Resilience in a Transportation System: Should ITE Include Resilience in its foundational documents

This white paper explores the definition of resiliency and how this concept relates to transportation systems. It then provides ideas for how resilience could be included in ITE’s foundational documents and, more generally, current transportation practices.

The use of the word ‘resilient’ is on the rise, but what does it mean?
A quick search in Google’s Ngram (Michel, et al., 2010) of the word ‘resilience’ shows a marked increase in its use in the last 15 years. Yet, compared to the word ‘sustainable’, it still is in the shadows.

Figure 1 - Ngram of the word 'resilience'
With the use of the word resilience growing and the idea of sustainability already included in ITE’s foundational documents, it now may be the time to consider if the idea of resilience should be included more formally.

This paper provides two premises that together form the basis for considering the idea of resiliency into the foundational documents of the ITE:

1. Resiliency outcomes are important to have in a transportation system
2. Resiliency is different than the term sustainability
   a. And there is a marked value in having both sustainable and resilient in the foundational documents.

To explore the points made above, first the definition of a system is provided since both sustainability and resilience may be considered properties of a system. From this systems perspective, resiliency is defined and the outcomes of a resilient transportation system are explored.

It is at this point that sustainability is defined and the Sustainability Policies that ITE have adopted are introduced and outcomes identified. A comparison of what a resilient transportation system would look like relative to the sustainability policies of ITE is then provided.

**Transportation Whole-System Approach**

When you are dealing with a system, and are acutely aware that everything is connected in some manner, the system’s response to an economic interruption or physical interruption all relates to its resiliency. When we look at our cities, if we look hard enough, it is possible to identify single components that are at play. But, these components, or elements, are influenced by other components, which are themselves influenced by other components.
Our cities are not factories that follow processes and flows, they are places where the built environment, technologies, and people all interact over a variety of time scales. These social-ecological systems are complex and adapt to influences over time, which means that understanding how individual elements function does not mean that the overall system can be understood or predicted. Given that we live in a complex world, one way that we can seek to understand our current situation is to view the system as a whole, acknowledging all the interconnected parts.

Some graphical models of the transportation system are provided below and demonstrate the interconnectedness of the various elements and the difficulty in isolating single variables.

**Figure 3 – Example of Automobile Use System as presented by Sterman** (Sterman, 2000)
As depicted above, our urban areas and societies have been built upon these connections, some being completely engrained in the way we think and do things. In some cases, new services (e.g. Uber or Car2Go) emerge and surprise us with their effectiveness and uptake. Perhaps this is because we are so comfortable in seeing the world within our personal viewpoints and do not or cannot recognize these potential disruptions. A whole-systems viewpoint will not provide a crystal ball into the future in order to predict these types of disruptions, but instead provides a better framework to understand why these changes are effective and how we could frame our policies and practices to recognize these new contexts.

To better understand the whole-system approach, it is important to provide a more formal definition of what a system is:

“A system is an interconnected set of elements that is coherently organized in a way that achieves something.”
(Meadows, 2008)

In this definition of a system it can be seen that the elements and the connections between them, the interactions, is present, but it is also important to note the element of a purpose or goal to which it also acknowledges. This purpose will be important to remember when we discuss the idea of values that would be held if a resilient system is sought.
Another, more academic, definition to consider for the system that we live in is that of a Complex Adaptive System. Somewhat fittingly, there is no widely accepted definition for a Complex Adaptive System, but some have said it has the following characteristics: (Levin, 1998)

- Sustained diversity and individuality of components
- Localized interactions among those components
- An autonomous process that selects from among those components, based on the results of local interactions, a subset of replication or enhancement

The definition for a system as presented in Meadows and that of a Complex Adaptive System are very similar and may actually differ only in the style of the language used to describe each. Both acknowledge that systems have parts (e.g. elements or components), connections, and a purpose.

It is with the idea of social-ecological systems in our minds that we now explore sustainability and resilience as properties of complex systems.

