MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT Center for Transportation & Logistics

Quantifying Supply Chain Resilience

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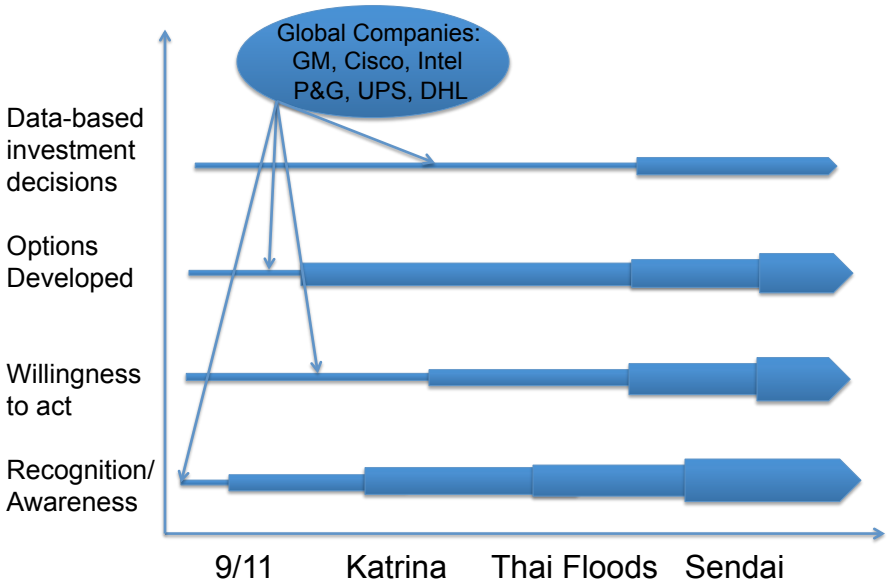
Overview

- Current State and Evolution of Supply Chain Resilience
- Quantifying Resilience Current State
- Industry Perspective and Actions
- Quantifying Resilience Challenges

Current State and Evolution of Supply Chain Resilience (SCR)

Evolution of SC Resilience



 Arrow/Bar size suggests adoption

Supply Chain Resilience Current State

- Operational uncertainty still exists
  - Daily variation
  - Disruptions
- Options for addressing uncertainty plentiful & known
- But pursuing resilience is proving difficult for practitioners

Why is it so difficult? → Lots of open questions

How resilient is our SC? How much resilience should our SC have?

Do you know your Tier 1 suppliers? And their factory locations?
How about T2, T3, T4+?

So many sources of risk – where do we start?

What is the ROI…. on an investment that avoids a disruption? + - %?

How much should we invest? And in what resilience initiatives?

How to choose between investing in Growth or Resilience?

Growth always wins*

*Gary Lynch, The Risk Project, April 2015

Network image from: http://www.informit.com/articles/article.aspx?p=2166717&seqNum=2

Most of these questions are addressed by Quantifying Resilience….

But it is only emerging recently

Quantifying Resilience Current State

Quantifying Resilience: Early Contributions

- Hendricks and Singhal studies (2003, 2005, 2009) indicated shareholder wealth drop >10% for shipment or production delays, almost 7% with excess inventory
  - Helped socialize the importance and potential impact of SC glitches
  - But Zsidisin, Petkova and Dam (2016) studies suggest lower impact, ~1.94% impact from glitch announcement

- Measurement of resilience only recently surfacing in literature reviews
  - Most work on risk mgt, quantifying risk, vulnerabilities growing from early 2000s
  - Christopher and Peck (2003) put forward a qualitative risk assessment tool
  - Pettit (2008) and Pettit, Fiksel and Croxton (2010), earlier authors to write about measuring supply chain resilience, described optimal resilience, a 'zone of resilience' outside of which eroding profits or exposure to risk serve as measures. Conceptual. But also proposed use of Supply Chain Risk Assessment Model (SCRAM)
  - Klibi, Martel and Guitouni (2008, 2010) a seminal brief on measurement and the challenges that exist for researchers desiring to model for supply chain network design
  - Schmitt and Singh (2009) measured risk, assessed mitigation strategies cf risks
  - Paulsson, Nilsson and Wandel (2011) estimate disruption risk exposure into estimated and known result impacts

