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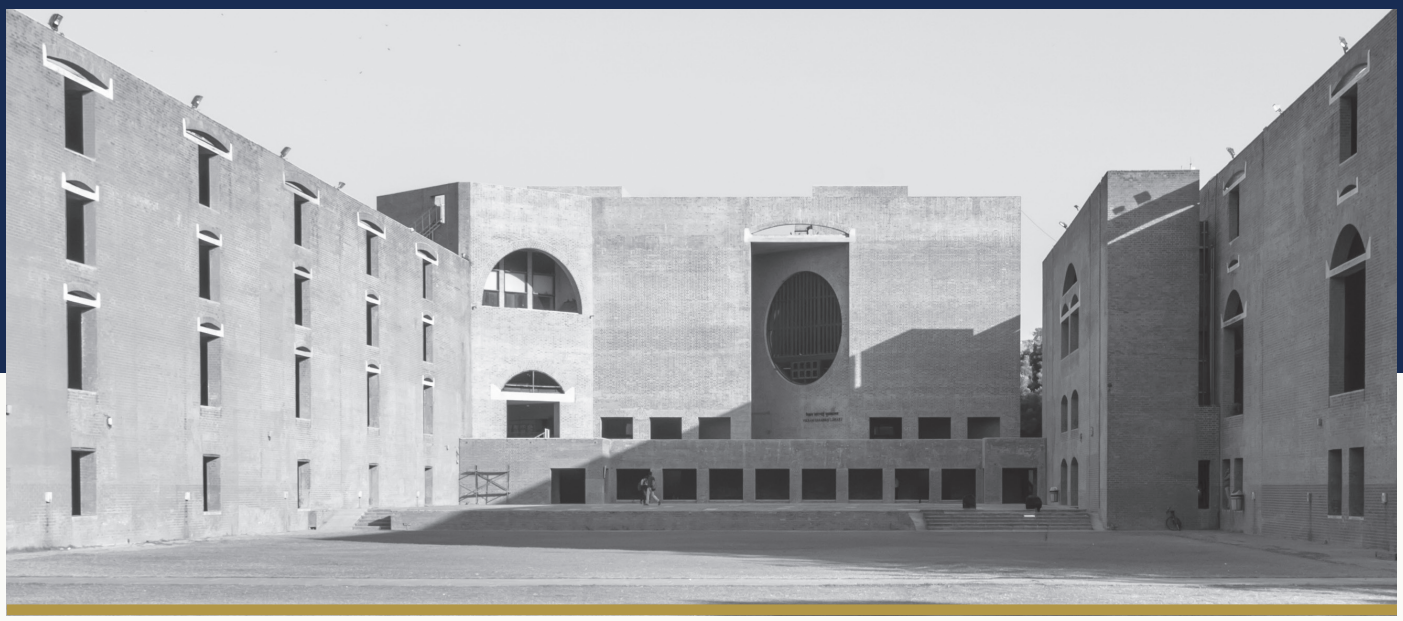
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SEMINAR SUMMARY REPORT

Building Resilient and Sustainable Supply Chains in a Changing Climate: Enterprise, Innovation, and the Future of Business

10 SEPTEMBER 2026



Speaker

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Seminar on

Building Resilient and Sustainable Supply Chains in a Changing Climate: Enterprise, Innovation and the Future of Business



by

Professor Julieanna Powell-Turner

Associate Dean (Research & Innovation),
Head of CREST
(Centre for Research into Environmental and Sustainable Transitions),
University of Chester, UK



September 10, 2026 **2:00 p.m. IST**

Seminar Room-10, AB-2, New Campus

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Table of Contents

About the Speaker 01

About the Moderator 02

Abstract 03

Introduction 04

Seminar Summary 07

Q & A Session 15

Key Takeaways & Conclusion 16

Acknowledgements 18

References 19

About the Speaker



Prof. Julieanna Powell-Turner

With more than 20 years' experience spanning academia, government and industry, Prof. Julieanna Powell-Turner has collaborated with a wide range of international organisations, including the Asian Development Bank, UNEP, DFID, GIZ and the European Union, as well as UK government and defence bodies. Her work has taken her across Europe, Asia and beyond, engaging policymakers, communities and industry partners on some of the most pressing sustainability and environmental challenges of our time.