**Resiliency defined**

Resiliency is tied as how a system can react to tremors, shocks, or catastrophes (OECD, 2014). These impacts can be over a short duration or long durations, and how well it can perform during these changes depends on how resilient the system is. Many times, the desire is for the system to just endure what has been going on, but sometimes the need is for the system to be able to change or adapt to what could potentially become a 'new normal'.

Some definitions of resiliency that have been used include:

- *The capacity of the system to function in spite of external drivers (both shocks and directed change).* "The resilience of what to what?" (Carpenter, Walker, Anderies, & Abel, 2001)
- *The capacity to sustain a shock, recover, and continue to function and, more generally, cope with change* (Walker, Holling, Carpenter, & Kinzig, 2004)
- *The ability of a system to absorb disturbance and still retain its basic function and structure* (Walker & Salt, 2006)
- *No single discipline deals with systems that range across all possible scales, therefore disciplines have generated their own definitions relevant to the class of problems they address* (Martin-Breen & Anderies, 2011)
- *Resilience is the ability of households, communities, and nations to absorb and recover from shocks, whilst positively adapting and*
transforming their structures and means for living in the face of long-term stresses, change, and uncertainty (Mitchell, 2013)

Underlying elements in all of these definitions are: systems and abilities to absorb and recover from shocks. One nuanced element of the definition is in relation to transforming abilities. Especially with climate change, social equity, and obesity epidemics becoming linked to our built environment and the transportation systems we currently have in many North American cities, change to our current systems are required, making the aspect of transformation very important to consider.

While it is important to know what a concept IS, it is also important to understand what a concept IS NOT. A leader in systems thinking, Dana Meadows, was clear in defining what resilience IS NOT in her book “Thinking in Systems: A primer” (Meadows, 2008):

"Resilience is not the same thing as stability, which we can define here as relative constancy over time. Resilient systems can be very unstable. Short-term oscillations, or periodic outbreaks, or long cycles of succession, climax, and collapse may in fact be the normal unstable condition, which resilience acts to restore!

And conversely stable systems can be un-resilient. The distinction between stability and resilience is important, because stability is something you can see; it's the measurable variation in the condition of a system week-by-week or year-by-year.

There are always limits to resilience.

Resilience is something that may be very hard to see, unless you exceed it and the system breaks down. Because resilience is not obvious without a whole-system view, people sacrifice resilience for stability, or for productivity, or for some other more immediately recognizable system property."

Of particular interest to transportation professionals is that resiliency is based on a system or network and is difficult to summarize simply into equations, quantities, even observations. By not considering all the other factors at play, a single answer may be found, but it may not mean the entire system is going to benefit. In addition, the system is constantly changing, as it is responding to feedback from all directions, internally and externally. As stated in Martin-Breen & Anderies, "ecosystems do not evolve toward a single stable climax state, but undergo periodic cycles of change." By not considering the whole system, practitioners can take a
singular perspective in the pursuit of a complex problem and result in detrimental or counter-productive outcomes.

**What does resiliency give you?**

The focus on disaster preparedness has been of major interest to organizations and governments. With billions of dollars (Ward, 2016) of damages associated with disaster relief, it is understandable that this is of concern. But, what is clear is that a focus on resilience can be a far more reaching topic than a single focus on one type of risk.

According to Walker and Salt in their book *Resilience Thinking – Sustaining Ecosystems and People in a Changing World* (2006), a resilient world would value diversity, ecological variability, modularity, acknowledge slow variables, tight feedbacks, social capital, innovation, overlap in governance, and ecosystem services. These values represent a strong foundation that societies and municipalities can, and do, base themselves around.

Additionally, structuring resiliency planning around these values is an approach that other organizations cite as a way to move past positions, which can be at odds with others. This, then, allows them to operate from a shared goal. The image below is from the International Association of Public Participation and describes the concept of moving away from positions and instead working from shared visions to resolve issues.

