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How to Create Organizational Resilience and Adaptability Through Embedded Plasticity-Rigidity Cycles

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This paper explores how organizational network structures influence cascading failure propagation and how embedded plasticity–rigidity cycles can create resilience and adaptability. Using real industrial examples from IT-telecom manufacturing, the study demonstrates how small disturbances in highly connected, overly lean (anorexic) supply chains can escalate into large-scale cascading failures, leading to "bulimia states" characterized by simultaneous excesses and shortages. The research introduces the concept of embedded plasticity – the deliberate integration of adaptable nodes and teams at multiple organizational levels – to dissipate disruptions and maintain performance stability. By analyzing typical network motifs such as bi-fans and bi-parallels, the authors identify the structural sources of ambiguity and competition that amplify systemic fragility. The framework includes the design of dual plastic-rigid team structures that align internal dynamics with external fluctuation patterns. These embedded plasticity cycles enable swift adaptation without compromising process quality or productivity. Appropriate levels of plasticity, strategically distributed across organizational sub-networks, are key to ensuring the robustness, flexibility, and continuous learning of complex, interconnected care systems.

1. Introduction

The growing frequency of global disruptions in the twenty-first century has revealed the increasing fragility of complex supply chain networks. As digitalization and globalization expand interconnections among organizations, minor disturbances can propagate rapidly, resulting in cascading failures that threaten overall system stability. One of the fundamental reasons for the increased sensitivity of supply chain networks is the growing interconnectedness of networks (Csermely, 2015). Excessive interconnectedness and structural rigidity significantly increase these vulnerabilities (Valdés et al., 2020). There are good initiatives to measure and nurture adaptive flexibility among organizations (Leoncuk et al, 2019). However, research has not focused on how intentional structural plasticity can mitigate those effects (Pech et al, 2021). From the molecular networks up to the societal ones, the combination of plasticity and rigidity, both structural and functional, creates the evolvability, learning, resilience, and other preferred properties. More rigid structural parts of the network (strong links, network skeleton, strongly connected modules, etc.) are responsible for the main properties of the network and for typical functioning in a "normal" environment. On the other hand, the weak links and more plastic parts of the network dissipate the excessive perturbations, preventing cascading failures in the network. Thanks to structural and functional plasticity, the biochemical and biological networks possess a smooth stability landscape with lots of alternatives for even unprecedented external disruption (Csermely, 2015). In today's increasingly complex environment, resilience and adaptability are essential qualities for individuals and organizations alike (Peddireddy, 2025). Resilience can be modeled allostatically through active inference, where resilient individuals sustain well-being by stabilizing core beliefs, updating situational ones, and minimizing uncertainty through adaptive action or information seeking (Waugh and Sali, 2023). Promoting resilience among employees and fostering a resilient organizational culture are essential strategies for enhancing an organization's ability to adapt and effectively manage change and challenges (Georgescu et al., 2024).

This paper builds on network science and organizational systems theory to explore how resilience and adaptability can be engineered through embedded plasticity–rigidity cycles. The investigation combines

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qualitative case analysis and network modelling, focusing on real industrial cases from IT-telecom manufacturing environments. Using graph-based representations of organizational subnetworks—covering material, human, and process interactions—the study identifies key network motifs, such as bi-fans and bi-parallels, that encode cascading failure dynamics.

The proposed framework demonstrates how right-sized plasticity, introduced at strategic nodes and team levels, can dissipate disruptions before they escalate. By aligning internal network behaviors with the cyclicity of external perturbations, the methodology provides a practical path to designing resilient, adaptive organizations capable of maintaining stability under continuous change.

2. Cascading failure propagation in the organization causes a bulimia state

That real-life cascading failure was observed in an IT-telecom 1st-tier supplier. They managed a usual MRP-driven, stretched, anorexic supply chain for saving on inventory carrying costs. The main customer (large OEM) raised its demands, which caused material shortages and OTD drop. Figure 1 shows the dynamics of failure propagation between the Finished Product (F) and Raw Material (R) echelons. The top picture shows the involved SKUs in the failure propagation from step 1 to step 5, while the bottom picture indicates the inventory value of both F- and R-echelons in million euros. To examine this issue, we will introduce a few concepts and abbreviations: CHI: cool hub in, CHO: cool hub out, CNI: cool node in, CNO: cool node out, DNI: disruptive node in, DNO: disruptive node out, PNI: priority node in, PNO: priority node out, CRE: creative element.