Prior to joining the University of Chester, Prof. Powell-Turner held senior roles at Cranfield University's School of Defence and Security and at UKAEA, working on environmental management, resource security and systems thinking within complex policy and organisational settings, including collaboration with UK defence and government agencies.

About the Moderator



Prof. Anish Sugathan

Prof. Anish Sugathan is a faculty member in the Strategy Area and the Chairperson of the Centre for Sustainability and Corporate Governance Research (CSCG) at the Indian Institute of Management, Ahmedabad. He pursued his PhD (FPM) from the Indian Institute of Management Bangalore (IIMB), a post-doctoral fellowship from the Harvard Kennedy School of Government, and is a visiting research fellow of the 2022 'Sustainable Futures' programme at Princeton University. He serves as a member of the expert committee appointed by the Honourable National Green Tribunal of India for environmental impact assessment and evaluation. He is also a member of the Sectional Committee for Sustainable Finance of the Bureau of Indian Standards. He has served on the board of the state-owned electricity distribution utility UGVCL, Government of Gujarat, as an independent director. He advises several start-ups in the energy tech, impact investment and innovative governance sectors.

Prof. Sugathan's research interests focus on the institutional and governance infrastructure of emerging economies, with a particular emphasis on sustainable development and corporate sustainability in India. His research has been published in reputable international journals as well as numerous national and international newspapers. His research has received several prestigious awards, including the SAP Labs India doctoral scholarship at

IIMB, the Giorgio Ruffolo post-doctoral research fellowship at Harvard, and the Fung Global Fellowship at Princeton. His current research work is supported by BP UK through the PROSPER programme, Evidence in Governance and Politics (EGAP) at the University of California, Berkeley, and Google through the Geo-for-Good research grant.

Abstract

This report presents the key insights from a seminar by Professor Julieanna Powell-Turner on “Building Resilient and Sustainable Supply Chains in a Changing Climate: Enterprise, Innovation, and the Future of Business,” jointly organised by the Centre for Transportation and Logistics, the Centre for Sustainability and Corporate Governance Research, and the PwC ESG Forum at IIMA.

Drawing on Professor Powell-Turner’s experience across academia, government and industry, the seminar examined supply chains as complex systems rather than simple linear sequences of production and distribution. The discussion connected supply-chain resilience and sustainability to six critical dependencies: materials and minerals, energy, finance and insurance, logistics and transport, rules and regulations, and people and skills. Particular attention was given to critical materials and rare earth elements, their geographic concentration, the difficulty of substitution and recovery, and the strategic vulnerabilities created by dependence on concentrated sources of supply.

The seminar also explored the relationship between climate risk and the energy transition, the distinction between resilience and sustainability, the role of circular-economy thinking and design, and the practical trade-offs among resilience, sustainability, cost, affordability, profit and growth. Through examples from mobile phones, food, defence, electric vehicles, renewable energy, and other industries, Professor Powell-Turner argued that organisations need to understand the broader system surrounding a product rather than focusing solely on the product itself. The seminar concluded with an emphasis on collaboration, control, communication and commitment as the “four Cs” needed to build resilient systems, alongside forward-looking design, diversification where feasible, recovery of materials after consumption, and better integration of climate and resource considerations into business and policy decisions.

Introduction

Supply chains are increasingly complex and interconnected as firms rely on geographically dispersed suppliers, specialised production networks, wider logistics systems and internationally sourced raw materials. Rather than functioning as simple linear sequences from suppliers to manufacturers and then to consumers, contemporary supply chains operate as interconnected systems in which disruptions at any point can propagate across multiple stages. This is particularly important because the performance of an individual firm often depends on factors outside its direct organisational boundaries, including the availability of materials, energy, transportation, finance, infrastructure, regulation, and specialised skills. Recent literature on supply-chain resilience therefore increasingly emphasises the ability of firms and supply-chain networks to anticipate, absorb, and recover from disruptions, rather than focusing solely on efficiency under normal operating conditions.

