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RESILIENCE, SUSTAINABILITY AND THE INFRASTRUCTURE BOTTOM LINE – MAKING AND DEFENDING CHOICES

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Abstract: Resilience has become the central theme in much of the thinking, planning and response to all manner of unforeseen or catastrophic events disrupting or damaging our communities, particularly in this epoch of climate change disorder. But it is a term that suffers from simplistic or inconsistent understanding – from 'bounce back' or rebound-recover, to adaption or transformation; and approaches ranging from engineering to social-ecological orientations. Things get even murkier when we add 'sustainability' into the mix. Resilience and sustainability have a lot to do with each other but are not the same – resilience an attribute of dynamic, adaptive systems, and sustainability about the continued assurance of human and natural well-being. This paper proposes that the resilience we are trying to plan and design for helps us move towards desired future sustainable systems states, and not, by lack of forethought, undesirable ones. Linked with care, they become lynchpins in understanding and executing the sustainable infrastructure business case supported and enhanced using Envision®. Envision® has become the premier tool supporting the planning, design and evaluation of infrastructure seeking to optimize its alignment with the holistic and triple bottom line characteristics of sustainability. Envision® recognizes that no project can 'do it all'. In this dramatic era of climate change and infrastructure deterioration, this has never been more apparent or important to address. As we consider options for sustainability, resiliency, and adaptation we must balance what is possible and what is feasible. Envision® was developed to provide designers, owners, and stakeholders with a transparent tool to understand, compare, evaluate and balance options. After 5 years' experience, the newly released Draft Envision® 3.0 enhances our ability to closely consider, make and defend these challenging choices the inclusion of a new triple bottom cost-benefit assessment. This paper offers a bridge between these propositions – a progressive approach to resilience and sustainability and the need to make and defend difficult choices.

1 Introduction

In an era characterized by resource and carbon constraints, threats of unforeseen or catastrophic events, and by a growing array of environmental, social, and demographic pressures, our infrastructure needs to be designed and integrated in even more efficient, adaptive, and responsive ways. The cumulative pressure of these intertwined and interdependent risks warrants the need for a holistic, systems-based approach to design and building, grounded in the infrastructure bottom line – social, economic, and environmental/ecological factors alike. Infrastructure systems are a complex ecology that require robust integration to advance the goals of sustainability. A critical understanding of the theories, distinctions, and intersections of sustainability and resilience is key to the conception of comprehensive frameworks for evaluating, planning, and implementing infrastructure projects. This integrated approach, such as is inherent to Envision®, is what will allow for increased success in sustainable design, resilient urban systems, and the value of infrastructure in the long-term.

2 Distinctions and Intersections – Resilience, Sustainability and the Infrastructure Bottom Line

"Resilience and sustainability need to be linked, but with care and clarity," (McPhearson, 2014). It is a common misconception that resilience is the 'new' sustainability, as the concept is on the rise at the same frequency and in similar applications as sustainability was about a decade ago. However, by definition, sustainability is about avoiding, minimizing or mitigating the adverse environmental, social and economic effects of human nature, while maximizing and maintaining enduring efficiency and value. While resilience is largely about rapid recovery and 'adaptive capacity' – the capacity of a system to experience shocks while retaining or re-establishing function, structure and stability.

Due to the broad, yet complex, nature of these two concepts, vast inconsistencies in their meaning and use have emerged, making it difficult for people to understand how best to implement resilience and sustainability in practice. Some believe that resilience is a necessary precursor to sustainability, while others feel that the opposite is true. It becomes clear that over-simplified definitions fail to highlight how interconnected and interdependent resilience and sustainability truly are; specifically, when implementing them into the planning and design of infrastructure projects and systems.

Resilience is often misinterpreted as solely being about 'bouncing back'. This is underlined by the hyper-focus of governments and city-planners on immediate rebuilding and remediation following extreme events. This approach neglects the fact that resilience is not only about returning to a state of normalcy after destruction, but also about the 'adaptive capacity' of the infrastructure from its conception. Resilience is also understood as the "ability to adhere or lock-in a specific pathway", (McPhearson, 2014). For this very reason, implementing resilience into an infrastructure project can either lock-in sustainable and desirable systems, or, unsustainable and undesirable ones. It becomes evident that it is potentially limiting or even dangerous to apply a resilience-centered approach without considering sustainability.