Ref. "Managing Risks: A New Framework", HBR 6-12, Kaplan and Mikes

Quantifying Resilience: Promising recent work

- Aqlan and Lam (2015)
- Cardoso, Barbosa-Póvoa, Relvas and Novais (2015)
- Barroso, Machado, Carvalho and Machado (2015)
- Munoz and Dunbar (2015)
- Snoek (2016)
- Braud and Gong (2016)

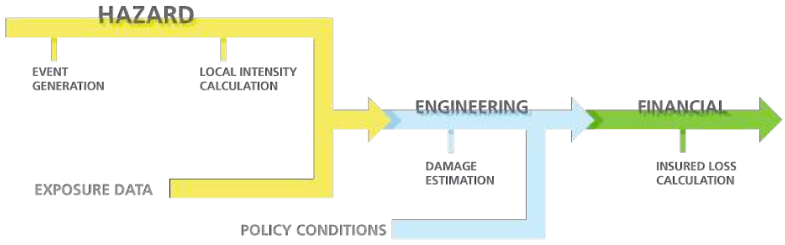
Quantifying Resilience: Risk Management

- Many models for risk management
  - Assessing vulnerabilities, focused on various sources of risk
  - Kaplan and Mikes simple segmentation into 3 risk types and specific actions to take for each
    - Risk Report Card, Risk Event Card

Ref. "Managing Risks: A New Framework", HBR 6-12, Kaplan and Mikes

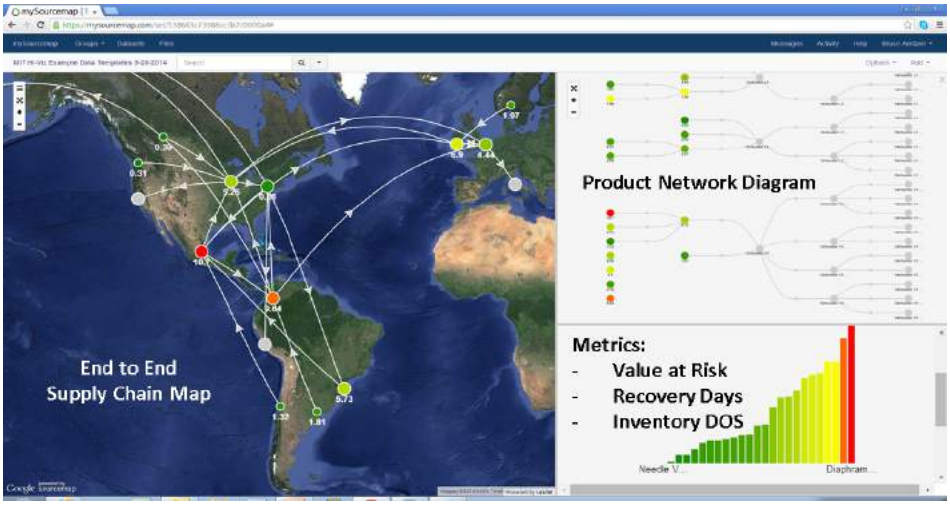
Quantifying Resilience: Catastrophe Models

- Catastrophe Models
  - Limited loss data from rare occurrences, Property focused
  - Very effective at leveraging new emerging data streams
  - Collect physical characteristics data on natural disasters, terrorism and generate full spectrum of potential events, then tested and sensitivities for intensity; these are then applied to detailed property data to create a damage function – identifies type of damage expected for properties of different characteristics (construction, use, occupancy) and then assesses financial damage associated with the physical damage
  - Output is a loss forecast over a range of 10-100 years
  - Not detailed enough for practitioners, only considers physical damage to property