The importance of resilience is even more pronounced in the context of climate change. Climate-related hazards can affect physical infrastructure, transportation networks, production facilities, agricultural systems, and the availability of essential resources. Unlike many conventional operational risks, climate-related disruptions can occur across geographically connected parts of a supply chain and may simultaneously affect several suppliers or logistics routes. . The impact of climate change is not only an environmental challenge but also a major operational and strategic challenge for businesses. Sustainable supply-chain management has thus evolved beyond a narrow focus on environmental performance to incorporate the economic, environmental and social dimensions of long-term supply-chain viability. Carter and Rogers (2008), for example, conceptualise sustainable supply-chain management as the strategic integration of economic, environmental and social objectives into the management of supply-chain relationships and processes.

A notable distinction is between sustainability and resilience. While sustainability is concerned primarily with maintaining environmental, social and economic systems over the long term, resilience concerns the capacity of a system to withstand disturbances and continue functioning. The two concepts are therefore related but not synonymous. A supply chain may perform well according to conventional sustainability indicators while remaining vulnerable to a major disruption.Conversely, measures undertaken to improve resilience, such as developing alternative sources of supply, improving resource efficiency or investing in recovery capabilities, may also contribute to sustainability. Understanding the interaction between these two objectives is important for organisations seeking to manage long-term environmental pressures while maintaining operational continuity.

Climate change also interacts with the global energy transition in ways that create new supply-chain challenges. The expansion of renewable energy, electric mobility, energy storage and other low-carbon technologies is increasing demand for a range of critical minerals. The International Energy Agency (IEA) notes that critical minerals such as lithium, nickel, cobalt, graphite and rare earth elements have become increasingly important because of their role in clean-energy technologies, while their markets remain exposed to supply bottlenecks, geopolitical risks and geographical concentration. The concentration of production and, particularly, refining capacity creates an additional dimension of supply-chain vulnerability. The IEA reports that the supply chains for several key minerals remain highly concentrated and that limited diversification can increase exposure to disruptions arising from geopolitical events, extreme weather and other shocks.

Rare earth elements provide a particularly relevant example of this challenge. Their supply chain extends beyond extraction to technically demanding stages such as beneficiation, separation, refining, alloying and magnet manufacturing. The geographical concentration becomes more pronounced at the processing and refining stages. The IEA reports that China accounted for approximately 60% of global mined production of magnet rare earths in 2024 and around 91% of global refined output, illustrating how control over processing capabilities can be as strategically important as access to geological resources. Such concentration means that a disruption at a major production or processing location can affect industries far beyond the country where the disruption occurs. It also demonstrates why supply chain analysis must examine upstream dependencies rather than focus only on a firm's immediate suppliers.

The transition toward a low-carbon economy, therefore, creates a potential paradox. Technologies designed to reduce environmental pressures may themselves depend on resource-intensive and geographically concentrated supply chains. The IEA highlights that the rapid expansion of clean-energy technologies is increasing demand for critical minerals while geographical concentration remains high across several stages of production. This creates a need to consider sustainability, resilience, and resource security simultaneously. Ensuring that the energy transition is environmentally sustainable may not be sufficient if the underlying material supply chains remain vulnerable to disruption.

Another important dimension is the design of the products themselves. The ability to recover, reuse, and recycle critical materials depends in part on how products are designed and assembled. Materials embedded within highly integrated products may be technically recoverable but economically difficult to separate without losing a substantial portion of their value. Circular economy approaches, therefore, seek to extend the useful life of products and materials through reuse, repair, remanufacturing and recycling. From a supply-chain perspective, such approaches can serve two purposes simultaneously: reducing environmental impacts and creating secondary sources of materials that can reduce dependence on virgin resource extraction. The IEA similarly emphasises that sustainability considerations in critical-mineral supply chains encompass environmental, social and governance issues alongside supply security.

