33rd Annual INCOSE international symposium

hybrid event

Honolulu, HI, USA
July 15 - 20, 2023

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On Evaluating System Resilience by the Degree of Order Disruption

Agenda

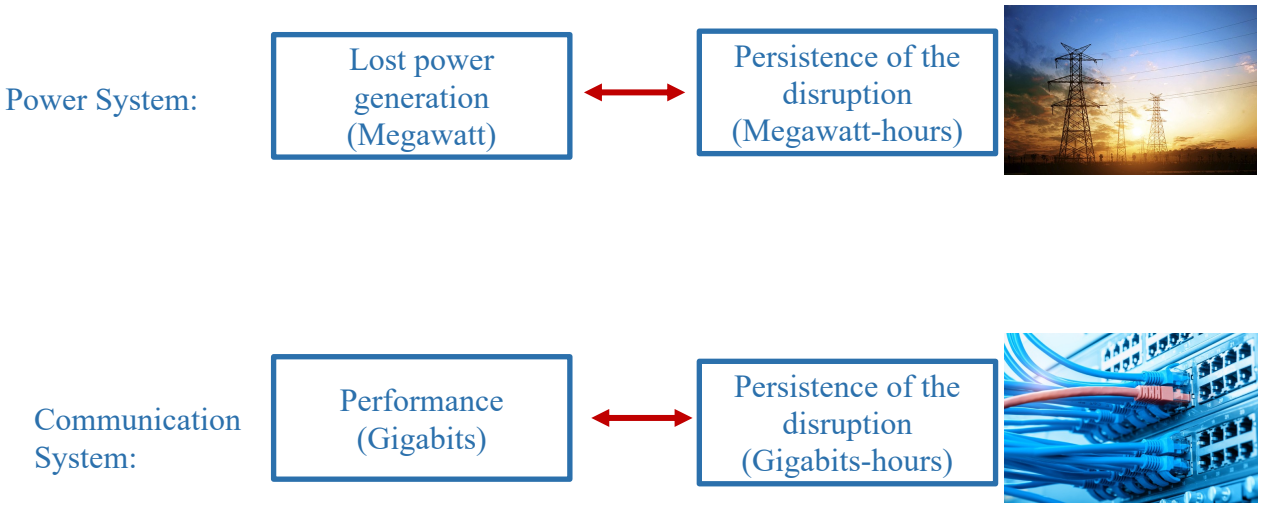
- Background/Rational
- Methods
- Results/Discussion
- Conclusions

Background/Rational

Background/Rational

- In a power system, the lost power generation is typically measured in megawatts;
- The persistence of the disruption is in megawatt-hours, as the area over the resilience curve.
- In a communications system, the performance in gigabits per second can be integrated over time as gigabits.
- How to compare the resilience between these different systems in nature?

The persistence is greater for less resilience



Risk Analysis

- **An influence of scenarios to priorities.**

Lambert et al. (2016, 2014, 2013, 2012, 2011, 2010, 2009)

- **The effect of uncertainty on objectives.**

ISO 31000 (2009)

- **What can be done in what time frames, what are the tradeoffs, and what are the impacts of current decisions on future options**

Haimes(1991)

- **What can go wrong, what are the likelihoods, what are the consequences.**

Kaplan and Garrick (1981)

- **Measure of the probability and severity of adverse effects.**

Lowrance, of Acceptable Risk(1976)

Risk Analysis

How classical risk management can address the risks with dynamic spirit:

- What can go wrong?
- How likely is it to happen?
- What are the consequences?

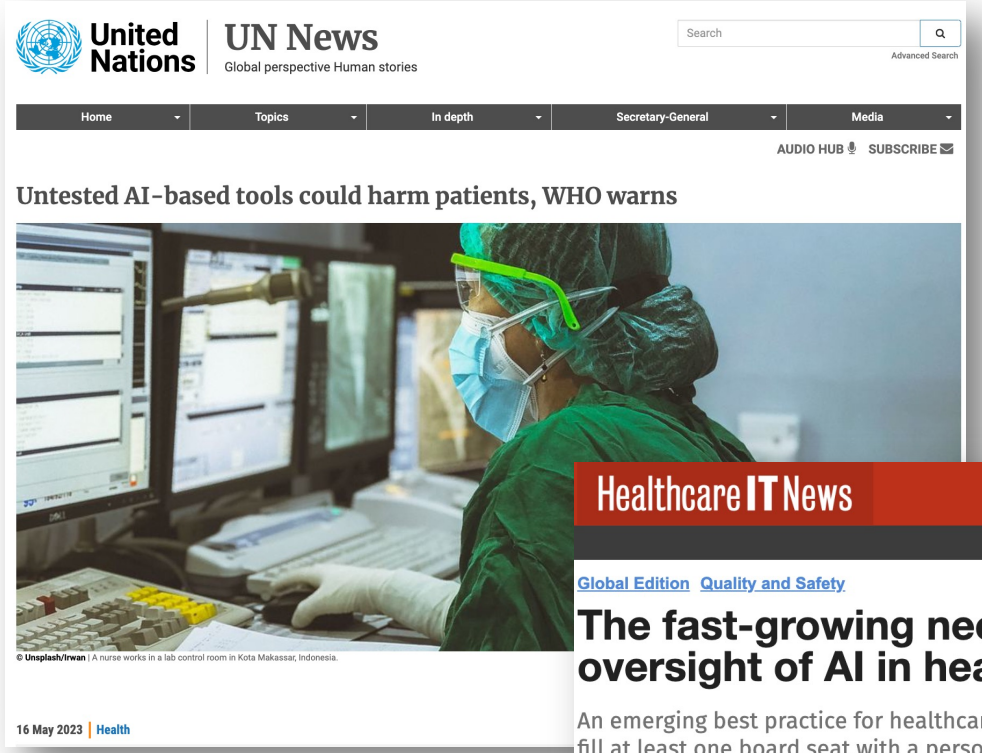
- What risks are addressed?
- What are the resources?
- What is monitored and evaluated?

Roege, P.E., Collier, Z., A., Chevardin, V., Chouinard, P., Florin, M., Lambert, J.,H., Nielsen, K., Nogal, M. and Todorovic, B., (2017)
Teng, Thekdi, and Lambert, (2012a, 2012b)

Risks of AI

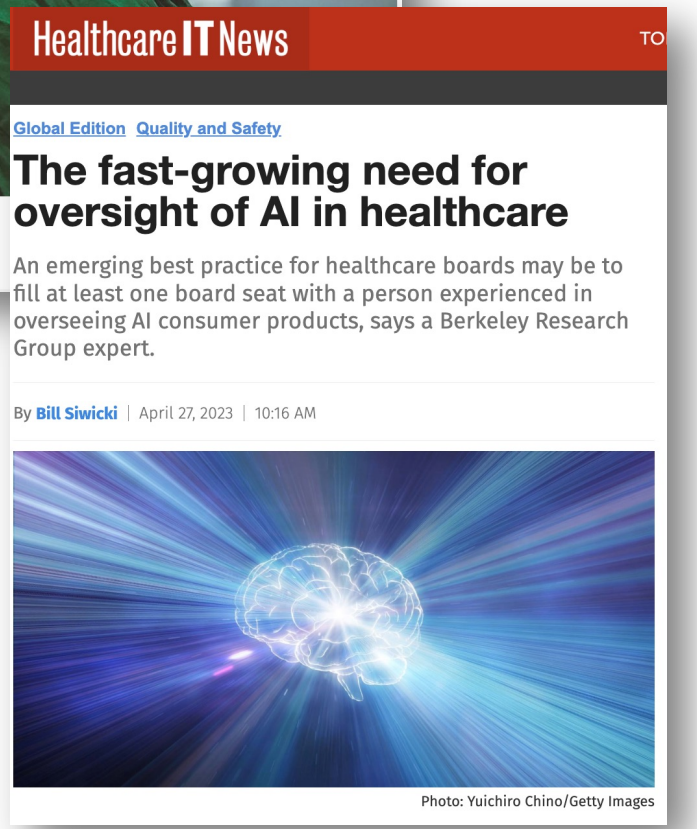
https://www.foxnews.com/health/adopting-ai-systems-too-quickly-without-testing-lead-errors-health-care-workers-who

https://www.medpagetoday.com/special-reports/features/104430



https://news.un.org/en/story/2023/05/1136707

https://www.medpagetoday.com/special-reports/features/104430



https://www.healthcareitnews.com/news/fast-growing-need-oversight-ai-healthcare

Emergent and Future Conditions

Regulatory
New guidelines or increasingly stringent national or international trade policies.

Technological
Immediate, unforeseen shifts in the directions of energy technologies (such as nuclear technologies, coal technologies, or promising renewable energy technologies).