"Operationalizing resilience thinking is, in part, about getting people to cross a mental threshold into a systems mind space in which systems with multiple stable states and adaptive cycles make sense. Cross this particular threshold of understanding and the world takes on a different light."

(Walker & Salt, 2006)
By planning for resiliency from key fundamental values, the actions needed to operationalize this type of thinking can be derived. Given the influence of whole system thinking in this area, these values alongside a stronger understanding of the system dynamics we are living within is necessary.

The table below provides a summary of the values a resilient system would hold as stated by Walker and Salt (2006), together with the possible outcomes that this value could contribute to within a transportation system.
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<thead>
<tr>
<th>Value</th>
<th>Supporting statement</th>
<th>Possible outcomes in transportation system under this value</th>
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<tbody>
<tr>
<td><strong>Diversity</strong></td>
<td>A resilient world would promote and sustain diversity in all forms (biological, landscape, social, and economic).</td>
<td>Meaningful engagement with stakeholders</td>
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<td>Diversity in land uses within near proximity</td>
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<td>Multi-modal transportation planning</td>
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<td>Diversified mobility choices for ridesharing</td>
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<td>Equitable allocation of mobility investment</td>
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<td><strong>Ecological variability</strong></td>
<td>A resilient world would embrace and work with ecological variability (rather than attempting to control and reduce it).</td>
<td>Context sensitive approaches, not one size fits all.</td>
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<td>Variety or reduction of policy and regulations based on desired outcomes and evidence-based</td>
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<td><strong>Modularity</strong></td>
<td>A resilient world would consist of modular components.</td>
<td>Gridded networks for all transportation modes to allow for multiple options from origins to destinations</td>
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<td><strong>Acknowledging slow variables</strong></td>
<td>A resilient world would have a policy focus on “slow,” controlling variables associated with thresholds.</td>
<td>Phasing out of surface parking over structured or hidden parking as redevelopment occurs.</td>
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<td>Land use changes and/or growth priorities within municipalities in the long-term</td>
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<td><strong>Tight feedbacks</strong></td>
<td>A resilient world would possess tight feedbacks (but not too tight).</td>
<td>Piloting projects to test potential outcomes</td>
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<td>Monitoring and Evaluation programs feeding into new development and planning procedures (e.g. refining trip generation rates)</td>
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<td>Social capital</td>
<td>A resilient world would promote trust, well-developed social networks, and leadership (adaptability).</td>
<td>Projects that not just build infrastructure, but contribute to communities strengthening their social bonds (e.g. Build a Better Block, Tactical Urbanism)</td>
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<tr>
<td>Innovation</td>
<td>A resilient world would place an emphasis on learning, experimentation, locally developed rules, and embracing change.</td>
<td>Local standards and national rules being accommodating for new evidenced-based designs or guidelines are published Working with standards &amp; guidance sources, as well as the legal system, to emphasize technical judgment and reasonability as key criteria in determining the appropriateness of transportation decisions rather than strict adherence to standards</td>
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<tr>
<td>Overlap in governance</td>
<td>A resilient world would have institutions that include &quot;redundancy&quot; in their governance structures and a mix of common and private property with over-lapping access rights.</td>
<td>Stronger emphasis on participatory planning and community engagement Regional partnerships and national associations being partners in governance of practitioners</td>
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<td>Ecosystem Services</td>
<td>A resilient world would include all the unpriced ecosystem services in development proposals and assessments.</td>
<td>Lifecycle cost accounting or full cost accounting that aims to include more externalities associated with infrastructure</td>
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The values and examples shown in the table above are only some of the possibilities that would present themselves in a more resilient system. These values could be applied to various aspects of transportation systems and the governance structures that own and operate them, such as policy and regulatory bodies, planning processes and guiding documents, design of infrastructure, incorporation of technology, and operation and maintenance of the existing infrastructure.