Ref. http://www.air-worldwide.com/Models/About-Catastrophe-Modeling/

Quantifying Resilience: Mapping Value-at-Risk
MIT Hi-Viz Project



 Ref.: B. Arntzen, MIT Hi-Viz Project Research Summary, Feb 2015

Quantifying Resilience: REI, VaR

- **Value at Risk** – a measure of the peak value (revenue, profit, contribution) that is assessed to be at risk within a supply network, often measured at nodes and then combined to provide a network-wide value at risk
- **Risk Exposure Index** (Simchi-Levi, 2012) provides an indexed risk rating of 0.0→1.0 based on the performance impact (revenue, margin, units) from disruption for each node. Uses Time to Recovery (TTR) at each supply chain node to identify the cost from a potential disruption, noting financial impact at the node and then across the network.
- **Time to Recovery (TTR)** per Cisco Systems, Inc. is "...based on the longest recovery time for any critical capability within a node, and is a measure of the time required to restore 100% output at that node following a disruption" (O'Connor 2009). Simchi-Levi defines it as "the time it would take for a particular node — a supplier facility, a distribution center, or a transportation hub — to be restored to full functionality after a disruption"
- **Time to Survive (TTS)** – proposed by Simchi-Levi (2015) "is the maximum duration that the supply chain can match supply with demand after a node disruption." Very useful to identify supply nodes where the TTR is longer than the TTS → blackout/outage predictable

Quantifying Resilience: Balanced Scorecard of Resil

BALANCED RESILIENCE SCORECARD		
QUANTITATIVE		QUALITATIVE
Value-at-Risk	Probabilities	**Survey-based, self-assessments***
Cost to Recover (=f(time to recover))	Cost to Mitigate	

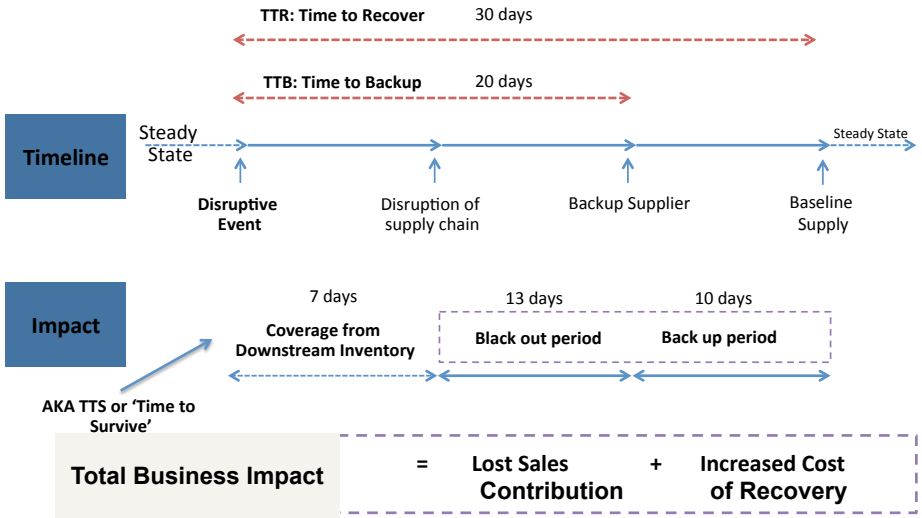
* SCRLC Risk Mgt Maturity Assessment, SCRAM Method, Cranfield/Christopher-Peck Method

- Multi-level assessment – node, supply chain, extended SC
- Various ways to understand the expected Business Impact
- Measure and quantify (Time to Recover (TTR))

Ref.: Jaspar Siu and Santosh Stephen, 2015

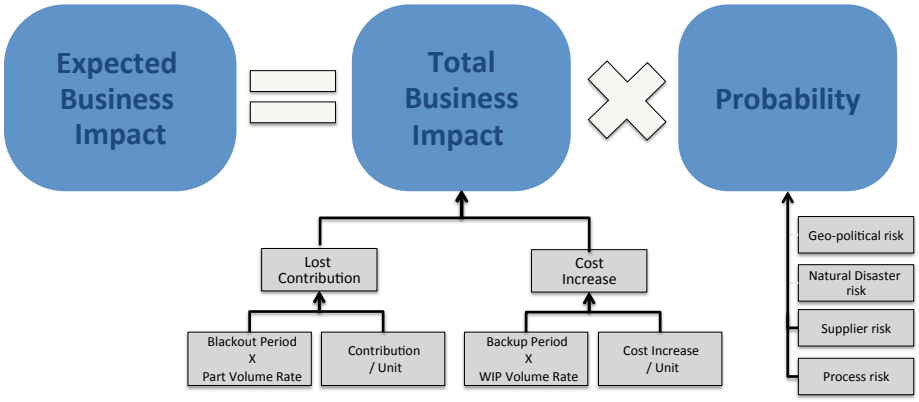
Disruption Timeline Data Ex.