Cyber
Known and unknown conditions of data/information and control systems

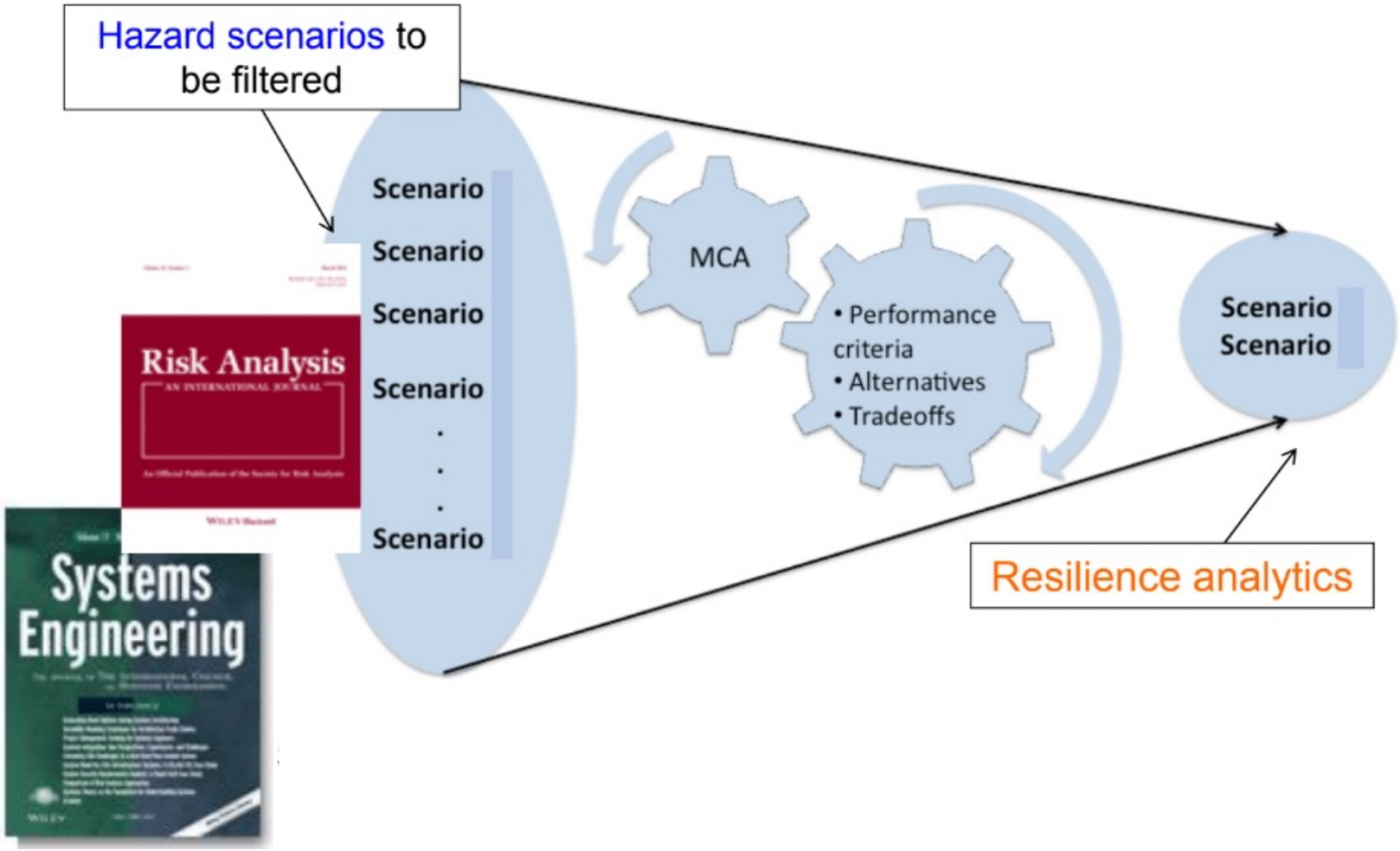
Geopolitical
Shifts in the geopolitical power relating to fossil fuels and natural gas that influence availability and costs of these energies.

Behavioral
Changes in societal viewpoints or lack of acceptance of energy legislation.

Climate and others
Disruption of infrastructure services, commercial energy grid failures, destruction of energy systems, and deterioration of energy and other infrastructure systems

Thorisson, Lambert et al. 2016;
Nakićenović, N. (2000). Energy Scenarios. Chapter 9 in United Nations Development Program. United Nations Department of Economic and Social Affairs. World Energy Council. World Energy Assessment. New York 2000

Opportunities, threats, and the influential scenarios



Thorisson, Lambert, et al. 2016;
Karvetskiand Lambert 2012

Resilience

"(T)he ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events"

There are 4 key attributes of resilient system:

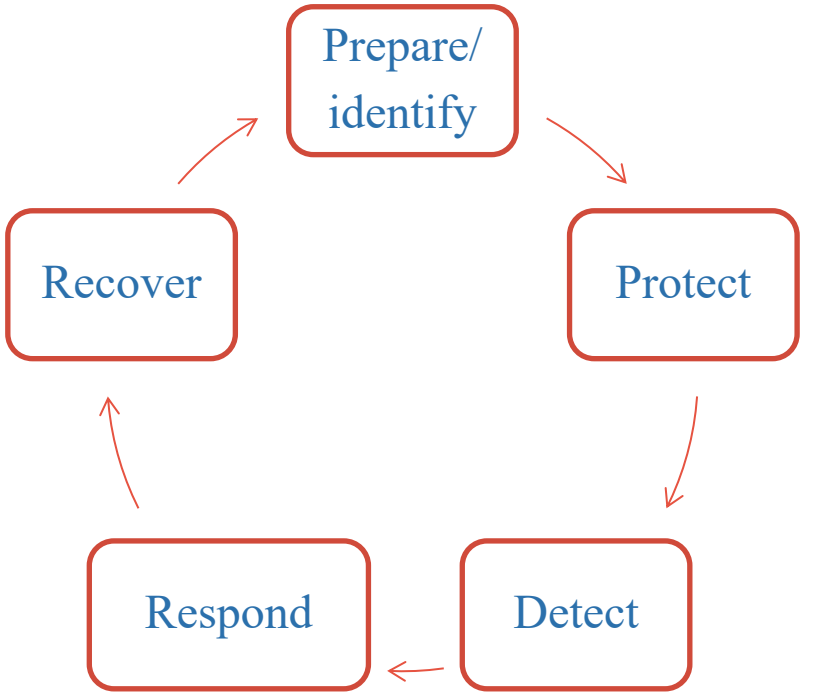
- Robustness (withstand disruptive forces),
- Redundancy (satisfy functional requirements with substitutable system elements),
- Resourceful- ness (effectively leverage resources to diagnose and solve problems), and
- Rapidity (recover quickly from a disruption).

Roege, P.E., Collier, Z., A., Chevardin, V., Chouinard, P., Florin, M., Lambert, J.,H., Nielsen, K., Nogal, M. and Todorovic, B., (2017), "Bridging the gap from cyber security to resilience", DOI 10.1007/978-94-024-1123-2_14

Address Risks Difficulties and its Lifecycle

There are 3 components to system' risk and resilience strategy:

1. Defensive measures
   - Traditional, protection-based methods which focus on maintaining the cyber system as is by preventing unauthorized system access.
2. Proactive measures
   - Measures which seek to anticipate threats and either counter a threat or prepare the system for attack.
3. Retroactive measures
   - Follow-up actions to deal with breaches and their consequences.



High-level strategic view of the lifecycle of an organization's management of systems risk.

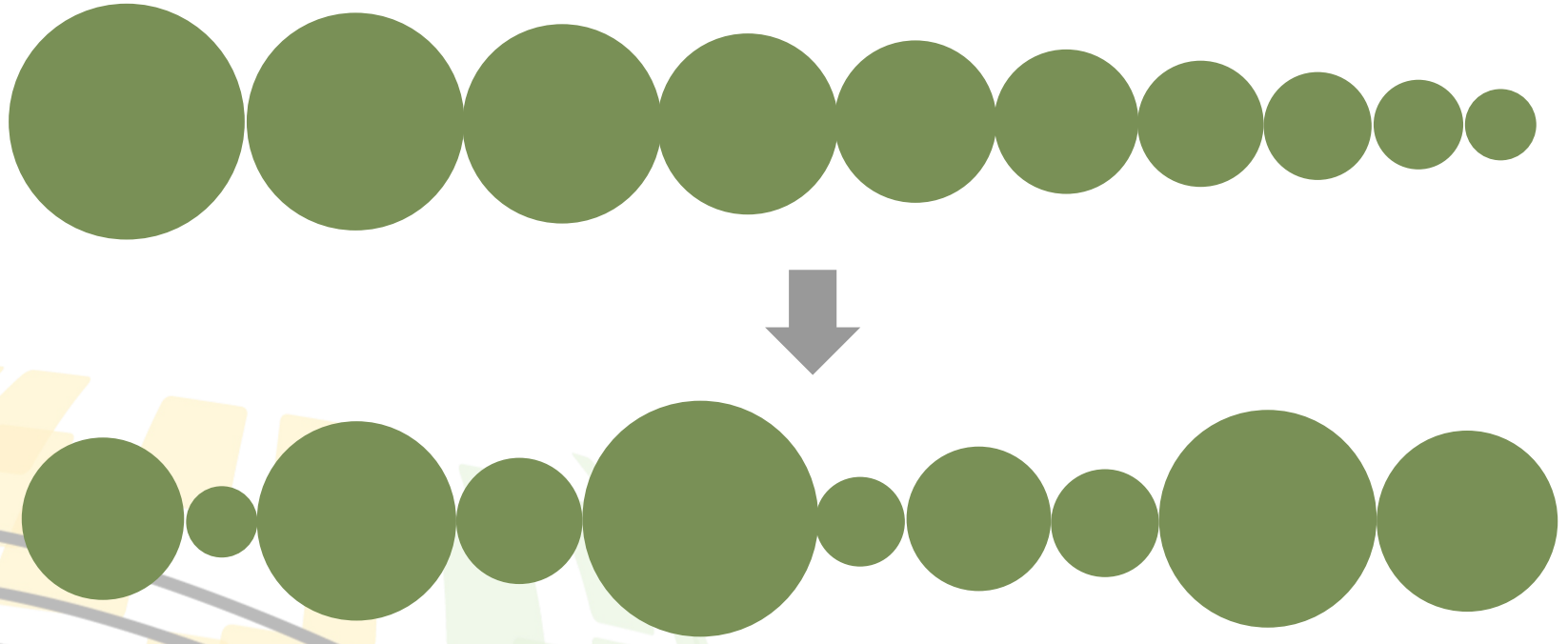
Roege, P.E., Collier, Z., A., Chevardin, V., Chouinard, P., Florin, M., Lambert, J.,H., Nielsen, K., Nogal, M. and Todorovic, B., (2017), "Bridging the gap from cyber security to resilience", DOI 10.1007/978-94-024-1123-2_14

Methods

Methods Outlines

- Focuses on disrupted order rather than disrupted performance in engineering.
- Multi-criteria analysis
- Priorities:
  - Importance orders of endangered species,
  - Radiological, chemical or biological containments,
  - Critical infrastructure assets,
  - Future projects or investments,
  - Policies,
  - Personnel or organizations,
  - Key personnel or organizations,
  - Geographic locations,
  - Others
- Kendall-tau statistic
  - Used to compare an initial, pre-shock set of priorities with the priorities after the shock.
  - Priorities evolve with time after the shock.