**How can you tell if you have a resilient system? - Measuring and Monitoring**

In many cases, it is not possible to determine if the system you are within is resilient or sustainable. Often, you can only see if you are doing a good job in the heat of the moment, when you are most in need of it being there. This, then, makes endeavours towards planning a sustainable and resilient system sometimes difficult since we only know how well we did when it's at the point where we don't have any other options other than hope. Climate Change could be current issue that is a relevant example of this occurring.

As a result of this ‘invisibility’, measuring and monitoring programs have been developed and studied to provide metrics that would help indicate the health of a ‘resilient’ system.

Often the phrase, “what matters, gets measured” or “what is measured, gets managed” is used. System indicators have been suggested for resiliency, so as to provide something to manage and advance a more resilient system. These indicators are from guidelines published by the OECD for the analysis of a resilient system (OECD, 2014):

- **System resilience indicators** (outcome indicators) look at the resilience of the main components of the system over time, including how the overall well-being of people and the system is affected when shocks actually occur, for example how political capital is affected by an actual earthquake, or how social capital is affected by new or escalating conflict. These indicators should be complemented by negative resilience indicators.
- **Negative resilience indicators** look at whether people are using strategies to boost resilience that may have negative impacts on other areas of the system, for example turning to crime to deal with unemployment; or negative impacts on certain vulnerable people, for example by reducing the number of meals eaten a day, or taking children out of school.
- **Process indicators** ensure that the resilience roadmap is being used in policy making and programming.
Output indicators show the results of implementing different parts of the resilience roadmap.

Proxy impact indicators help show the results of resilience programming. These must be used with caution, but can be necessary when other more nuanced measures (such as system resilience indicators) are difficult to create, or difficult to communicate to a specific target audience.

The scope of the system that you are concerned with will determine the headings or parts of the system that are evaluated. Then, these various parts of the system and the associated well-being can be mapped (OECD, 2014). These categories could include Human, Social, Political, Natural, Physical, and Financial, with ongoing monitoring of the system necessary to determine how the system is performing over time.

**Sustainability defined**

With resiliency defined and some of the possible outcomes associated with a more resilient system presented in the previous sections, it is important to consider how a resilient system relates to a sustainable system. This is of particular importance given that the ITE has already included sustainability in the foundational documents (e.g. Sustainability Policies).

To explore the relationship between these two ideas, the definitions of the terms will first be considered. Using dictionary definitions as the starting point for comparison, the definitions for sustainability and resiliency are shown below.

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<th>Sustainability Dictionary Definition</th>
<th>Resiliency Dictionary Definition</th>
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<td>Able to be maintained at a certain rate or level</td>
<td>Able to withstand or recover quickly from difficult conditions</td>
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As shown, a difference in the two definitions exists in how the system’s state is referenced. With respect to sustainability, the system state is ‘maintained’ at a level, with no reference to any actions that may influence it. For resiliency, the desired system state could still be similar to the state in the sustainability definition, but it implicitly refers to a reaction of the system to move back to that state. As stated in definitions of resiliency referenced earlier in this paper, resiliency is often associated with a system’s ability to absorb and recover from shocks and some sources cite the system’s ability to be adaptable to new states. These are nuanced aspects to the definitions, but something that should be given due consideration especially since there is a potential need to depart...
from a current system state given the poor outcomes that are now being correlated to our transportation systems (e.g. health, social equity, environment).

In 2013 the ITE’s Sustainability Standing Committee published a State of the Practice Review on sustainable transportation, with one aspect focusing solely on the definitions used. Many agencies had adopted the Brundtland Report (World Commission on Environment and Development, 1987) definition of sustainable development, as shown below:

“Development which meets the needs of current generations without compromising the ability of future generations to meet their own needs”.

Another definition of sustainable transportation from the Centre for Sustainable Transport emerged that was found to be quite comprehensive and worthy of note:

A sustainable transportation system is one that:

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
- Limits emissions and waste within the planet’s ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

Many agencies that adopt sustainable transportation policies or objectives often use the Triple Bottom Line (Ecology, Economy, Equity) as metrics to be optimized.