Step 1: To avoid losing production capacity, the organization decided to produce those products for which all the materials were available. That resulted in a tiny deviance of 0.05 MEUR excess stock in three F-SKUs.

Steps 2 and 3: Production of the three not-needed F-SKUs consumed five critical, common raw materials. Those five R-SKUs were nearly all-time on the shortage list in the last quarter, with a value of about 1 MEUR. Step 4: The five cannibalized common R-SKUs blocked the production of the other 12 critical F-SKUs's in a value of about another 1 MEUR. Step 5: But for those 12 blocked F-SKUs, the MRP had already called off the other R-SKUs that were either sitting in the warehouse or steadily flowing in, causing a relative excess in the value of 3 MEUR.

Steps 1 to 5 demonstrate a clear example of cascading failure propagation ignited by a tiny 0.05 MEUR deviance and summing up to an overall deviance of about 5 MEUR (!). At the same time, the customer OTD dropped to a catastrophic 30-40 % level. Consequently, in a highly connected, too lean, anorexia supply network, the errors are firing back-and-forth, causing cascading failure. The inventory profile, both at echelon- and SKU-levels, shows a bulimia-state as we have too much and too little or nothing cases at the same time.

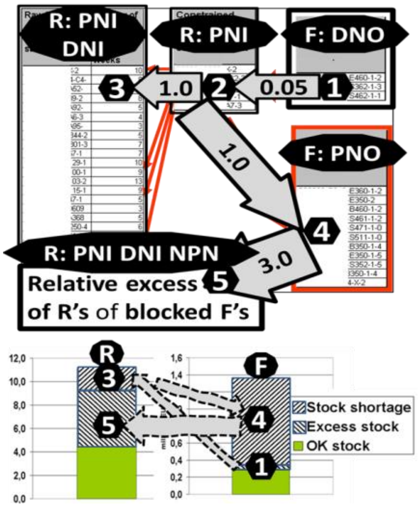

Figure 1: Cascading failure propagation in the material subnetwork of an organization

3. How cascading failure is encoded in the network structure

There are two important motifs characteristic of directed material conversion and transport networks that are widespread in the supply chain networks. Those are the bi-fans and bi-parallels.

Figure 2 shows three typical cases of bi-parallel in supply chain networks. Bi-parallel occurs also between at least 4 nodes where the links from the source node go to two nodes. From those two nodes, either they converge immediately into a sink node, or the convergence may happen several steps later. The bi-parallel formed by a supplier (S), two resource nodes (R), and a finished product node (F) creates a competitive relationship between the R-nodes. That may cause an ambiguous situation at the supplier, especially in the scarcity of resources at its premises. If the supplier is unaware of that bi-parallel pattern, it may fulfil at least one R-node's order (to reach 50 % in OTD) and not deliver the other one, but the real value of its delivery turns out to be zero for its customer. The middle bi-parallel in Figure 2 causes a competitive relationship between the F-nodes, while the bottom elongated bi-parallel creates latent dependency between the two value streams. Obviously, in real networks, we can detect a combination of bi-parallels and multi-phans. Several bi-parallels and bi-fans just among six nodes create a strong competitive relationship between the two shown value streams. Kappel et al. (2020) underline the importance of such a competitive relationship when conceptualising a supply network map structure model.