Order Disruption

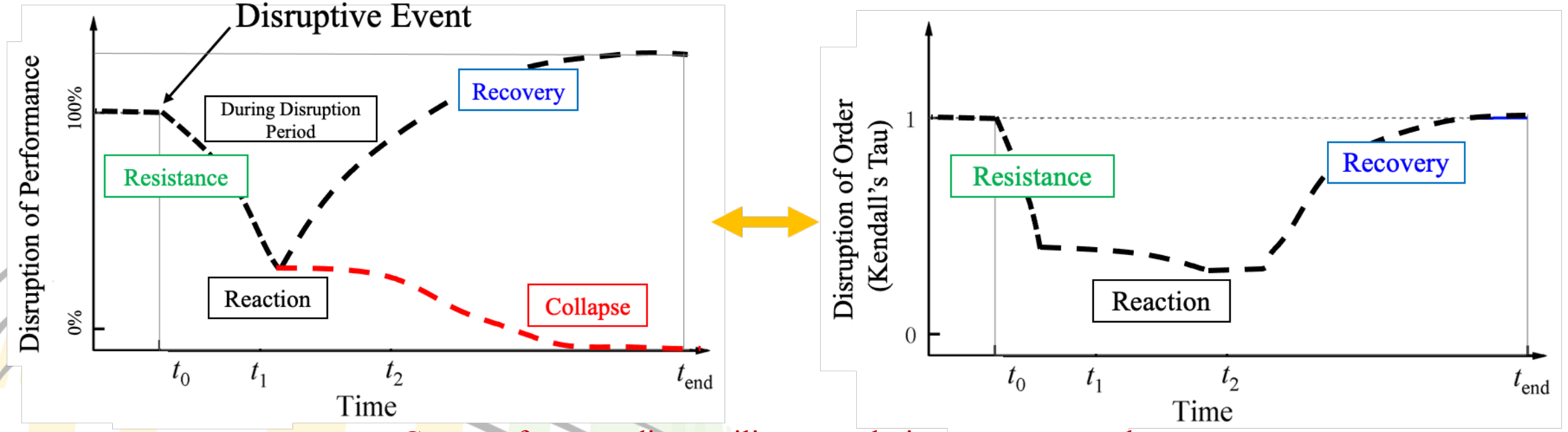


Top Figure: Sorted tokens by size.

Bottom Figure: Disrupted order of tokens by size.

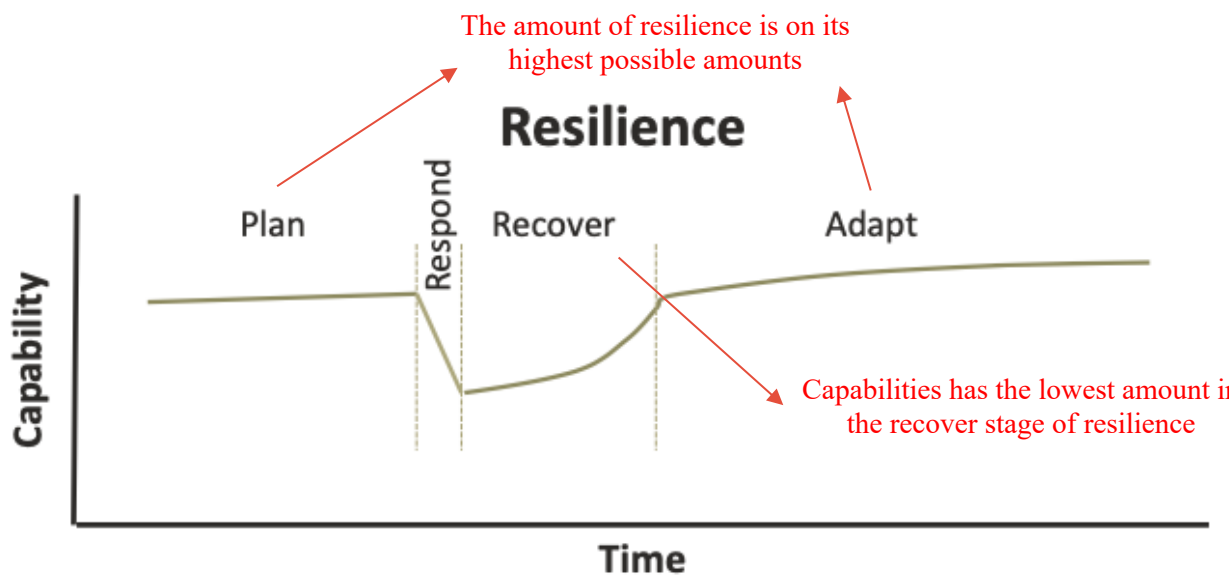
Order Disruption

- Resilience curve describes the diminished performance of a system over time following a shock.
- The area integral above the curve representing the persistence of the lost performance.

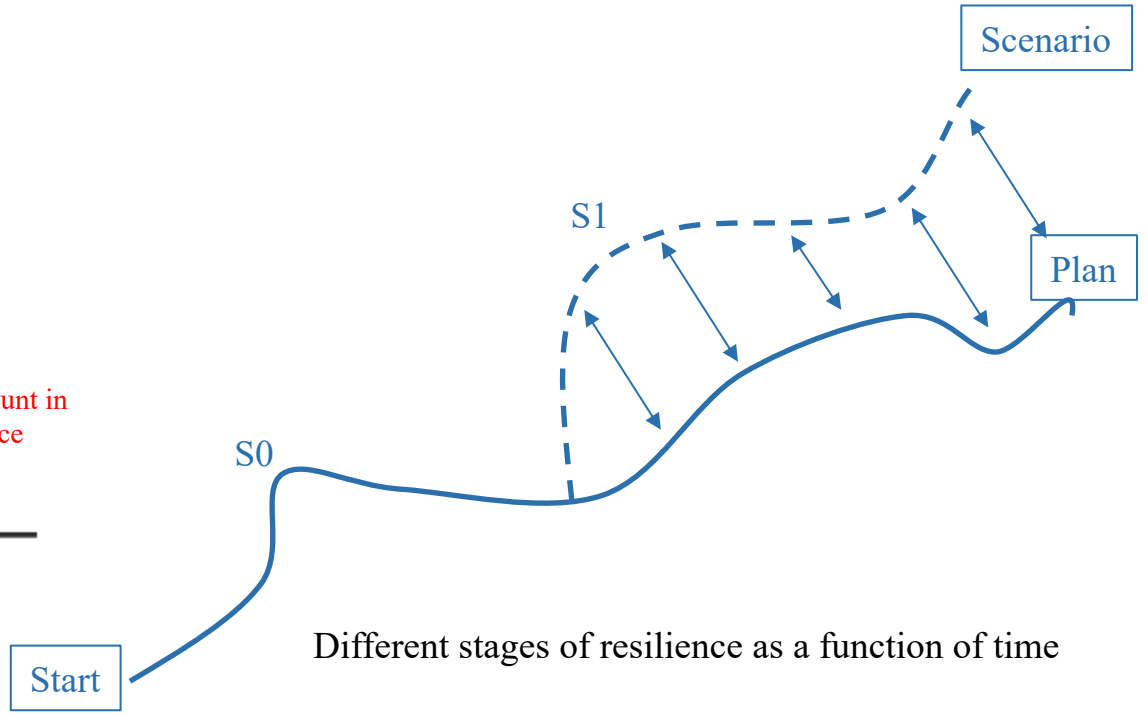


Concept for extending resilience analytics to systems order.
Left figure shows **a traditional systems resilience curve** and
Right figure **shows disruption of order curve**