On the other hand, sustainability is often simplistically viewed as either an inflexible state of unchanging stasis, or, as a somewhat romantic utopia characterized by balance and harmony. Neither of these dichotomies recognizes the essential dynamism embodied by systems evolving towards a state characterized by multi-dimensional health and productivity. Nor do these absolutist views capture the ongoing vitality and interplay of elements fundamental to a truly sustainable system. It is critical that resilience, particularly the capacity to transition between dynamic states in both organized and self-organizing ways, is prominent in the path towards true sustainability.

When considering risks, unforeseen events and the instability of our planet's future, we must therefore consider how best to intertwine sustainability into the design of resilient, and therefore, truly adaptive systems. Once this happens, sustainability and resilience will reinforce each other and together, will change the underlying problem and meet the needs of the present, all without compromising the ability of future generations to meet their own needs (World Commission on Environment & Development, 1987).

3 The Infrastructure Bottom Line – An Integrated Approach to Resilience & Sustainability

"Harnessing resilience to reinforce system dynamics that promote sustainability is key to achieving future desired sustainability states," (McPhearson, 2014). To begin a discussion about the place infrastructure holds in such a dynamic, it may be useful to consider the entirety of the urban or social fabric as a living system. If any system were deemed to be vital, it is proposed that such analogy is relevant – such that its social, economic and environmental/ecological dimensions were intertwined in a healthy, living way. If this is accepted as reasonable, then within such a system, our civil infrastructure could be considered as if it were the skeletal, circulatory and digestive systems of the social organism. If, in both the short and long-term, these components and systems (waste, water, transport, etc.) are individually and collectively integrated, the system as a whole will inherently be best set up for resilient, responsive and sustainable evolution.

If this is the desired case, then at the root of both sustainability and resilience, is the infrastructure bottom line. Social, economic and environmental/ecological factors are closely intertwined, and without considering all three, the other two are severely compromised. It is moral, strategic and essential for projects to consider all three aspects. Evaluating all three aspects, their associated risks and opportunity costs, will help ensure the protection of society, the planet and the long-term economic and financial feasibility of a project. With these protections at the forefront, communities will be best positioned to make choices and institute initiatives that pursue enhanced adaptive capacity and societal cohesion in accord with sustainable values.

3.1 Social

"Social resilience is about the abilities of social entities to tolerate, absorb, cope with and adjust to threats of various kinds. The development of the concept of social resilience started with a rather unspecific understanding of social resilience as the capacity to respond, which then evolved to incorporate notions of learning and adaptation to form a composite definition, which includes the acknowledgement of the importance of the roles played by power, politics, and participation in the context of increasing uncertainty and surprise," (Patrick Sakdapolrak, 2015).

When considering the planning and design of socially resilient and sustainable infrastructure, it becomes clear that the roles of power, politics, and participation must be meticulously and strategically evaluated. A critical method for ensuring this is stakeholder engagement. The more engagement initiatives and activities that project teams undergo, in combination with a high degree of respect and active participation from participants, the more likely projects are to be socially resilient and sustainable. Without authentic stakeholder engagement, important topics of discussion can be overlooked or neglected, and the more likely it will be that this narrow engagement seeds ongoing discord and distrust. To the contrary, there is evidence that enhanced communal trust and participation strengthens social adaptive capacity in the face of both unforeseen events and stressors (Janowitz et al., 2012).

When implementing a meaningful stakeholder engagement strategy, it is essential to engage a wide variety of stakeholders – from lower-income community members to corporate entities to the non-profit sector. Within this stakeholder engagement, it is also of utmost importance that the project team be transparent about the pros and cons of project options, as well as the gains and losses associated with project decisions. It is impossible to satisfy everyone's needs and desires, and for that very reason, highlighting the give and take of decision making within the confines of the project's constraints is very important for stakeholder and general public understanding and involvement. Being open about what is possible versus what is feasible also builds trust with stakeholders and in turn, the greater community where the project is taking place.

Engaging stakeholders, like politicians and non-profit organizations, is also critical in planning for unforeseen events, risk avoidance and risk mitigation. Socially resilient infrastructure is defined by planning that provides the right tools for communities to work as a united front and respond efficiently and effectively to complex or undesirable situations. Listening to the knowledge of local officials and local peoples helps project teams better integrate local politics into the planning and design of infrastructure – such as understanding how to improve the struggles of less fortunate neighborhoods while managing the expectations of affluent citizens.