It is against this broader background that the seminar by Professor Julieanna Powell-Turner was organised. The seminar approached supply-chain resilience from a systems perspective, arguing that a supply chain should not be understood simply as a sequence of firms or transactions. Instead, it is a network of interdependent relationships involving materials and minerals, energy, finance and insurance, logistics and transport, rules and regulations, and people and skills. This perspective was introduced through an interactive discussion on mobile phones, in which participants were asked whether they knew where their phones were assembled, where their critical materials originated, and how those materials could be recovered once the devices reached the end of their useful lives. The exercise illustrated the limited visibility that consumers, and potentially firms, may have over the deeper dependencies embedded within apparently familiar products.

The seminar then examined how climate change, energy transitions, critical-material dependence, resource scarcity and geopolitical disruptions interact with business operations. Attention was given to the distinction between sustainability and resilience, the strategic importance of rare earth elements and other critical materials, the trade-offs associated with concentration and diversification, and the importance of designing products for recovery and reuse. The discussion also highlighted the practical difficulties faced by organisations, as resilience and sustainability require investment, while firms simultaneously face pressures relating to cost, profitability, affordability and growth.

The central message of the seminar was therefore that resilient and sustainable supply chains cannot be created through isolated interventions. They require organisations to understand the wider system in which they operate, identify critical dependencies, anticipate potential points of failure and consider the consequences of decisions across the entire product lifecycle. In this sense, supply-chain resilience and sustainability are not separate corporate objectives but interconnected dimensions of long-term organisational and societal resilience. The seminar provides a useful framework for examining these issues through the four Cs of collaboration, control, communication and commitment, while also highlighting the importance of circularity, product design, resource security and forward-looking risk management.

Seminar Summary

The seminar began with Professor Powell-Turner establishing that the supply chain is not simply linear. Instead, it is a system in which different dependencies interact with one another. She compared this idea to the butterfly effect, wherein a relatively small disturbance in one part of a system can produce much larger consequences elsewhere. This perspective is especially relevant to modern global supply chains as production is geographically dispersed and relies on specialised materials, infrastructure, energy, finance, logistics and skills. A product can therefore appear to be locally available while relying on a very large, internationally distributed network.

She identified six broad dependencies to consider when analysing a supply chain. The first is materials and minerals, which provide the physical inputs required to make products. The second is energy, which is required for extraction, processing, manufacturing and transportation. The third is finance and insurance, which enable firms to invest and manage risk. The fourth is logistics and transport, which move inputs and outputs across locations. The fifth is rules and regulations, which determine where and how products can be manufactured, imported, or exported. The sixth is people and skills, which provide the knowledge and capabilities necessary for the system to function.

The importance of these dependencies is that a product cannot be separated from them. A company may have an efficient manufacturing process, but if the material it requires is unavailable, transport is disrupted, regulations change, insurance becomes unavailable, or the necessary skills are missing, then the product may not be produced. Professor Powell-Turner connected this systems view to systems engineering and defence planning, where attention is routinely given to interdependence and interoperability rather than to a single component in isolation.

The implication for business is that supply-chain analysis should move beyond questions such as “Who is our supplier?” toward broader questions such as “What does our supplier depend upon?” and “What other systems could interrupt the flow of the material, energy, information or capability we require?” This deeper analysis is important because the most serious vulnerabilities may sit several stages upstream from the focal firm. A company may diversify its immediate suppliers while still depending on the same mineral-processing facility, energy source, transport corridor or country further upstream.

The seminar next placed supply chains within the broader environmental system. Professor Powell-Turner emphasised that there is one Earth and that resources are finite. At one end of the system are sources, from which society extracts materials such as water, minerals and energy resources. At the other end are sinks, where discarded materials eventually enter the atmosphere, soils, water bodies, seas or landfill. The supply chain, therefore, operates within a closed system rather than an unlimited open environment.

She presented two basic principles for thinking about this closed system. First, resources should not be removed faster than they can be renewed. Second, waste should not be discarded faster than it can be absorbed. These principles provide a simple way of understanding why sustainability cannot be treated merely as a reporting exercise. If extraction continually exceeds renewal and waste continually exceeds the capacity of natural or engineered systems to absorb it, the system becomes increasingly vulnerable. This perspective also changes the meaning of waste. A material treated as waste at the end of one supply chain may still hold economic and strategic value for another. Recovering, recycling, and remanufacturing materials can therefore reduce dependence on the primary inputs while simultaneously reducing environmental pressures. The argument is particularly important for critical materials, where the supply of primary resources may be geographically concentrated and difficult to expand quickly. The closed-system perspective also connects environmental sustainability with supply security. If a firm relies entirely on primary materials from external sources, a disruption in those sources can create both a sustainability problem and a resilience problem. Conversely, the ability to recover materials from products already in circulation can create an additional source of supply. Circularity, therefore, becomes not only an environmental objective but also a potential component of resource security.