Order Disruption



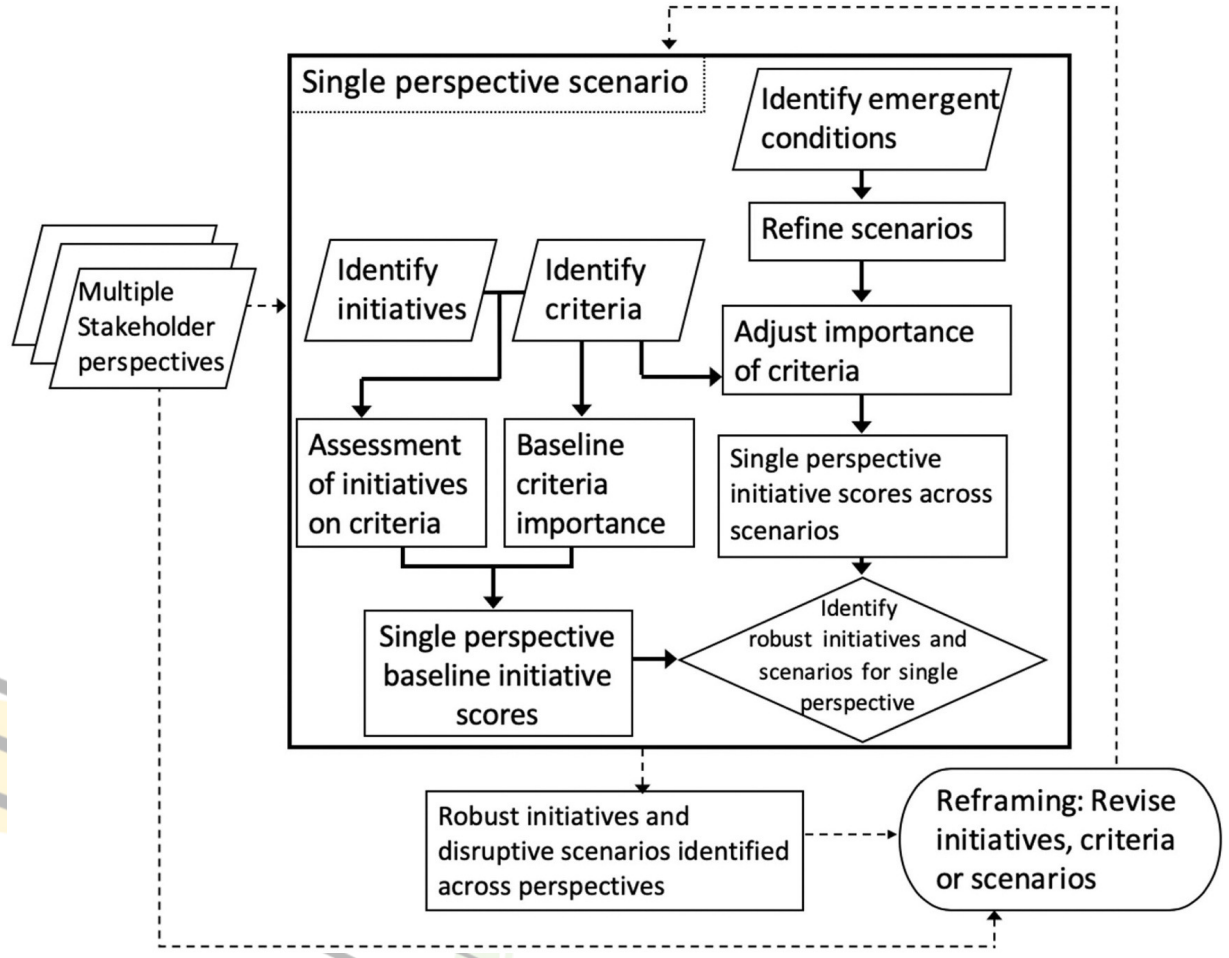
Conceptual Model of the stages of resilience as a function of time



Different stages of resilience as a function of time

Roege, P.E., Collier, Z., A., Chevardin, V., Chouinard, P., Florin, M., Lambert, J.,H., Nielsen, K., Nogal, M. and Todorovic, B., (2017), "Bridging the gap from cyber security to resilience", DOI 10.1007/978-94-024-1123-2_14
Thorisson, Lambert, et al. 2019, 2018, 2017

Multi-Criteria Analysis

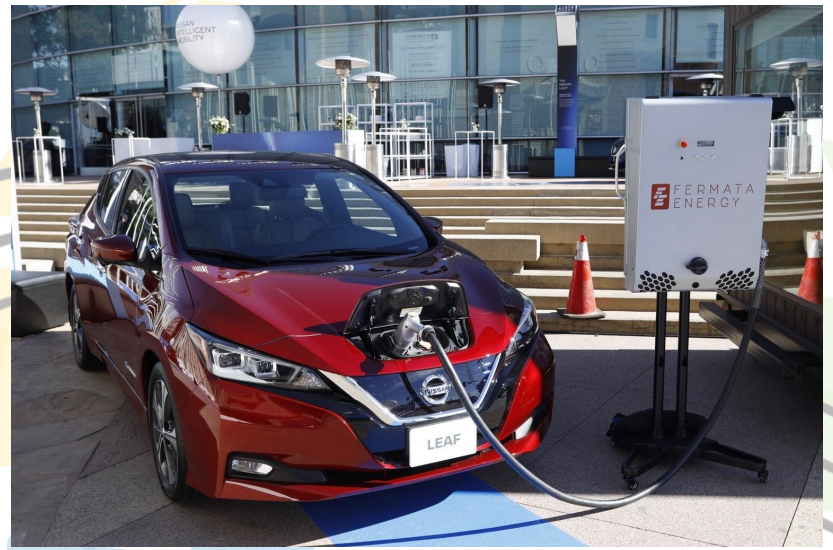


Summary of methodology to identify scenarios that most and least matter in enterprise risk analysis (Hassler, 2019).

Multi-Criteria Analysis

Success Criteria:

- Measure the performance of investment initiatives based on the system objectives.
- Created for the stakeholder's main values.



https://fermataenergy.com/

Index	Criterion	Description
c.01	Lower Economic Cost	Do the initiatives help make the creation of the charger less costly?
c.02	Increase Economic Revenue	Combined low operating costs with higher revenue
c.03	Keep Up with Market Standards	Can the chargers remain up to date in security/technology?
c.04	Reduce Carbon Emissions	
c.05	Reduce Cyber Attack Vulnerability	
c.06	Availability	Making chargers widely available to everyone
c.07	Reduced Energy Consumption	Do the chargers reduce net loss of energy to the grid
c.08	Affordability	Make sure the public chargers are low cost to users
c.09	Durability	Making sure chargers can withstand physical stress
c.10	Increase Self Sufficiency	Reduce the need for human support/maintenance workers
c.i	Other	

Multi-Criteria Analysis

Initiatives:

- A set of decision-making alternatives in the form of technologies, policies, assets, projects, or other such investments.
- Identified by elicitating stakeholders and experts and reviews of third-party analyses to determine what hardware components, actions, assets, organizational units, policies, locations, and/or allocations of resources constitute the system.

https://fermataenergy.com/

Index	Initiative
x.01	Simulation for market variability
x.02	Regional resource planning
x.03	Standards of encryption
x.04	Develop charge controllers
x.05	Understanding load cycles
x.06	Identify at-risk components
x.07	Test at-risk components
x.08	Develop tools for showing benefits of bidirectional charging
x.09	Analysis of time-of-use rates
x.10	Build out to rural networks
x.11	Analysis of long-term wear on batteries
x.12	Understanding effects of battery use on the environment
x.13	Cost-effective resource allocation to portfolios of security measures for embedded devices in a large-scale system
x.14	Trusted Enterprise Communications and Cyber-Physical Integration of Advanced Fleet Electrical Vehicle Chargers in a Mobile Electric Grid
x.15	Secure Processor Design by RISC-V Framework
x.16	Current Sensing based On-chip Analog Trojan Detection Circuit Compatible with Chip Design and Validation Flow
x.17	Stochasticity, Polymorphism and Non-Volatility: Three Pillars of Security and Trust Intrinsic to Emerging Technologies
x.18	Design Obfuscation and Performance Locking Solutions for Analog/RF Ics
x.19	Connectionless RFID based Secure Supply Chain Management
x.20	Leveraging Hardware Isolation for Secure Execution of Safety-Critical Applications in Distributed Embedded Systems
x.i	Other

Multi-Criteria Analysis

Emergent Conditions

- Stakeholder beliefs or values, future events, or trends that could impact the system's ability to meet success criteria.
- Could potentially disrupt the prioritization of initiatives by posing danger to the system or exploiting vulnerabilities.

Scenarios

- Scenarios are comprised of one or more emergent and future conditions

Index	Scenario
s.01	Private Support
s.02	Public Support
s.03	Electricity Market
s.04	Green Movement
s.05	Technology Innovation
s.06	Funding Decreases
s.07	Change of Vendor
s.08	Obsolete Technology
s.09	Change In Government Policy
s.10	Other

Index	Emergent Condition
e.01	New fuel economy standards
e.02	Reduced battery costs
e.03	Enhanced electric vehicle efficiency
e.04	Cyber Security Attack
e.05	Material Supply Shortage
e.06	Increased power grid reliability
e.07	Increased electricity usage
e.08	Increased renewable energy generation
e.09	Increased electricity prices
e.10	Cyber Security Practices Become Outdated
e.11	Implementation Goes Over Budget
e.12	Implementation Takes Longer Than Expected
e.13	Government Policy Changes
e.14	Shortage of production materials
e.15	New/increased amout of suppliers
e.16	Increased renewable energy dependence
e.17	Counterfeit product in supply chain
e.18	Change in worldwide energy stance
e.19	Development of newer, more advanced hardware security
e.20	Development of more powerful chargers
e.21	Increased EV purchase subsidies
e.22	Versatility of charging locations
e.23	Denial of Service
e.24	Attacks on IoT Service
e.25	Ransomware
e.26	Unauthorized Access Attacks
e.27	Data Collection: Phishing, Spamming, Spoofing
e.28	User Authentication Issues
e.29	Poorly Encrypted Data/No Data Encryption
e.30	Limiting Employee Access to Hardware
e.31	Pilot Testing of Services to Ensure Security Functionality
e.32	Auditability/Ease of Monitoring System Activity
e.33	Development of More Advanced Blockchain Storage/Distributed Data Storage
e.34	Physical disruption of charging networks
e.35	Denial of Service Attacks
e.36	Reliable and Resillient power grid
e.37	Charging infrastructure capacity
e.i	Other

