed to better incorporate sustainability in tandem with resilient street design, managing tensions and promoting co-benefits as transportation networks continue to evolve.

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Table 3. Results of a simple analysis outlining potential co-benefits and tensions between five common Complete Streets design measures and resilience goals.

Complete Streets Measure	Relevant Discussion from Guides	Potential Resilience Co-Benefits	Potential Resilience Tensions
Roundabouts	Modern roundabouts are typically yield-controlled and can service up to 45,000 vehicles daily depending on the design used (AASHTO, 2018). In addition, drivable curbing or truck aprons can be easily applied (WSDOT, 2022).	- Operations are not electricity dependent as the design is typically yield-controlled. - Drivable curbing or truck aprons can allow for easier emergency vehicle or transit vehicle passage.	- Congestion may occur during episodic, high-demand events (e.g., an evacuation).
Road Diets	While not appropriate for all road configurations, road diets can assist in affecting modal shift, improving traffic flow, reducing conflicts, and building safer streets (NACTO, 2013).	- Modal shift can help lower emissions and can reduce traffic during high-demand events. - Lowered modal conflicts can reduce collisions and operational disruptions during a hazard.	- Road capacity for vehicles may be lowered, causing congestion during an evacuation or high-demand event.
Dedicated Bus / Bike Infrastructure	Dedicated bus and bike infrastructure involves creating separate infrastructure (e.g., transit lanes, bike lanes, shared used paths) and related features (e.g., transit signals, bike parking, etc.). Though promoting multi-modality, converted vehicle lanes can sometimes disrupt road characteristics or features such as lane widths and intersections (NACTO, 2013 & AASTHO, 2018).	- The promotion of alternative modes of transportation reduces reliance on personal vehicles, which could reduce vehicle congestion during high-demand events. - Sufficiently wide transit or bike lanes can service emergency vehicles when necessary, such as during evacuations.	- Congestion may increase for vehicles if vehicle demand still exceeds roadway capacity, despite mode shifts.
Signal Light Progression	When optimized, signal light progression can increase corridor capacity for vehicles. Alternatively, "reverse progression" can occur for public transit buses when they miss the signal progression window, causing an increase in travel times (AASHTO, 2018).	- Higher corridor capacities and fewer delays can improve evacuation times, even when personal vehicles are primarily used.	- Reverse progression for transit may discourage modal shift and may promote personal vehicle usage. - Signal systems are reliant on electricity and are potentially unreliable if outages occur.
Traffic Calming Measures	Traffic calming measures such as curb extensions or other horizontal/vertical deflection measures can help manage speeds and provide visual cues to drivers to slow down, while also increasing pedestrian safety (WSDOT, 2022 & NACTO, 2013). Roadside features such as street trees or parklets and the reallocation of roadway space or lane widths can also improve road user safety and slow speeds (ODOT, 2023). Temporary traffic calming can also be implemented prior to a full reconstruction, providing immediate safety benefits (NACTO, 2013).	- Improved pedestrian safety can encourage mode shift and may reduce personal vehicle usage during high-demand events such as evacuations. - Speed cushions allow for emergency vehicles to pass unaffected. - Slower speeds result in reduced crash severities, leading to faster collision removal times and shorter disruptions. - Bus bulbs reduce transit delay when merging back into traffic and assist in mode shift.	- Vertical deflection traffic calming on snow routes requires care from plow or sweeping operations to avoid damage. - Horizontal deflection measures, if placed incorrectly, may create bottlenecks that can negatively affect high-demand events.

REFERENCES

Burden, D., and T. Litman. 2011. "America Needs Complete Streets." *ITE Journal* 81 (4): 36–43.

Fields, Billy, and John L. Renne. 2021. *Adaptation Urbanism and Resilient Communities: Transforming Streets to Address Climate Change*. Edited by Billy Fields and John L. Renne. Routledge. https://doi.org/10.4324/9780429026805.

Jordan, Samuel W., and Stephanie Ivey. 2021. "Complete Streets: Promises and Proof." *Journal of Urban Planning and Development* 147 (2): 04021011. https://doi.org/10.1061/(asce)up.1943-5444.0000684.

LaPlante, J., and B. McCann. 2008. "Complete Streets: We Can Get There from Here." *ITE Journal* 78 (5): 24.

Markolf, Samuel A., Christopher Hoehne, Andrew Fraser, Mikhail V. Chester, and B. Shane Underwood. 2019. "Transportation Resilience to Climate Change and Extreme Weather Events – Beyond Risk and Robustness." *Transport Policy* 74 (February): 174–86. https://doi.org/10.1016/j.tranpol.2018.11.003.

Sharifi, Ayyoob. 2019. "Resilient Urban Forms: A Review of Literature on Streets and Street Networks." *Building and Environment* 147 (January): 171–87. https://doi.org/10.1016/j.buildenv.2018.09.040.

Wong, S.D. 2020. "Compliance, Congestion, and Social Equity: Tackling Critical Evacuation Challenges through the Sharing Economy, Joint Choice Modeling, and Regret Minimization." University of California, Berkeley. https://www.proquest.com/docview/2509694368?pq-origsite=gscholar&fromopenview=true.

SUPPLEMENTARY MATERIALS

Supplemental Data

Download: https://findingspress.org/article/116296-integration-of-resilient-and-complete-streets-in-geometric-and-roadway-design-guides/attachment/223367.pdf