A major theme of the seminar was climate and energy, and how they should be considered together. Professor Powell-Turner described them as two forces that work hand in hand rather than taking turns. Climate-related events can disrupt physical infrastructure, transportation and production, while the energy transition changes the material requirements and geographical dependencies of industrial systems. As countries attempt to decarbonise and move toward net-zero objectives, these two dimensions become interconnected.

Climate risk can affect supply chains directly through natural disasters and extreme events. The speaker used volcanic activity and the resulting disruption to air travel and freight as an example of how a physical event can rapidly affect transportation systems. Passengers may be temporarily stranded, but freight disruptions can have more complex consequences for businesses that depend on just-in-time flows. Companies with stockpiles or contingency arrangements may absorb such a shock more effectively, while companies without mechanisms for managing disruptions can experience sudden interruptions. The energy transition introduces another form of disruption. Industries are moving away from a historical

dependence on oil and gas while expanding the use of renewable energy, hydro, wind and nuclear power. Professor Powell-Turner stressed that the transition should be understood as an energy nexus rather than as a simple replacement of one source by another. Every energy technology itself depends on materials, manufacturing capabilities, infrastructure and transport. Consequently, decarbonisation can reduce one category of risk while creating or intensifying another if the material dependencies of the new technologies are not considered. The discussion, therefore, suggested that climate considerations need to be incorporated into decision-making at multiple levels. Firms must consider physical climate risks to their facilities and suppliers, while governments and policymakers must consider the resilience of national and international systems. Climate is also increasingly part of strategic, political and geopolitical decision-making. The important point is not that every climate risk can be eliminated; Professor Powell-Turner explicitly recognised that natural disasters cannot ultimately be controlled. Instead, organisations can identify vulnerabilities, prepare for disruptions and reduce the consequences where possible.

Professor Powell-Turner made an important distinction between sustainability and resilience. Although the terms are sometimes used interchangeably, she argued that they are not identical. Sustainability is fundamentally concerned with maintaining systems over the long term, including consideration of environmental and social impacts and the consequences of today's decisions for future generations. She connected this perspective to the established idea of sustainable development and to the "people, profit and planet" framework associated with the triple bottom line. Resilience, in contrast, was described primarily in terms of a system's capacity to absorb a shock and continue functioning. The key question is, therefore, what happens when a disruption occurs. A resilient supply chain may experience a shock but continue operating, whereas a vulnerable supply chain may stop functioning. Resilience thus places greater emphasis on disturbance, response, and recovery. The distinction becomes especially useful when considering firms that perform well on conventional sustainability indicators but remain exposed to severe operational vulnerabilities. A company may report its environmental impacts, understand its emissions and have a strong sustainability reputation, yet still be unable to operate if a critical material, component or transport route becomes unavailable. Sustainability initiatives are, therefore, necessary but do not automatically guarantee resilience.

At the same time, the two concepts often lead organisations toward overlapping decisions. For example, recovering waste can reduce environmental impacts while also lowering dependence on primary materials. Improving energy efficiency can reduce emissions while lowering operating costs and reducing exposure to energy-price volatility. Building alternative sources of supply can increase resilience while potentially supporting more sustainable resource use. Professor Powell-Turner's broader point was that sustainability and resilience may ask different questions, but they can ultimately lead to the same practical investment decision.

The seminar did not present sustainability as an issue relevant only to environmental advocates or corporate reporting teams. Professor Powell-Turner identified several business arguments for taking sustainability seriously. The first concerns regulation and obligation. International agreements, national policies and laws determine how companies operate and what environmental or social requirements they must meet. Sustainability, therefore, has a compliance dimension.