Scenarios

Scenarios are:

- Projected from stakeholders
- Related to aspirations or advocacy positions

Scenarios not necessarily:

- Mutually exclusive or complete
- An event space
- Objective or primitive mathematical constructs
- Repeatable across experts and elicitations

Multi-Criteria Analysis

Criteria-Initiatives Assessment

- Compares criteria to initiatives and provides a score that signifies the degree to which **an initiative addresses a criterion.**
- This score is used to **rank the effectiveness of each initiative.**

	Criteria-Initiative Assessment		
1	●	1	strongly agree
2	◐	0.667	agree
3	○	0.334	somewhat agree
4	–	0	neutral

the criterion c.xx is address by this initiative	x.01	x.02	x.03	x.04	x.05	x.06	x.07	x.08	x.09	x.10	x.11	x.12	x.13	x.14	x.15	x.16	x.17	x.18	x.19	x.20
c.01 - Lower Economic Cost	–	○	–	○	◐	◐	◐	–	○	○	○	–	●	–	–	–	○	–	–	–
c.02 - Increase Economic Revenue	○	◐	○	–	●	◐	◐	○	○	●	◐	–	○	○	–	○	◐	○	–	–
c.03 - Keep Up with Market Standards	◐	●	◐	●	◐	○	○	–	○	○	◐	○	○	○	◐	◐	◐	○	○	–
c.04 - Reduce Carbon Emissions	–	–	–	–	○	–	–	–	–	◐	–	○	–	–	○	–	○	–	–	–
c.05 - Reduce Cyber Attack Vulnerability	–	–	●	–	–	◐	●	–	–	–	–	–	◐	◐	●	●	○	○	●	●
c.06 - Availability	◐	●	–	–	○	○	–	◐	◐	●	○	–	–	–	–	–	–	–	–	○
c.07 - Reduced Energy Consumption	–	◐	–	◐	◐	–	○	–	●	○	–	○	–	–	–	–	–	–	–	–
c.08 - Affordability	–	◐	–	○	○	–	–	–	◐	○	○	–	–	–	–	–	–	–	–	–
c.09 - Durability	–	–	○	–	–	◐	◐	–	–	–	●	–	–	–	–	–	–	–	○	–
c.10 - Increase Self Suffiency	–	○	◐	–	○	◐	◐	–	–	–	◐	–	–	●	◐	◐	–	–	–	◐
c.i - Other																				

Multi-Criteria Analysis

Criteria-Scenario Assessment & Criteria-Scenario Relevance

- Each success criterion is assigned an assessment of low, medium, or high relevance to the listed success criteria.
- These assessments are translated into numerical values of 1, 2, and 4, respectively, which are then used to derive baseline weights.

Index	-	Relevance among the other criteria
c.01 - Lower Economic Cost has	high	relevance
c.02 - Increase Economic Revenue has	high	relevance
c.03 - Keep Up with Market Standards has	high	relevance
c.04 - Reduce Carbon Emissions has	high	relevance
c.05 - Reduce Cyber Attack Vulnerability has	high	relevance
c.06 - Availability has	high	relevance
c.07 - Reduced Energy Consumption has	high	relevance
c.08 - Affordability has	high	relevance
c.09 - Durability has	high	relevance
c.10 - Increase Self Sufficiency has	high	relevance

The value function for initiative x.i in scenario s.k

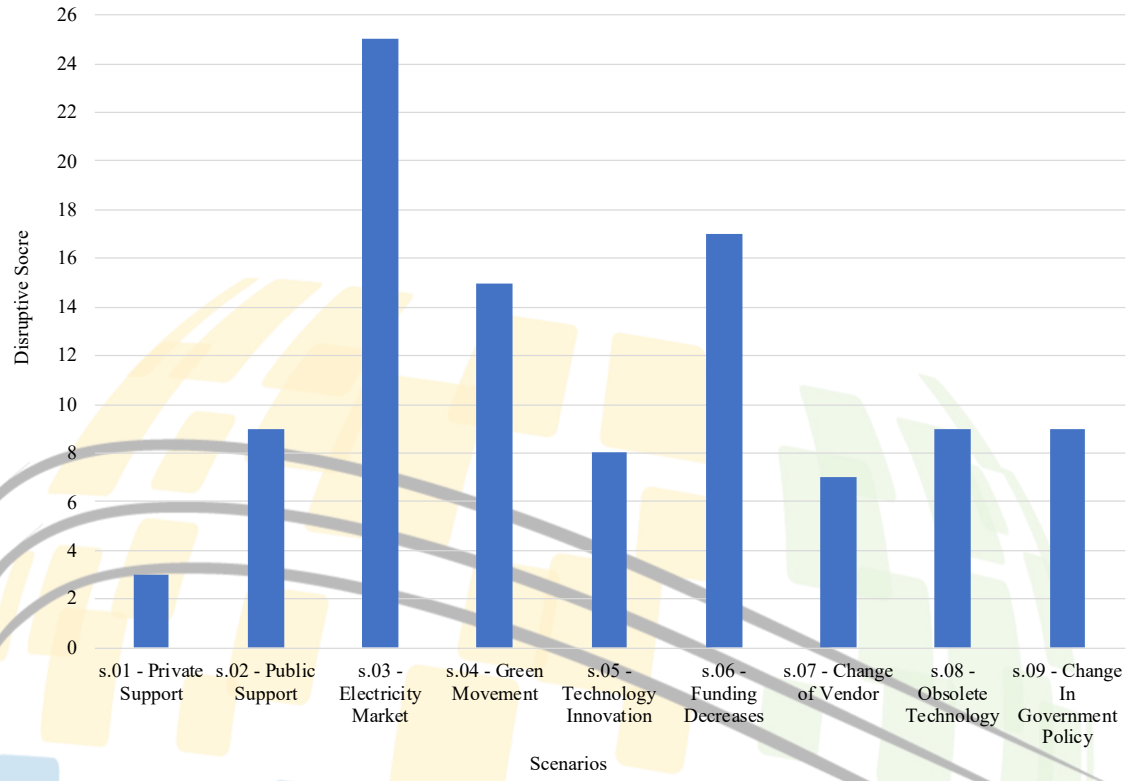
Partial value function of initiative x.i along with criterion c.j

$$Value\ Function \quad V_k(x.i) = \sum_{j=1}^{m} w_{jk} v_j(x.i)$$

The weight assigned to criterion c.j in scenario s.k

	s.01 - Private Support	s.02 - Public Support	s.03 - Electricity Market	s.04 - Green Movement	s.05 - Technology Innovation	s.06 - Funding Decreases	s.07 - Change of Vendor	s.08 - Obsolete Technology	s.09 - Change In Government Policy
c.01 - Lower Economic Cost	-	-	Decreases Somewhat	-	-	-	-	-	Increases Somewhat
c.01 - Lower Economic Cost	-	-	Decreases Somewhat	-	-	-	-	-	Increases Somewhat
c.02 - Increase Economic Revenue	Increases Somewhat	Increases	-	-	-	Decreases	-	Decreases Somewhat	Increases Somewhat
c.03 - Keep Up with Market Standards	Increases Somewhat	Increases Somewhat	-	-	Increases Somewhat	-	-	Decreases Somewhat	Increases Somewhat
c.04 - Reduce Carbon Emissions	-	Increases	-	Increases	-	Decreases Somewhat	-	Decreases Somewhat	Increases Somewhat
c.05 - Reduce Cyber Attack Vulnerability	Increases Somewhat	-	-	-	-	-	Increases Somewhat	-	-
c.06 - Availability	-	Decreases Somewhat	Increases	-	-	Decreases	Increases Somewhat	-	Increases Somewhat
c.07 - Reduced Energy Consumption	-	Decreases	Decreases Somewhat	Decreases	Increases	Decreases Somewhat	Increases Somewhat	-	Decreases Somewhat
c.08 - Affordability	Increases Somewhat	-	Decreases Somewhat	Decreases Somewhat	Increases	Decreases Somewhat	Increases	Decreases Somewhat	-
c.09 - Durability	-	Decreases Somewhat	-	-	Increases	-	Increases Somewhat	Decreases Somewhat	-
c.10 - Increase Self Suffiency	-	-	-	-	Increases	-	Increases Somewhat	Decreases Somewhat	-