"The concepts of social resilience focus on the resilience at different levels starting from the individual level, continuing with group/family, organization/institution, community, and finishing with the level of society as a whole. Feeling of safety is among the most essential primary human needs on which the quality of life depends," (Pitrenaite-Zileniene et al., 2014). Therefore, considering social resilience in infrastructure planning and design, in tandem with integrated systems thinking, is a necessary step to ensuring the long-term sustainability, feasibility and value of any infrastructure project.

3.2 Economic

Economic resilience has been defined as the "inherent ability and adaptive response that enables firms and regions to avoid maximum potential losses. Economic resilience has primarily been studied in the

context of seismic response and recovery, community behavior and disaster hazard analysis," (Pant et al., 2013). Linked with sustainable thought, economically resilient infrastructure become less about response and recovery and more about the successful linking and integration of past, current and future economic system states into planning and design. In such a context, economic resilience is valued as a key driver of equitable economic and social development, creative alleviation of draining economic conditions and means of fostering innovation, entrepreneurism and participation by all elements of society – especially beyond the privileged and previously advantaged.

Economically sustainable projects are ones that employ the local (especially minority or underserved) workforce during and beyond the project conception, implement strategies for the procurement of local materials and engage local businesses in the building, maintenance and monitoring of the project. This approach to the design and planning of infrastructure projects enhances both sustainability and resiliency. For example, if there is an unforeseen event that leads to some form of deterioration, local peoples and companies are aware of how and with what materials the project was built. Recovery and rebuilding can happen much more quickly and efficiently, with far less oversight needed from the original project team, drawing on local knowledge of the project, its maintenance and access to the necessary locally-sourced materials. In turn, by strengthening local skills and business capacity, the community will be more capable of economic prosperity and adaptation into the future. Further, in many cases, an infrastructure project or program can foster ancillary or integrated economic benefits through factors such as resource synergies, reuse of otherwise unwanted waste/byproduct materials, or by trainings that become the foundation of new or expanded business or export opportunities.

3.3 Environmental/Ecological

Environmental or ecological resilience, closely linked to the concept of environmental sustainability, is grounded in the capacity of an ecosystem to respond to disturbance by resisting damage and recovering quickly. Driven by mounting global sustainability concerns, environmental and ecological issues tend to be the most widely discussed in media and theory. However, as exemplified by the analysis of social and economic understandings of resilience and sustainability, it is impossible to extract environmental and ecological concerns without considering the social and economic implications as well. For example, doing what is best for a community's people may not be what is best for the environment, ecosystems, or other species. These are the trade-offs that must be weighed and balanced.

Projects that impact one part of an ecosystem, may impact another part of the system, and in turn, throw off the whole system all together. This imbalance is a sign of infrastructure that is not environmentally resilient. A crucial first step in improving environmental and ecological resilience is to approach the infrastructure project as just one part of a much larger system. The natural world within which the project is being created is as previously suggested, organismic in nature – everything is interconnected and intertwined – including environmental but also social and economic conditions. Addressing how to be aware of and minimize the negative impacts to ecosystems encourages a symbiotic and synergistic relationship between the project and its natural surroundings.

When combined with sustainable thought, environmental and ecological resilience becomes not only about the symbiosis and integration of infrastructure projects into the natural world, but also about doing it in a way that is respectful and valuable to the environment in the long-term. This is ensured by measures such as the tracking and monitoring of the quantity, source and characteristics of project materials, water and energy. This evaluation, and the project or program choices that are based upon them, will expose how ecologically and environmentally sustainable a project is within the natural world that it exists.

3.4 Synthesising the Infrastructure Bottom Line, Sustainability and Resilience

It becomes clear that the triple bottom line objectives (social, economic, and environmental/ecological), sustainability and resilience all reinforce and strengthen each other. When discussed separately and in isolation, the analysis clearly lacks the necessary depth and strength to make informed, viable and valuable project decisions. As has often been said in other contexts, the sum is greater than the parts.

4 Envision®

Envision® is a sustainable infrastructure framework, rating system and economic comparison tool that is grounded in the holistic planning, design, implementation and evaluation of infrastructure projects seeking to ensure sustainability and resilience. It was created and implemented by the Institute of Sustainable Infrastructure and its industry-supported think tank, which operates at the Zofnass Program for Sustainable Infrastructure at the Harvard Graduate School of Design. Now becoming well known across the United States and Canada, and gaining attention in Latin America, Europe, and beyond, Envision® is rapidly establishing a new basis to evaluate the relative sustainability of comparable projects, to identify leading examples for the recognition of resilient infrastructure and to make defensible design choices. The success of Envision® highlights the impressive progress in the sphere of systems-based planning and design within civil infrastructure.