Cost to Recover
Cost to Mitigate Consequences



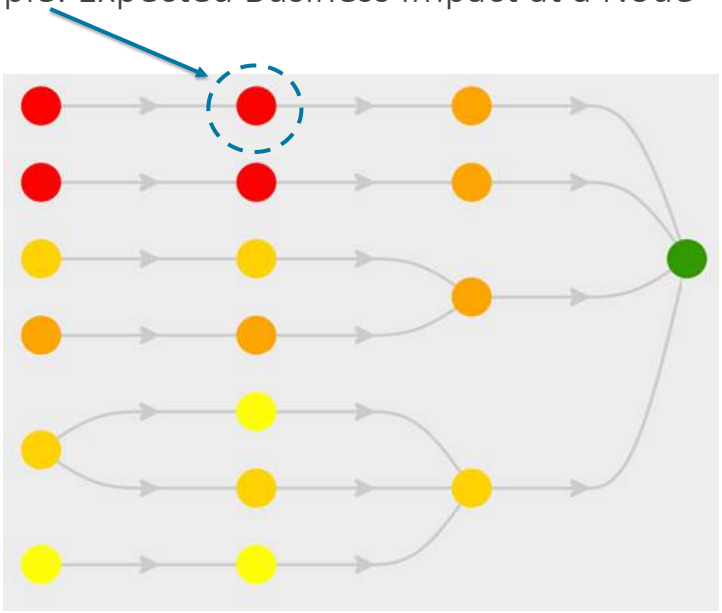
Ref.: Jaspar Siu and Santosh Stephen, 2015

Explanation: Computing Expected Business Impact



Ref.: Jaspar Siu and Santosh Stephen, 2015

Example: Expected Business Impact at a Node



Ref.: Jaspar Siu and Santosh Stephen, 2015

Resilience Analytics: Quantitative Data Needs

- Value-at-Risk
- Risk Exposure Index
- Expected Business Impact
- Cost to Recover
- Cost to Mitigate consequences
- Cost to Mitigate probabilities
- Time to recover
- Time to survive
- Blackout
- Time to backup

Ref.: Jaspar Siu and Santosh Stephen, 2015

Quantifying Resilience: An Assessment

- Risk Exposure Index & Value at Risk
  - Helps identify priorities, and quantify revenue or profit loss potential; but does not provide insight into which options to choose or how much to invest
- Expected Business Impact
  - Difficult to take into consideration different risk preferences and uncertainties
- Balanced Scorecard of Resilience
  - Provides a more holistic assessment, but depends on qualitative work in addition to quantitative assessment
- The Frontier
  - Defining the business investment case, getting full set of data to make choices is starting to take shape (e.g. DSL Ford study)

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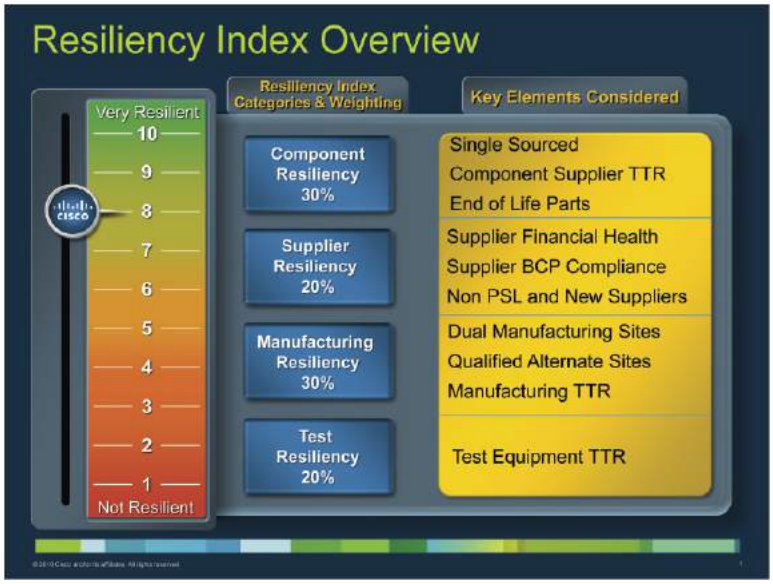
Industry Perspective and Action