Multi-Criteria Analysis

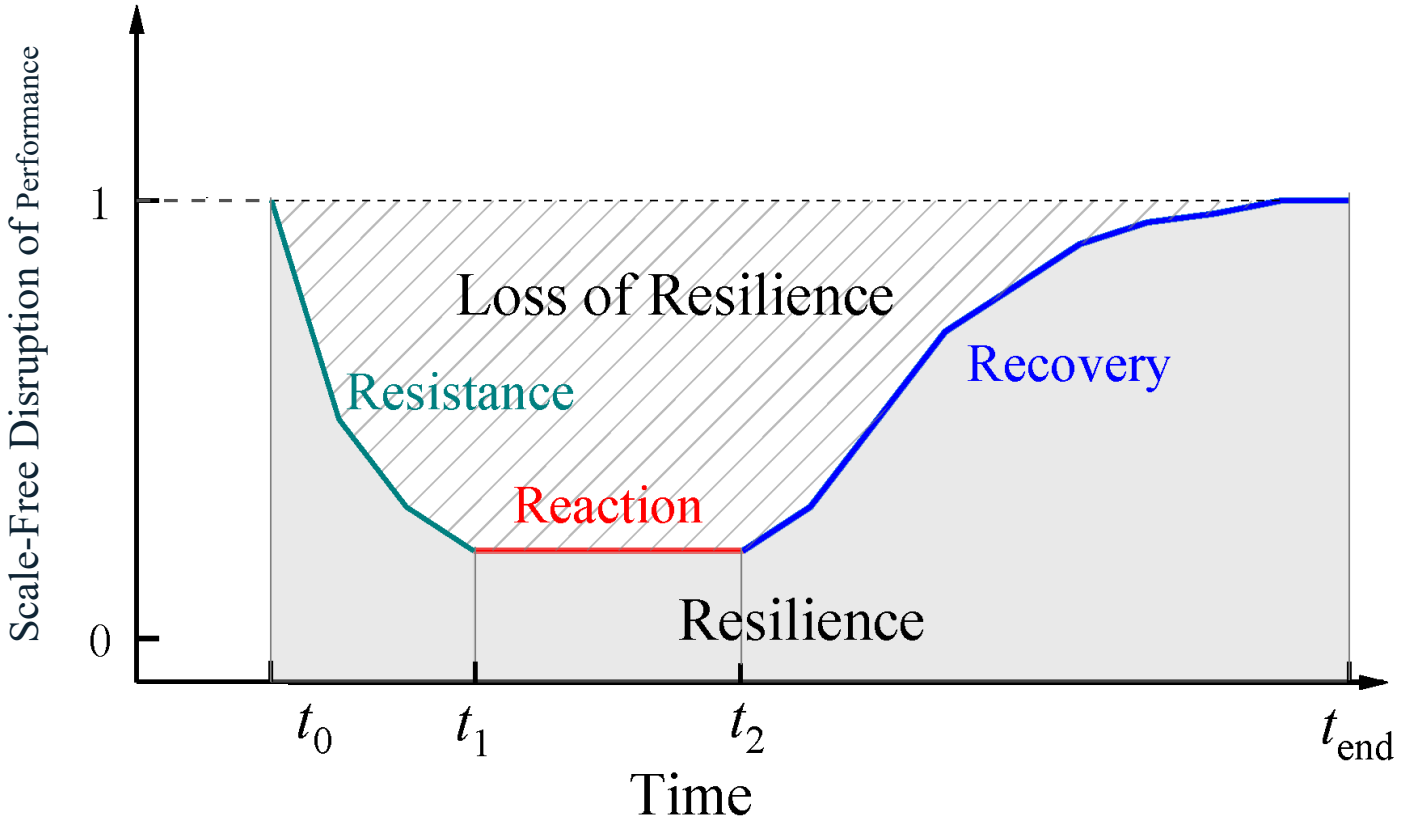


Disruptive Score of Potential Scenarios

- Based on which have the least mitigated emergent conditions by the applicable Initiatives.

Multi-Criteria Analysis

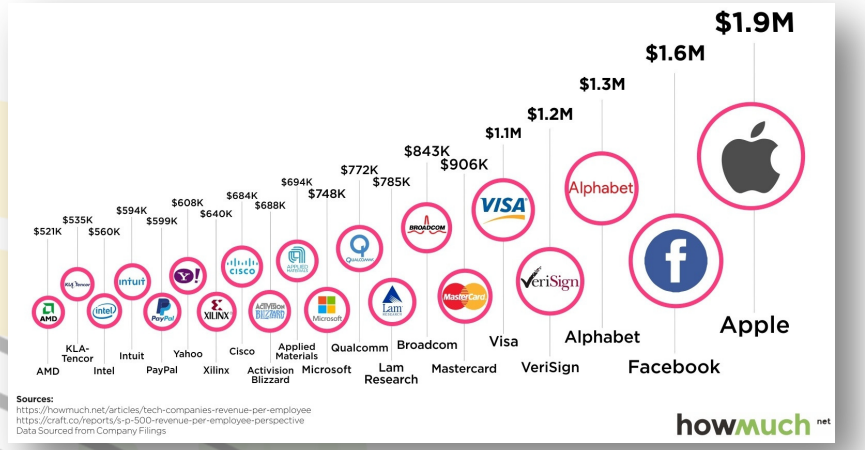
- We realize that scenarios are slices in different time as different business plans.
- Disruption over time is equal to resilience



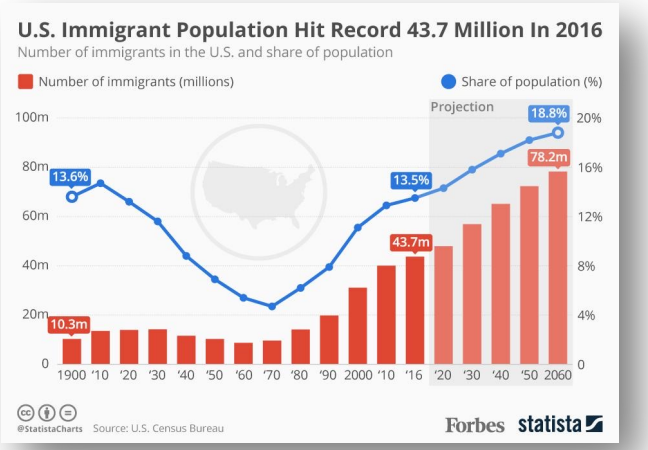
Scale-Free Disruption of Performance

- Diminished performance of immigration to the U.S. based on the number of immigrants;
- Diminished performance of technology companies based on generated revenue; and
- Diminished performance of pharmaceutical companies based on generated revenue.

https://www.proclinical.com/blogs/2022-6/who-are-the-top-10-pharma-companies-in-the-world-2022



https://www.visualcapitalist.com/top-20-tech-companies-revenue-per-employee/



https://www.vox. https://www.forbes.com/sites/niallmccarthy/2017/10/18/the-u-s-immigrant-population-climbed-to-a-record-43-7-million-in-2016-infographic/?sh=7fa176d95e99 /2015/1/12/7474897/immigration-america-maps

Scale-Free Disruption of Performance

Top 10 successful pharmacutical companies

	2022	2021	2020	2019	2018	2017	2016	2015
1	Johnson & Johnson	Johnson & Johnson	Johnson & Johnson	Johnson & Johnson	Roche	Roche	Pfizer	Bayer
2	Roche	Roche	Roche	Roche	Bayer	Pfizer	Bayer	Roche
3	Pfizer	AbbVie	Bayer	Bayer	Pfizer	Bayer	Novartis	Novartis
4	AstraZeneca	Bayer	Abbott	Pfizer	Abbott	Novartis	Roche	Pfizer
5	Bayer	Bristol-Myers Squibb	Merck & Co	Abbott	Novartis	Merck & Co	Merck & Co	Merck & Co
6	AbbVie	Merck & Co	Pfizer	Merck & Co	Sanofi	Celgene	GlaxoSmithKline	Sanofi
7	Merck & Co	Pfizer	Celgene	Sanofi	Merck & Co	Sanofi	Sanofi	GlaxoSmithKline
8	Bristol-Myers Squibb	GSK	GSK	Celgene	Celgene	GlaxoSmithKline	Celgene	Biogen
9	GSK	Novartis	Sanofi	GlaxoSmithKline	GlaxoSmithKline	Abbvie	Valeant Pharmace	Valeant Pharmace
10	Sanofi	Sanofi	AbbVie	Novartis	Biogen	Biogen	Biogen	Celgene

Top 10 Tech Companies based on USD$

	2022	2021	2020	2019	2018	2017	2016	2015
1	Apple	Apple	Amazon	Amazon	Amazon	Google	Apple	Apple
2	Amazon	Amazon	Google	Apple	Apple	Apple	Google	Google
3	Google	Google	Apple	Google	Google	Amazon	Amazon	Microsoft
4	Microsoft	Microsoft	Microsoft	Microsoft	Microsoft	Microsoft	Microsoft	Samsung
5	Facebook	Samsung	Facebook	Facebook	Samsung	Facebook	Facebook	Amazon
6	Samsung	Facebook	Samsung	Samsung	Facebook	Samsung	IBM	General Electric
7	Huawei	WeChat	Huawei	Huawei	Tencent	IBM	General Electric	IBM
8	WeChat	Tencent	WeChat	WeChat	Huawei	Alibaba	Intel	Intel
9	TikTok	Huawei	Tencent	Tencent	IBM	Oracle	Oracle	Facebook
10	Taobao	Taobao	Taobao	Taobao	Oracle	Huawei	Huawei	Oracle

Top 10 Countries of Origin for Immigrants to the U.S.

	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
1	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico	Mexico
2	India	China	Cuba	China	China	China	India	China	China	China
3	China	India	China	Cuba	Cuba	India	China	India	India	India
4	Dominican Republic	Dominican Republic	India	India	India	Philippines	Philippines	Philippines	Philippines	Philippines
5	Vietnam	Philippines	Dominican Republic	Dominican Republic	Dominican Republic	Cuba	Cuba	Dominican Republic	Dominican Republic	Dominican Republic
6	Philippines	Cuba	Philippines	Philippines	Philippines	Dominican Republic	Dominican Republic	Cuba	Cuba	Cuba
7	El Salvador	Vietnam	Vietnam	Vietnam	Vietnam	Vietnam	Vietnam	Vietnam	Vietnam	Vietnam
8	Brazil	El Salvador	El Salvador	El Salvador	Haiti	Iraq	South Korea	South Korea	Haiti	South Korea
9	Cuba	Jamaica	Haiti	Jamaica	El Salvador	El Salvador	El Salvador	Colombia	Colombia	Colombia
10	South Korea	Colombia	Jamaica	Haiti	Jamaica	Pakistan	Iraq	Haiti	South Korea	Haiti

Kendall's Tau

How to compare the resilience between these different systems in nature?