The emergence of this holistic tool that emphasises 'triple bottom line' and 'sustainable return on investment' values also challenges planning and design teams to create solutions that deliver for maximum social, economic and environmental/ecological impact. It increases transparency and allows all stakeholders involved the ability to understand, compare and balance options. Envision® systematically poses a comprehensive set of progressive performance objectives, tied to explicit evaluation criteria, to identify design opportunities that fulfill the sustainable values and commitments held by the project owners. The framework provides a sensible basis to assess risk, cost-benefit and investment parameters of various alternatives.

Envision® separates aspects of sustainability into five categories – Quality of Life, Leadership, Resource Allocation, Natural World, and Climate & Risk. These five categories include 60 criteria that encompass key focal points of the infrastructure bottom line. Envision® allows for fair evaluation of projects relative to these triple bottom line performance indicators as well as return on investment. The tool establishes new benchmarks for sustainability in infrastructure, allows planners and designers to compare a diverse array of project options, gauge progress and recognize superior systems and outcomes. Beyond enhancing our ability to make and defend choices, Envision® opens the doors to important new vehicles for infrastructure financing and asset management.

It is important to note, however, that Envision® in theory is only as valuable as its application in practice. Understanding the framework is just the first step. It is the implementation and integration of the key sustainability performance indicators into a project that employs sustainability on the ground. For Envision® to be 'successful' regarding sustainability, resilience and the infrastructure bottom line, on-ground complexities and their associated risks and returns must be addressed with prudence, direction and expertise.

5 Lifecycle Assessment (LCA)

Lifecycle assessment measures the economic, social, and environmental costs associated with projects – from planning and design to deconstruction and decommissioning. It is important to be aware that infrastructure projects accrue costs in a cyclical manner. Front end capital costs are merely first stage expenses. Over the project lifecycle those early costs are amortized and balanced with ongoing maintenance and operational costs, and ultimately with end-of-project life renewal, replacement and decommissioning. Even these full cycle costs are impacted by decisions made by planners and designers before them, and they reciprocally influence the sustainability and economic implications of future infrastructure services in the same jurisdiction.

Although lifecycle cost-benefit analysis was, from the outset, recognized as a significant decision parameter, the early versions of Envision® were not able to incorporate such assessment directly. This deficiency was recognized, and a solution emerged during the recent review and refinement of Envision®, based on the first four years of operational experience. After considerable effort supplied by industry and public-sector partners, the newly released version of Envision® 3.0 includes an additional credit within the Leadership category focused on conducting lifecycle economic evaluations. The credit was added with the intent of incenting long-term and holistic financial thinking and planning. It proposes that project planners and designers utilize economic cost-benefit analytic models to identify the full economic

implications and broader social and environmental benefits and costs of prospective projects. This credit also impacts the resilience of infrastructure, in that projects are considered as entities that are designed to respond and adapt to changes and events within their social, economic and environmental/ecological context for decades to come.

The new credit utilizes industry and academically accepted economic analysis to provide a better measurement of the value of a project over the entirety of its lifecycle. This new value recognition helps build defensible justification for integrating sustainability into the conception of a project. Taking a lifecycle economic approach to project planning, design and evaluation is a means to present a coherent, short and long-term business case, substantiated by a more complete, quantified picture of economic, social and environmental/ecological benefits. Such assessment is intended to enhance and validate decision making that encourages the most effective management of resources and assets, and in most cases, supports project options aligned with sustainable values. Lifecycle economic evaluations are a powerful tool for better understanding the trade-offs between upfront capital costs and long-term operational savings that may accrue from sustainable design. An intended outcome of most infrastructure investment is to optimize benefits or reduce negative impacts to the community, the environment and society. Economic analysis and evaluation can be used to measure, value and monetize these benefits quantitatively, and substantively translates qualitative outcomes into defensible economic metrics.