Ongoing Mapping and Monitoring

- Design and install monitoring systems
  - Global event monitoring: geographic, political, weather
  - Supplier operational and financial health
  - Monitor entire network, find your sources
- Mapping monitoring services can help
  - Mapping upstream supply chain
  - Maintaining supplier data bases
  - Disaster tracking, monitoring, alert/notification management
  - Have helped companies mitigate

Cisco Resilience Index



Ref: US Resilience Project Case Report: Cisco, August 8, 2011

Supply Chain Risk Leadership Council

SCRLC Supply Chain Risk Mgt Maturity Model*

SCRLC Supply Chain Risk Management Maturity Model

Helpful Hints: Use whole numbers between 1-5; enter rating in Column C or use the drop down arrow

If unsure between two stages, score at the lower stage

Category	Sub-category	Your Rating	Rating Notes	Stage 1 Reactive	Stage 2 Aware	Stage 3 Proactive	Stage 4 Integrated	Stage 5 Resilient
1. Leadership	1A. Executive Leadership	1	Insert comments about your rating in this space	No supply chain risk management leadership defined.	Functional managers have responsibility for leading risk management within their domain.	SCRM has senior management support, but leadership is found at functional levels.	SCRM has senior management leadership functionally defined and is coordinated across functions.	SCRM has a senior management defined leadership role and active engagement of management is enterprise-wide.
	1B. Line/ Functional Leadership	2		Individuals assume responsibility when an event is triggered.	SCRM activities is led by affected pre-designated functional managers.	SCRM activities are coordinated through supply chain manager(s) with focus on management within the functions.	SCRM activities are lead by a collaborative team of functional managers with focus on internal management including critical supply chain partners.	SCRM is coordinated across the enterprise including multi-tier critical supply chain partners with defined roles and responsibilities.
	1C. Governance	3		No supply chain risk management framework.	Functional managers use risk management frameworks appropriate for their function with no cross function coordination.	SCRM is coordinated across functional units with defined roles of key internal supply chain stakeholders.	SCRM is governed by a cross-functional well defined framework including critical supply chain partners.	Supply chain risk management framework is well defined across the enterprise including multi-tier critical supply chain partners.
	1D. Resources & Commitment	4		No designated supply chain risk management resources.	SCRM resources are identified within functional units and risk management is considered a collateral duty.	SCRM resources designated for functional units. Accountability and resource allocation within functional level.	SCRM has committed resources with well defined roles and responsibilities on a cross-functional level and considering critical supply chain partners.	SCRM is embedded within the organization's culture and seen as a value added activity with appropriate resources committed. Enterprise-wide accountability and resource allocation considered as part of regular fiscal allocations.
	1E. Program Communication	5		No defined internal or external SCRM communication.	Informal SCRM communication occur within the functional units.	Formal SCRM communications occur within functional units. Supply chain partner communications occur as they relate to individual functions.	Integrated SCRM communications and consultation across functional units and includes critical supply chain partners.	Enterprise-wide communication and consultation includes multi-tier critical supply chain partners.

* Model available for download at http://www.scrlc.com/

One company's approach

- No "single system metric" to quantify supply chain risk
- Supply Chain risk reduction is part of Enterprise Risk Management
- Assess three factors
  - Impact, vulnerability and speed of onset
  - High, medium, low and some dimensions of each
  - Plot on Vulnerability – Impact chart to create relative priorities

- Executives are assigned to reduce the risk to an agreed to manageable level, making informed risk/reward based decisions
- Decisions based on qualitative and some quantitative information, committee input

Proposed Standard Measures

- Revenue protected by meeting risk criteria
- Time to Recover
- Time to Survive
- Value at risk
- Estimated Maximum Loss
- Probable Maximum Loss
- Likelihood of Occurrence
- Sole supplier
- Strategic Product Protection
- Critical sites protection
- Risk Mitigation Actions status
- Categorization of risk type
- Risk Investment cost