Put the same scenarios over time.

Compare them with Kendall-tau statistic in resilience over time.

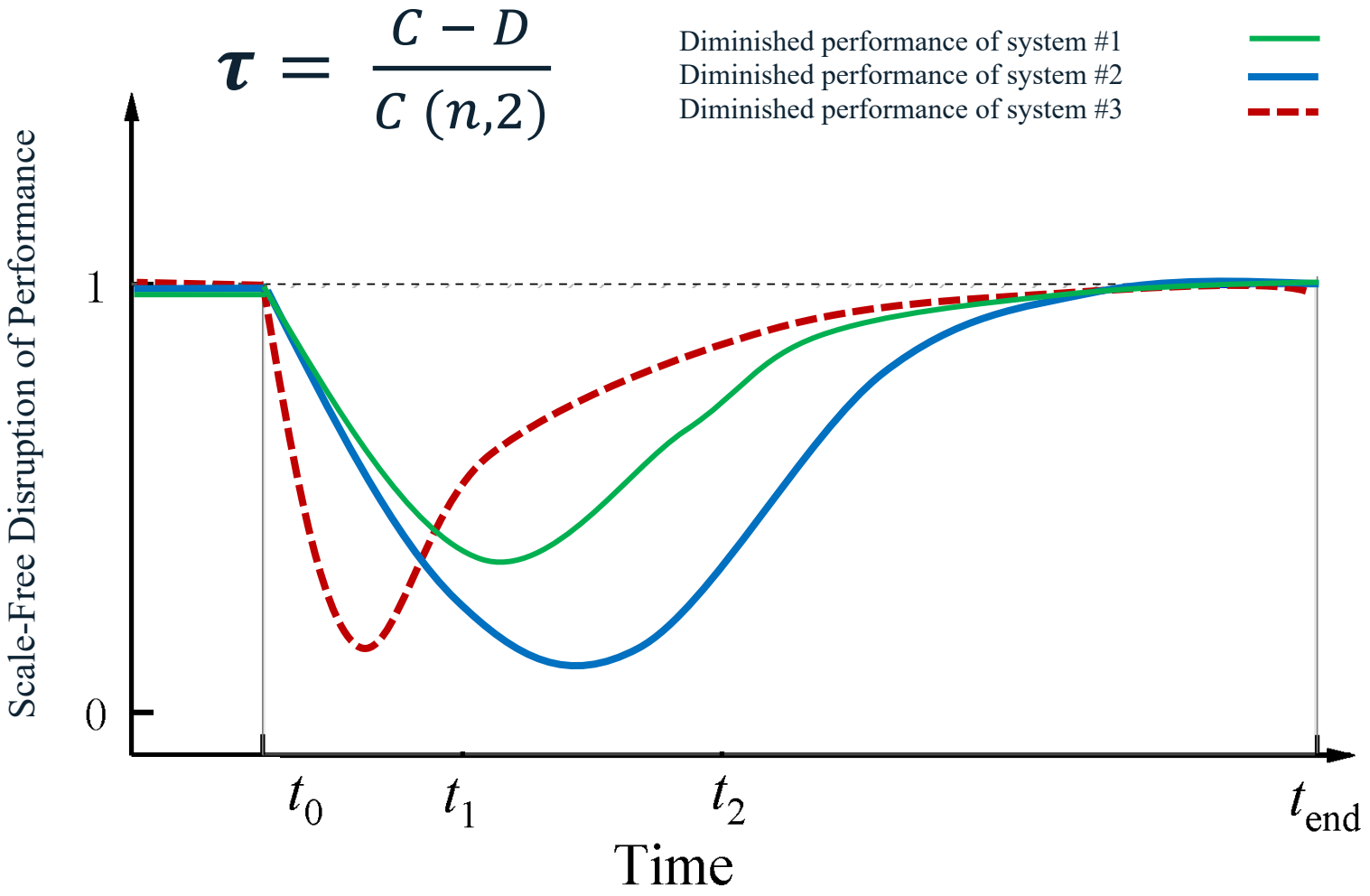
Concordant if ($x_i > x_j$ and $y_i > y_j$) or ($x_i < x_j$ and $y_i < y_j$)

C = The number of Concordant pairs

Discordant if ($x_i > x_j$ and $y_i < y_j$) or ($x_i < x_j$ and $y_i > y_j$)

D = The number of Discordant pairs

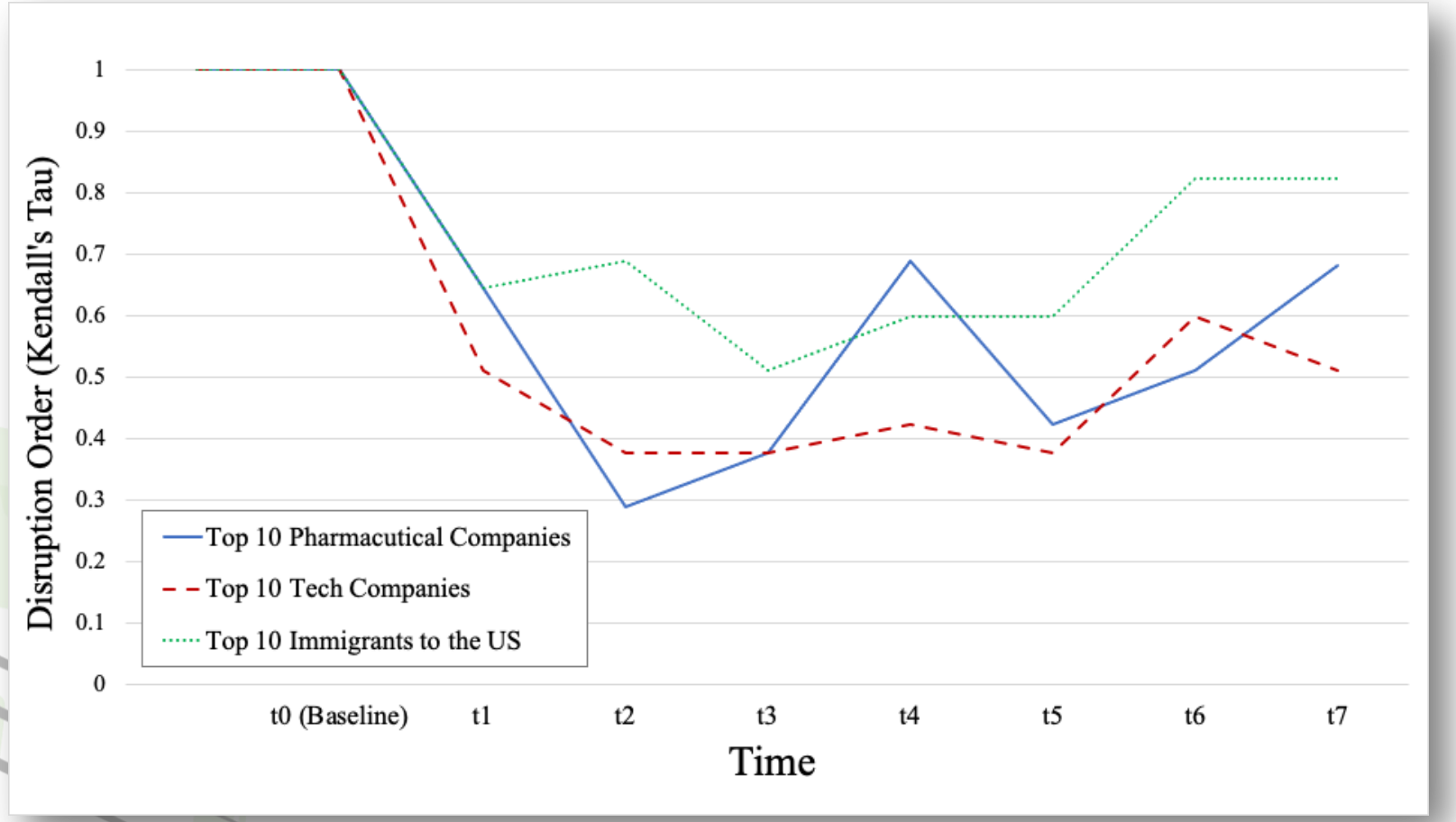
$$\tau = \frac{C - D}{C\,(n,2)}$$



Scale-Free Disruption of Performance

Time	Top Ten Pharmaceutical Companies	Top Ten Tech Companies	Top Ten Immigrants to the US
t_0	-	-	-
t_1	0.64	0.51	0.64
t_2	0.29	0.38	0.69
t_3	0.38	0.38	0.51
t_4	0.69	0.42	0.60
t_5	0.42	0.38	0.60
t_6	0.51	0.60	0.82
t_7	0.68	0.51	0.82

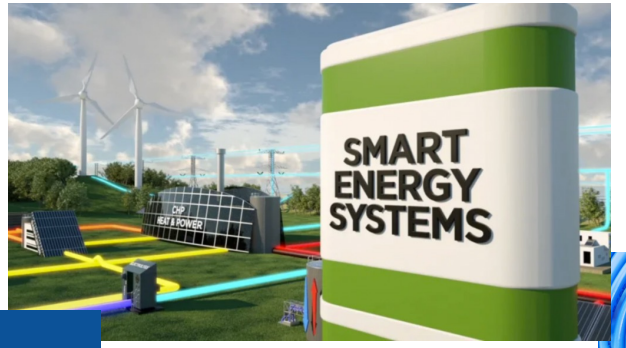
Calculated Kendall's tau scores for the examples of estimating disruption of order