Employing rigorous economic analysis through the understanding of infrastructure investment as complex and cyclical helps organizations apply their resources in the most strategic ways possible. Over many generations of project planning, upfront capital costs have been the key driver to capital planning decisions, especially since the pre-construction decision-makers have typically not been responsible for long-term cost management consequences. However, analyses that only take into consideration upfront capital costs neglect to incorporate lifecycle project costs, risks and uncertainty into the overall economic equation, or the broader outcomes that impact the environment and society. This can result in sustainability-related investments being overlooked due to the higher upfront capital costs, even if they may ultimately generate cost savings over the lifecycle of the project.

Lifecycle cost and risk assessment is one way to implement systems-based thinking in practice. It often supports sustainable design by substantiating choices that address sustainable and resilient outcomes that are in accord with sound economic, fiscal and risk management prudence. Recognizing that decision makers (technical, administrative and political) are ultimately judged and accountable for choices, tools that assist them to reasonably evaluate, make and defend those choices are especially valuable.

6 Conclusion: The Future of Sustainable and Resilient Thought and Design

There is a growing recognition that individual infrastructure components cannot be thought of as isolated, passive, single function resources. Rather, they play an active and interactive role (intentionally or unintentionally) in shaping and influencing broader characteristics of communities. Any infrastructure component serves society towards its specific objective (waste management, transport, recreation, energy generation, etc.), even as it dynamically interacts with other infrastructure and communal structures. Understanding the organismic nature of urban systems generates increased awareness and therefore the ability to forecast and reconcile these intersections with forethought for their implications. Designs can and should reflect the understanding that each decision made, from a project's conception to deconstruction, will impact the whole of the social, economic and environmental/ecological framework. Therefore, the infrastructure bottom line is more clearly appreciated as inextricable from the societal bottom line influencing the future sustainability, resilience and ultimately fundamental viability of these living systems.

However, more substantial and holistic planning, design and management changes are not going to evolve unless owners and engineers embrace them as sensible solutions from both a 'values and value' point of view. The 'values' perspective is simply about 'doing the right thing'; making and defending choices grounded in sustainability and resilience because these, after all, represent the 'right' thing to do. This perspective is critical in motivating infrastructure planners and designers to explore sustainable alternatives. Increasingly, owners, financiers and the public aspire to act in accord with sustainability values. However, to convince those same policy makers, taxpayers, investors and financial advisors to

make difficult choices and act on behalf of those values that integrate sustainability and resilience into infrastructure projects, it is important to leverage the 'value' perspective. This is about 'doing the thing right'. In other words, having the tools and frameworks, like Envision®, to defend choices and to prove that projects will still produce attractive financial and economic outcomes. There is a growing body of experience that demonstrates that sustainable design is cost effective even at the front end, which should be no surprise since sustainability is in essence aligned with principles of system, resource and energy efficiency. But even if beneficial economic payouts accrue incrementally over a lengthy project lifecycle, they still justify sensible sustainable decisions. Combining the two perspectives, 'values' and 'value', presents the compelling logic of 'doing the right thing right' – reconciling the initial financial responsibilities of the investor, constructor, or commissioning body with the essential requirements of stability and security for the natural world and socio-economic state in the long-term.

Understanding the intersections between sustainability, resilience and the infrastructure bottom line is a necessary precursor to adopting these practices. Examining and merging each of the three components of the infrastructure bottom line – social, economic and environmental/ecological – into a coherent business case analysis demonstrates that when resilience and sustainability are considered in tandem, both theories are strengthened in practice. Sustainable infrastructure case studies provide substantial evidence that affirms the view that such models increase long-term value, mitigate risk and warrant preferential investment (Zofnass Program Workshop, 2017). Utilizing lifecycle cost analysis allows project teams to quantify values and risks yielding defensible design recommendations, substantially in alignment with sustainable and resilient objectives.

Envision® is a framework that is rapidly gaining wide acceptance and application, and thereby playing a transformative role in the integration of sustainability and resilience theory and practice. It is critical that these tools are approachable and accessible to all key stakeholders - planners, NGOs, governments, designers, owners, municipal officials, architects, social scientists, ecologists, and financing agencies among others. Clarifying the indistinct relationship between theories of sustainability, resilience and the infrastructure bottom line is an important step. However, this robust analysis must be accompanied by the leveraging of practical tools, methodologies and frameworks, like Envision®, that help direct and focus project teams to key sustainability and resilience indicators. Further, a growing body of experience must be marshalled within the engineering and planning professions to build consensus and confidence that the principles of applied sustainability and resilience are warranted and beneficial. Finally, this knowledge and expertise must be shared widely, through highlighting the advantages of projects that have "done the right thing right".

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