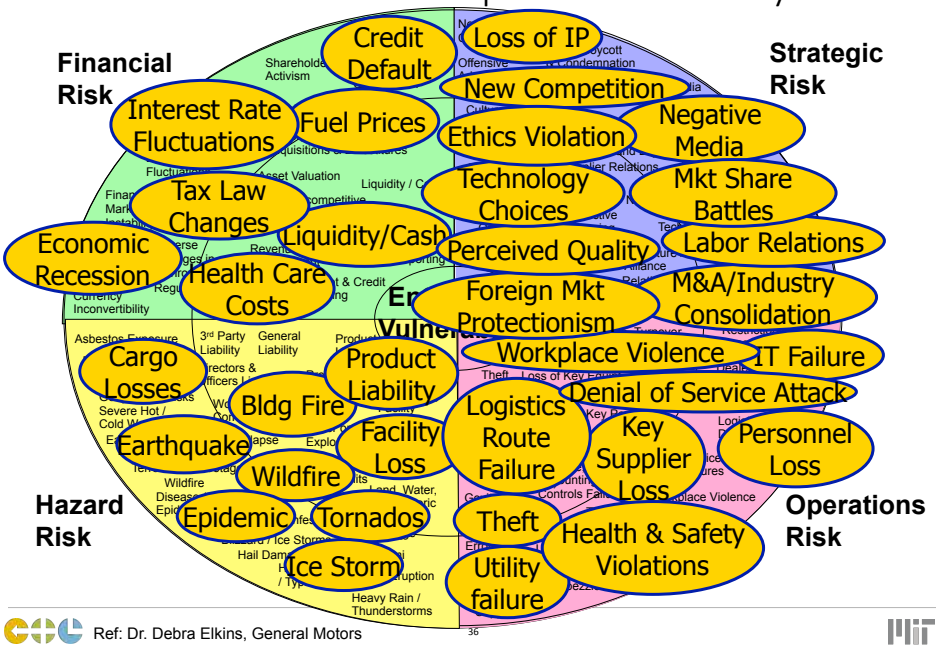
That's a lot of data!
Accessible?
Qualitative?
Calibrated?

Quantifying Resilience Challenges

The Challenges & My Suggestions

- Focus on source of disruption risk or outcome from the disruption?
  - Most research is conducted on the many different sources of risk, rather than the predictable set of limited outcomes → Failure Modes.

Known Risk – Enterprise Vulnerability



Ref: Dr. Debra Elkins, General Motors

Supply Chain Failure Modes/Predictable Outcomes

All disruptions result in a loss of one or more of these capacities:

- Capacity to acquire materials (supply)
- Capacity to ship/transport
- Capacity to communicate
- Capacity to convert (internal operations)
- Human resources (personnel)
- Financial flows

Sources: "SC Response Project Interim Report" by J. Rice, F. Caniato, Aug 8, 2003; Draft of SC Response Book project, Oct. 2004

The Challenges & My Suggestions

- Focus on source of disruption risk or outcome from the disruption?
  - Most research is conducted on the many different sources of risk, rather than the predictable set of limited outcomes → Failure Modes.
- Refine the use of 'Mitigation'
  - Mitigate the probability of a disruption? → Prevention, focus on source of risk
  - Mitigate the consequences of a disruption? → Resilience, focus on outcomes
- Finding and accessing the data
  - The raw data is not readily available and process not scalable
  - Identify proxies and processes that can work to get TTR, TTS, Blackout, Cost to mitigate consequences, Cost to recover
- Develop resilience analytics to enable the investment decision
  - Using new data sources, options analysis, tradeoffs; bring innovation (and marketing) into the process

Guidance we can provide today

How resilient is our SC? Measure REI, VaR, EBI, TTR, TTS, Cost to recover, Cost to mitigate, Balanced Scorecard

Upstream mapping resources

Available in public domain….
But it requires constant attention

So many sources of risk – where do we start?
Focus on 'failure modes, predictable and limited # of outcomes

Calculate ROI?

+ - %?

Enlist advocates and build the business case

Which investment options?
Structured options and resilience analytics

Growth or Resilience?

Resilience (especially flexibility) enables growth

Network image from: http://www.informit.com/articles/article.aspx?p=2166717&seqNum=2

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Auto OEM Business Continuity Planning Executive

"Yes, I agree that investing in supply chain can absolutely drive growth –

we just need to help the leadership see the connection."

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Thank You

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