Using Biomimicry to Support Resilient Infrastructure Design

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1 Introduction

With rapid development and aging systems, this is an opportune time to rethink how managers approach infrastructure design. Natural systems are resilient to known and unknown disturbances when viewed through a lens of living organism's capacity to restructure and evolve to changing environments; infrastructure may learn through biomimicry how to become more resilient to shocks and stressors.

2 Resilient Infrastructure Design Landscape

Resilience in Practice

- Critical Infrastructure Resilience Study
- National Infrastructure Protection Plan
- Climate-Resilient Infrastructure
- Community-Level Resilience
- Project-Level Resilience (i.e. LEED)

Resilience Frameworks

- Socio-Ecological Systems (SES)
- Sensing, Anticipating, Adapting, Learning (SAAL)
- Wood's Four Concepts: Rebound, Robustness, Graceful Extensibility, Sustained Adaptability

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3 Life's Principles†

Life's Principles	Metrics
1.0 Evolve to Survive	1.1 Replicate strategies that work 1.2 Integrate the unexpected 1.3 Reshuffle information
2.0 Adapt to Changing Conditions	2.1 Incorporate diversity 2.2 Maintain integrity through self-renewal 2.3 Embody resilience through variation, redundancy, and decentralization
3.0 Be Locally Attuned and Responsive	3.1 Leverage cyclic processes 3.2 Use readily available materials and energy 3.3 Use feedback loops 3.4 Cultivate cooperative relationships
4.0 Integrate Development with Growth	4.1 Self-organize 4.2 Build from the bottom up 4.3 Combine modular and nested components
5.0 Be Resource Efficient	5.1 Use low energy processes 5.2 Use multi-functional design 5.3 Recycle all materials 5.4 Fit form to function
6.0 Use Life-Friendly Chemistry	6.1 Break down products into benign constituents 6.2 Build selectively with a small subset of elements 6.3 Do chemistry in water

† *Biomimicry 3.8, 2013.*

4 Results

Table 1. Alignments (green), Contradictions (orange), Gaps (**white**), and Contentions (blue) of the Resilient Infrastructure Design Landscape to Life's Principles. Darker shades represent principles and lighter tones show metrics. Emphasized core concepts are those prevalent in 'Resilience in Practice.'

Core Concepts	1.0	1.1	1.2	1.3	2.0	2.1	2.2	2.3	3.0	3.1	3.2	3.3	3.4	4.0	4.1	4.2	4.3	5.0	5.1	5.2	5.3	5.4	6.0	6.1	6.2	6.3
Adaptability																										
Flexible																										
Agile																										
Diversity																										
Holistic Design																										
Resourcefulness																										
Efficiency																										
Anticipating																										
Cohesion																										
Graceful Extensibility																										
Innovation																										
Learning																										
Rebound/Recover																										
Robustness																										
Sensing																										
Status Quo																										

5 Discussion

Evolve to Survive

Infrastructure design precisely plans projects to ensure infrastructure will survive; however, nature conducts a test of trial-and-error.

Adapt to Changing Conditions

Current practice emphasizes the importance of recovering functionality; however, the status quo prevents transformation to more adaptive infrastructure.

Be Locally Attuned and Responsive

Looking at a system holistically, infrastructure managers may be able to identify stressors and understand failure consequences of shocks more rapidly.

Integrate Development with Growth

The only life's principle not acknowledged by existing infrastructure design, but it is thoroughly addressed by adaptability, flexibility, and agility.

Be Resource Efficient

Although large gaps appear when addressing resource conservation, the prevalence of efficient design makes this a dominant principle.

Use Life-Friendly Chemistry

The underlying ideas behind this principle, especially building selectively with a subset of elements, promote reducing complexity.

6 Conclusion

Through an agglomeration of core concepts in 'Resilience in Practice' and 'Resilience Frameworks,' infrastructure design is capable of addressing each of Life's Principles and metrics. The resilient infrastructure design landscape shows dominance in *evolve to survive*, *adapt to changing conditions*, and *be locally attuned and responsive* (chiefly through 'Resilience Frameworks'); however, the remaining principles are not unaddressed and one—*be resource efficient*—is often evoked through 'Resilience in Practice.' Biomimicry supports the resilient infrastructure design landscape, and infrastructure managers should not ignore the wealth of information that biomimicry can provide.