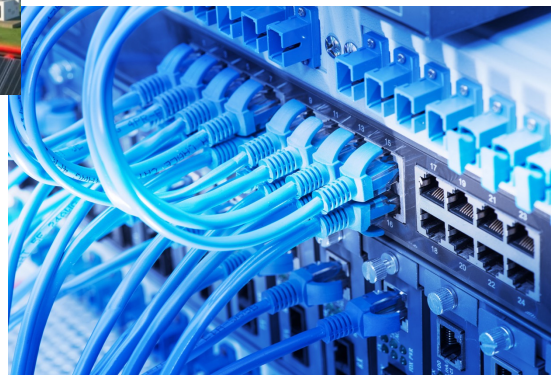


Compare the resilience between three different systems using Kendall's tau

Discussion and Conclusions

Results/Discussion

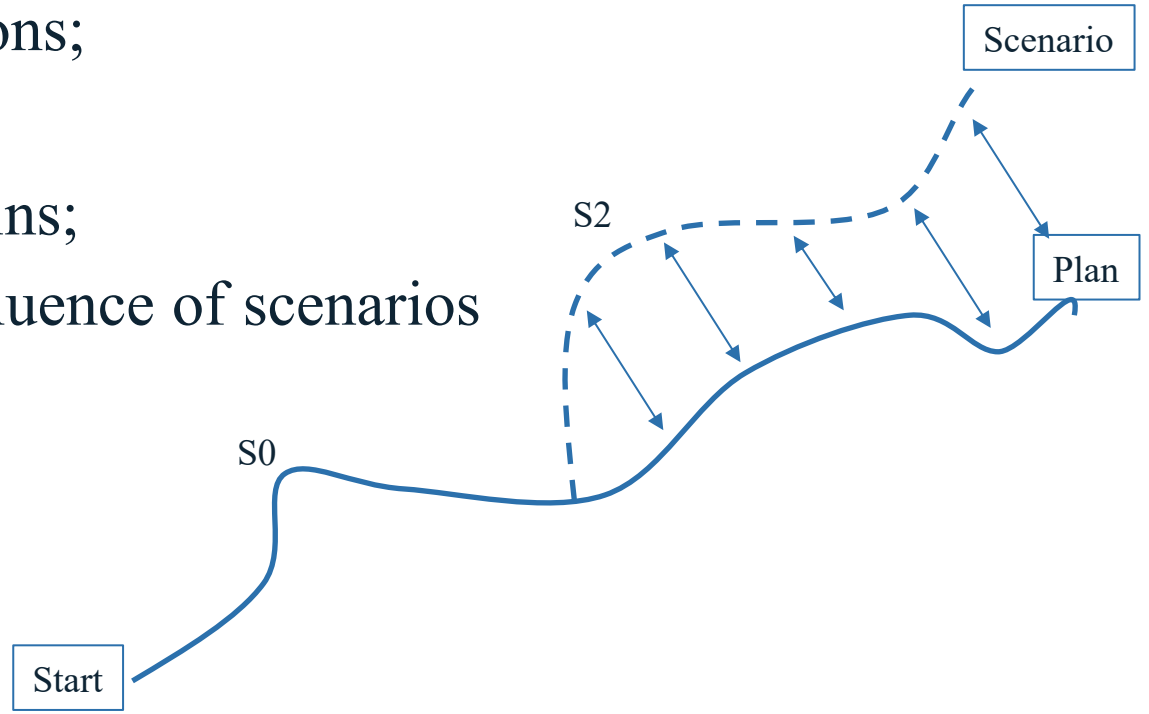




Qualitative Results/ Discussion Points
Disrupted order is a viable metric of risk
Order can be across any and several types of system component/ element/ parts
The trajectory of disrupted system order is system resilience
Managing risk/ resilience as order disruption enables system-of-systems comparison of risk

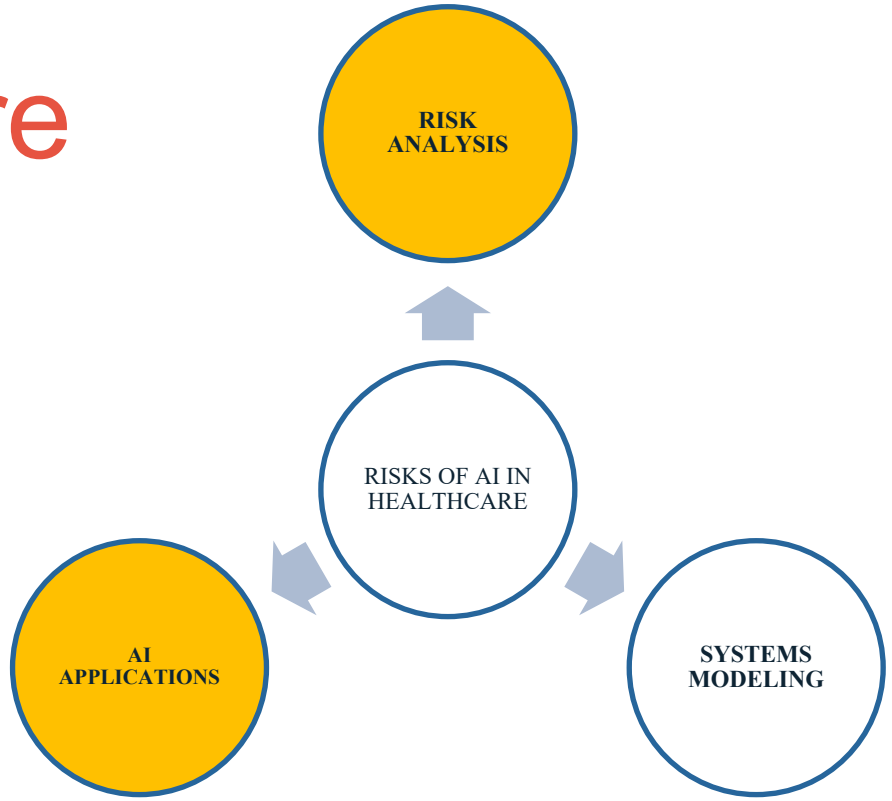
Conclusions

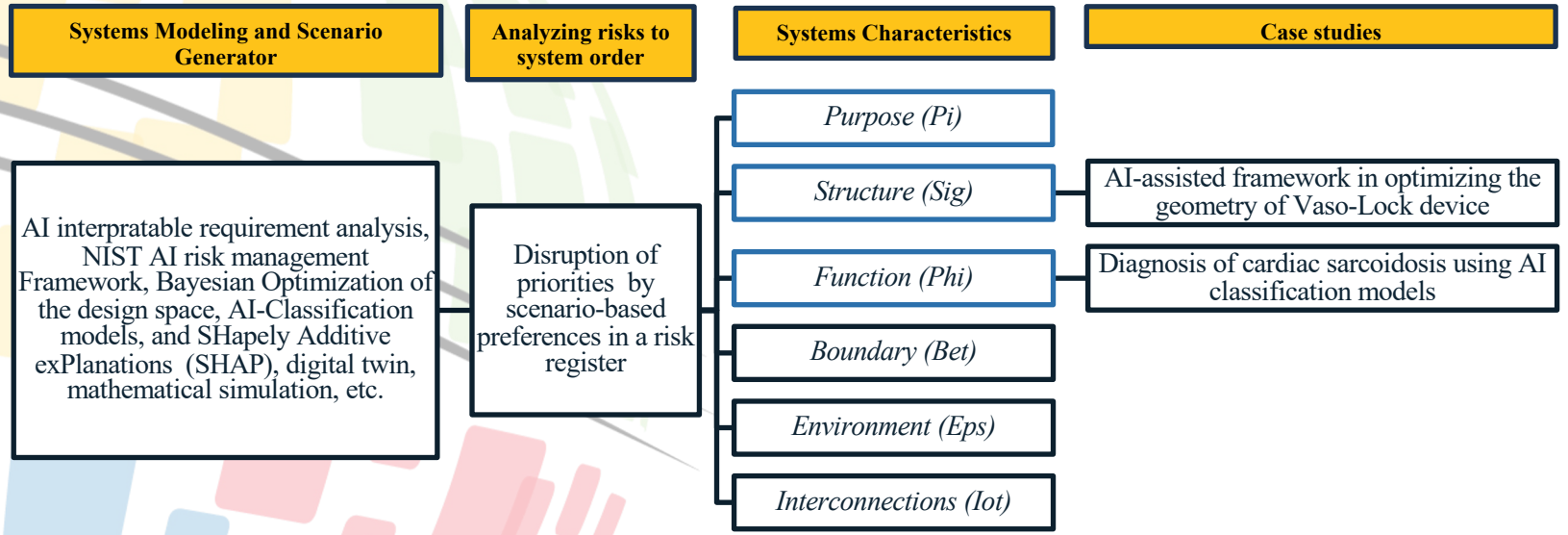
- Describe replacing system function by system order in the estimation and integration of resilience curves, thus enabling a new quantification of resilience as a disruption of system order;
- Enables management and policy decisions;
- Scale-free;
- Comparisons of resilience across domains;
- Addresses risk and resilience as the influence of scenarios to priorities;



Risks of AI in Healthcare

- An intersection between risk analysis, systems modeling, and AI applications in healthcare; and
- Demonstrate enterprise of risk management of AI in this domain using scenario-based preferences (Moghadasi et al., 2023).





Thank you

On Evaluating System Resilience by the Degree of Order Disruption

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