The second argument concerns pressure from shareholders, customers and investors. Stakeholders increasingly care about reputation, brand, sustainability commitments, and firms' ability to secure the resources required for continued production. A company's sustainability position can therefore influence how it is perceived by external stakeholders. The third argument is supply security, wherein companies need to know whether the materials and other inputs on which their products depend will remain available. The fourth argument is cost and resource efficiency. Professor Powell-Turner described this as perhaps the least glamorous argument, but potentially one of the most financially important. If firms continuously import primary materials, discard recoverable resources and pay for waste disposal, they may incur substantial costs. Recycling, recovery and remanufacturing can reduce these costs. Sustainability can therefore become directly connected to operational efficiency rather than remaining separate from the commercial side of the business. Finally, she discussed opportunity and value creation. Sustainability can create new business opportunities when firms identify ways to reduce resource use, recover materials, develop new products or manage risks more effectively. This shifts the conversation from sustainability as a constraint to sustainability as a potential source of value. However, the seminar also recognised that business decisions are ultimately shaped by competing objectives, particularly profitability and growth.

Critical materials were among the most detailed components of the seminar. Professor Powell-Turner used the periodic table and examples from modern technologies to explain why certain elements are strategically important. Rare earth elements are used in a wide range of electronic and advanced technologies, including magnets and components in products such as mobile phones.

Powell-Turner used the periodic table and examples from modern technologies to explain why certain elements are strategically important. Rare earth elements are used in a wide range of electronic and advanced technologies, including magnets and components in products such as mobile phones. Their importance is not simply a function of scarcity in the geological sense; it also reflects the difficulty of replacing, processing, and recovering them on a large scale. Professor Powell-Turner explained that

rare earth elements can provide valuable technical characteristics. In certain applications, their relatively low weight and performance characteristics can contribute to efficiency and agility. This becomes particularly important in advanced technologies, including aerospace and defence applications, where component weight, fuel consumption and performance are closely connected. The strategic problem arises when extraction, processing and refining are geographically concentrated. She further highlighted the concentration in rare earth processing and explained that a country may possess mineral resources but still have limited strategic value from them if it lacks the capacity to process and refine them. This distinction between possessing a resource and controlling the capability to turn that resource into a usable input is central to resource security. The consequences of concentration are visible across sectors. Electronics, renewable-energy technologies, electric vehicles and defence systems can depend on materials that are difficult to substitute. She emphasised that substitution is not equally feasible across products. In relatively simple applications, alternative materials may be introduced with manageable changes. In highly integrated systems, however, replacing one material can require redesigning the entire system, leading to high costs and long lead times.

One of the seminar's strongest messages was that some supply-chain problems are created at the design stage. Professor Powell-Turner explained that many products are designed as integrated units in which critical materials are embedded in ways that make post-consumption recovery difficult. This creates a tension between short-term product design and long-term resource security. A product can be highly efficient to manufacture and perform extremely well during its useful life, while being difficult to disassemble or recycle afterwards. From a narrow production perspective, such a designmay be commercially attractive. From a systems perspective, however, the product creates a downstream waste and resource-recovery problem.

The seminar moved across several sectors to demonstrate how the systems framework operates in practice. Food was introduced as one of the oldest and most familiar supply chains. The cocoa and chocolate example illustrated the difference between an important input and a critical input. Food is essential because people must eat, but food products can generally be substituted to some degree. Critical materials in advanced technologies can be different because their specific technical functions may be much harder to replace. The defence sector provided another strong illustration of the consequences of material dependency. Professor Powell-Turner described how advanced defence equipment may require specialised materials and components for which substitutes are not readily available. Even when alternatives technically exist, they may be heavier, less efficient, or much more expensive. Replacing a component can also require redesigning other interconnected parts of a system. As a result, substitution is not simply a procurement decision; it can become a long-term engineering and investment project.