Another viewpoint on sustainability is that of a transportation system that promotes or allows for a sustainable society. The nuanced approach of not having sustainable as an adjective for transportation but for society speaks to an understanding that the transportation system is derived from the needs of society and that the goals of the society are the important elements to seek rather than the sustainment of movement.

With respect to ITE’s position on sustainability, the organization has adopted six Sustainability Policies. These policies are Balanced Goals,
Are the values of resiliency already held within the foundational documents of ITE, just with different wording?

To help understand whether resiliency has a place within ITE policy, these values of resiliency can be compared to the ITE Sustainability Policies. The table below shows a comparison of the ITE’s Sustainability Policies to the Resiliency Values described earlier.

As shown, the value of Diversity has the strongest representation in the existing ITE Sustainability Policies. The remaining resilience values have some strong or moderate alignment with the Policies, with the exception of Tight Feedbacks that does not explicitly correlate to any of the ITE Sustainability Policies. As a result of looking at how values associated with a resilient system correlate to the existing ITE Sustainability Policies and knowing the importance of having a resilient transportation system, it is recommended that resiliency play a stronger role in the foundational documents of ITE.
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Resilience in a Transportation System
Innovation - A resilient world would place an emphasis on learning, experimentation, locally developed rules, and embracing change.

Overlap in governance - A resilient world would have institutions that include “redundancy” in their governance structures and a mix of common and private property with overlapping access rights.

Ecosystem services - A resilient world would include all the unpriced ecosystem services in development proposals and assessments.

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Strong alignment between ITE Sustainability Principle and Resiliency Value

Moderate alignment between ITE Sustainability Principle and Resiliency Value
Recommendations for how resiliency should be incorporated into ITE foundational documents

To incorporate resiliency more into the transportation guidance of ITE, a number of possibilities are available. Similar to the Sustainability Policies, the resiliency values could be adapted and adopted as a policy of ITE. This level of adoption of a policy would be a strong signal to ITE’s membership and other agencies of the importance of having a transportation system that is able to absorb and respond to disruptions, as well as support communities that are more vibrant and livable.

To further reinforce ITE’s encouragement of its members to be leaders in sustainability and resilience, ITE could adopt sustainability and resilience as new sections within the current Canons of Ethics for Members. The three sections within the Canon of Relations with the Public, Relations with Employers and Clients, and Relations with Other Professionals could be easily incorporated to have sustainability and resilience, as these are unifying ideas between all of these categories.

Given the ‘whole system’ perspective of resiliency and sustainability, it would be inappropriate not to extend the pursuit of a resilient transportation system to partnering organizations. These partnerships could be with other transportation associations, either more local or international, with other professional associations, such as planning or ecology, or with Non-Governmental Organizations (NGO) already in pursuit of creating a more resilient society.

Since the Institute of Transportation Engineers has a focus towards serving its members and providing membership services, educational components of resiliency could be made available through ITE. This could be in the form of online webinars or training sessions during annual conferences or practitioner tools. A useful tool that could be developed for ITE members could be guidelines on the measurement and monitoring of resiliency in transportation systems. This would allow for a very practical entry point of the resiliency values into agencies, which would then afford more focused institutional change.

Given the close nature of resiliency to sustainability, it would be appropriate that the above programs and projects be the responsibility of the Sustainability Standing Committee of the Transportation Planning Council or the Coordinating Council. As such, the following actions are requested:

- Adapt or adopt resilience as a policy of ITE
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- Include sustainability and resilience in the current Canons of Ethics for Members
- Explore partnerships with other organizations, be those transportation associations, various professional associations, or NGOs
- Provide educational offerings to the members of ITE with respect to resiliency concepts or development of measurement and monitoring tools of resiliency in transportation systems

In closing, the concept of resiliency is important to consider as transportation professionals and ITE can play a role in advancing this idea to its members in a number of meaningful ways.
Works Cited