The seminar also connected critical materials to the renewable-energy transition. Solar and wind technologies have become more accessible and economically viable than they were many years ago. Professor Powell-Turner noted India's significant role in photovoltaic-cell production and highlighted the country's manufacturing capabilities. At the same time, she emphasised that manufacturing capacity does not automatically eliminate upstream dependencies. If critical inputs or processing capabilities remain concentrated elsewhere, domestic manufacturing can still depend on international supply chains. Electric vehicles provided another example through the growing demand for batteries and associated materials. The transition toward electric mobility increases demand for specific minerals, creating new supply chain dependencies. The broader lesson was that technologies designed to address one environmental problem can introduce new resource and supply-chain questions. Energy transition strategies, therefore, need to consider not only emissions but also the material systems required to build and maintain low-carbon technologies.

Another important issue was the trade-off between concentration and diversification. Concentrating production in one location can generate powerful efficiency benefits. A manufacturer may develop specialised skills, infrastructure, suppliers, and economies of scale in one place, making the production system highly competitive. However, the same concentration can create fragility. If the concentrated location experiences a natural disaster, geopolitical disruption, regulatory change or supply interruption, a large part of the supply chain can be affected simultaneously. Professor Powell-Turner therefore described concentration as potentially efficient but fragile. The challenge is that firms have commercial incentives to maintain concentration when it lowers costs and improves efficiency. Asking companies to diversify purely for resilience can therefore be difficult if the additional cost is immediate while the benefit materialises only when a disruption occurs. Diversification is also not a universal solution. If every alternative supplier depends on the same upstream processor or mineral source, apparent diversification may not remove the underlying vulnerability. The systems approach requires firms to trace dependencies far enough upstream to determine whether alternatives are genuinely independent. Resilience therefore depends not simply on the number of suppliers but on the structure of the underlying network. This issue is especially important for governments because strategic dependencies may exist across many firms simultaneously.

The seminar also considered India's efforts to strengthen resilience in the context of critical

materials and supply chains. Professor Powell-Turner referred to India's collaboration with partners, including the United Kingdom, the United States, and Australia, and described these efforts as examples of forward planning. The emphasis was on anticipating potential supply-chain shock points and implementing mitigation measures rather than waiting for a disruption to occur.

She then introduced the "four Cs": collaboration, control, communication and commitment. Collaboration is important because no individual firm, researcher, or government agency can understand all dependencies in a complex system. Different organisations possess different knowledge, capabilities and resources. Sharing information and coordinating action can therefore improve resilience. Control refers to understanding which parts of the system an organisation can actually influence. Not every risk can be controlled. Natural disasters, for example, cannot be eliminated. However, firms can control elements such as inventory policies, design choices, supplier relationships, recovery systems and contingency planning. Distinguishing controllable from uncontrollable risks helps organisations allocate resources more effectively. Communication is equally important because a disruption can become more severe when information does not move quickly across the network. Firms need to communicate with suppliers, customers, regulators, logistics providers and other stakeholders. Finally, commitment is necessary because resilience investments often require resources before a crisis occurs. Without long-term commitment, companies may repeatedly postpone investments in redundancy, recovery and preparedness because their benefits are difficult to observe during normal conditions.

Toward the end of the seminar, Professor Powell-Turner returned to the difficulty of reconciling multiple organisational objectives. She emphasised that people, profit and planet do not automatically move in the same direction. Resilience adds another important objective. In an ideal world, all four would reinforce one another, but in practice, organisations frequently have to make compromises. People-related decisions may involve employment, skills, workforce planning and employee welfare. Profit and growth involve margins, market share, shareholder expectations and investment returns. Planet involves environmental impact, sustainability targets and resource use. Resilience involves preparedness for shocks, continuity of operations and the ability to recover. Each objective can require different investments and may generate different priorities for management. For example, a highly resilient supply chain may require multiple suppliers and additional inventory, which can increase costs. A highly sustainable design may require materials or engineering processes that are initially more expensive. A business focused strongly on immediate profitability may prefer concentration and minimal inventories. A company facing financial difficulties may reduce spending on environmental initiatives even when those initiatives are beneficial in the long term. The speaker's point was not that one objective should always dominate the others. Instead, organisations need to recognise the trade-offs explicitly. The four objectives should be treated as interacting pressures within a decision system. Understanding the trade-off is itself part of good management because it makes clear what is being sacrificed when a particular decision is made.



Q & A Session

Q. Since you are mentioning that the inability to recover materials after consumption can be viewed as a design problem. There are newer technologies associated with the energy transition, such as solar panels, where manufacturers are already aware of shortages and the strategic importance of certain inputs. Were there any attempts to design such products in ways that would make post-consumption material recovery cheaper?

A. Yes, for some materials and products, the inability to recover material is indeed linked to design choices. The speaker explained that there is increasing attention to “design for sustainability” and “design for the environment.” Rather than allowing products to become waste at the end of their useful life, designers are considering how materials can be recovered and recycled. Where components cannot be easily separated, researchers are also considering whether materials can be smelted and used in another product or in another part of an existing system.

She emphasised that this area is receiving substantial research attention because critical materials are becoming increasingly important. Post-consumption recovery may appear less prominent than the manufacturing stage, but it has both environmental and economic significance. Materials that were previously discarded as waste can become valuable secondary resources. Recovering them can reduce dependence on virgin materials and reduce the environmental burden associated with extraction and disposal.

Please click here to watch the video.



Conclusion and Key Takeaways



The seminar presented a broad systems-based approach to one of the central challenges facing contemporary organisations. The starting point was simple but important, i.e., a supply chain is not a line. It is a system of interdependent materials, energy, finance, insurance, logistics, regulation, people and skills. A disruption in any one dependency can affect the wider network, sometimes in ways that are disproportionate to the original disturbance.

A second major takeaway was that the Earth itself is a closed system with finite resources and limited capacity to absorb waste. This makes resource recovery, recycling, and remanufacturing important not only for environmental sustainability but also for economic and strategic resilience. Critical materials illustrate this connection clearly. Where resources or processing capabilities are geographically concentrated, and substitution is difficult, dependence can become a major vulnerability.

A third takeaway concerns the relationship between climate and energy. Climate risks can disrupt physical supply chains, while the energy transition is creating new material and technological dependencies. Decarbonisation, therefore, cannot be considered only in terms of replacing fossil fuels with low-carbon technologies. It also requires attention to the materials, processing capabilities, infrastructure and skills needed to build those technologies.

The seminar also clarified the difference between sustainability and resilience. Sustainability focuses on long-term environmental, social and economic continuity, while resilience focuses on the capacity to absorb shocks and continue functioning. They are distinct concepts, but many investments can serve both objectives. Resource recovery, efficient energy use, diversified sourcing and better product design are examples of actions that can potentially improve both sustainability and resilience.

Another important takeaway was that resilience has a cost. Businesses operate under pressure to control expenditure, protect margins and deliver growth. Sustainability and resilience initiatives can therefore be difficult to justify when their benefits are uncertain or long-term. The seminar suggested that one way forward is to frame these initiatives in terms of the full range of organisational benefits, including cost savings, supply security, regulatory compliance, reputation, efficiency and value creation.

The four Cs - collaboration, control, communication, and commitment provide a practical framework for translating these ideas into action. Collaboration helps organisations address problems that cross institutional boundaries. Control helps distinguish risks that can be managed from those that cannot. Communication ensures that information about vulnerabilities and disruptions moves through the system. Commitment ensures that investments in preparedness and sustainability are maintained beyond short-term business cycles.

The seminar's final message was that resilient and sustainable supply chains cannot be created through isolated interventions. They require a systems perspective that connects design, sourcing, manufacturing, logistics, resource use, consumption and recovery. Concentration may improve efficiency but can increase fragility; substitution may work in some sectors but not in highly integrated technologies; recovery may be difficult after consumption but can be enabled through better design. The challenge for firms and governments is therefore to understand these trade-offs before shocks occur rather than after the system has already failed.

Overall, the seminar encouraged participants to look beyond the visible product and examine the network that makes the product possible. It demonstrated that sustainability and resilience are not separate corporate agendas but interconnected dimensions of how modern supply chains operate. In a world shaped by climate change, the energy transition, geopolitical uncertainty, and the growing demand for critical materials, the ability to anticipate dependencies, design for recovery, collaborate across boundaries, and make informed trade-offs will become increasingly important for enterprises, governments, and society.



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