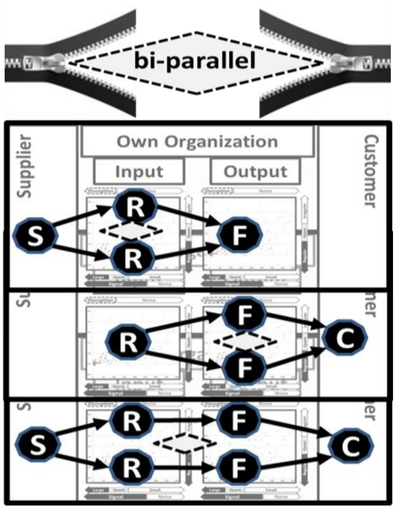

Figure 2: Bi-parallel creates a competitive relationship between two resources, finished products, and value streams

Mature supply chain networks are highly connected with a large number of multi-phans and bi-parallels. The ambiguity and the competition between the players in such mature networks are built into the structure. As a consequence, in such an overconnected, often too lean (anorexia) supply chain network, the errors are firing back-and-forth, causing cascading failure and resulting in a bulimia state.

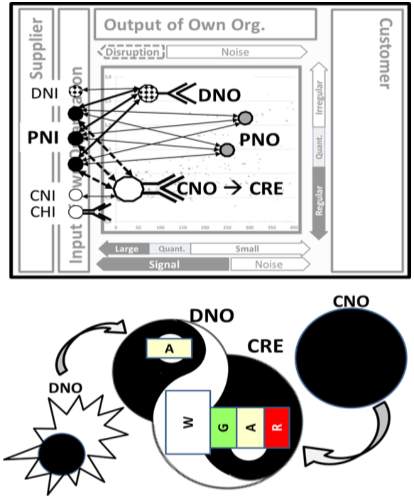

Figure 3: The creative-element motive and the symbiosis of Creative Element (CRE) with Disruptive Node Out (DNO)

The abovementioned network patterns and the behavioral node archetypes of an organization can be determined by our matrix modelling approach (Fekete et al., 2016). In another article (Fekete and Hartványi, 2013), the behavioral node archetypes characterizing the network skeleton of the organization are explained. The essence of it is highlighted in Figure 3. As can be seen in the squeezed CQIG of Figure 3, the highways of cascading failures build the creative element motive: DNO-PNI-PNO-path of a large, finished product item with correlating demands (DNO) linked through several common resources (PNI) to several finished product items of high priority due to their important customers (PNO); and DNO-PNI-CNO-path of DNO linked through PNIs to a large finished product item with non-correlating demands (CNO). Please look at the dynamics of cascading failure among the behavioral node archetypes in Figure 1 compared to Figure 3 as well.

In the heart of the creative element motive lies the creative element node (CRE) formed from the CNO-type finished product by introducing a very sophisticated target inventory profile to it. The well-designed plasticity in the creative element motive is dependent on the interlinked, interdependent nodes (DNO, PNI, PNO, CRE, DNI). The detailed calculation of inventory elements was published in a separate article (Fekete and Hartványi, 2018). Attention is drawn here to how the disruptive node out (DNO) and the creative element (CRE) are formed into a symbiotic unity. The mission of cooling the white inventory of CRE immediately can dissipate the disruptive demand tsunamis entering the organization at DNO and so protect the connected PNOs. While the cooling ice, the white inventory is a meta-level plasticity for the product-cluster, the amber inventory of CRE is a node-level plasticity giving freedom to the supplier/supplier process. In fact, the implementation of the creative element motive utilizes the demand pooling effect (Snyder and Shen, 2011) indirectly, through the high connectedness of the material subnetwork of the organization.

4. Embedded plasticity delivers organizational adaptability and resilience

The aim was to build such an organizational structure and processes where the embedded plasticity and swift transitions ensured the quick adaptation to changing demand situations, while the rigidity in standards and processes guaranteed the consistent, high-quality, and productivity. In a nutshell, the classical supply chain and operations management tools and approaches induce predominantly functional and structural rigidity. Rigidity is good. It guarantees the repeatability, high quality and productivity, the lowest possible waste, the focus, and channeling. On the other hand, the disruptions break the rigid structures and functions. Biological organisms, as billion-year-old successful networks, are the result of an optimal balance between structural and functional flexibility and rigidity. That dynamic balance guarantees the exemplary resilience and adaptability of the viable networks.

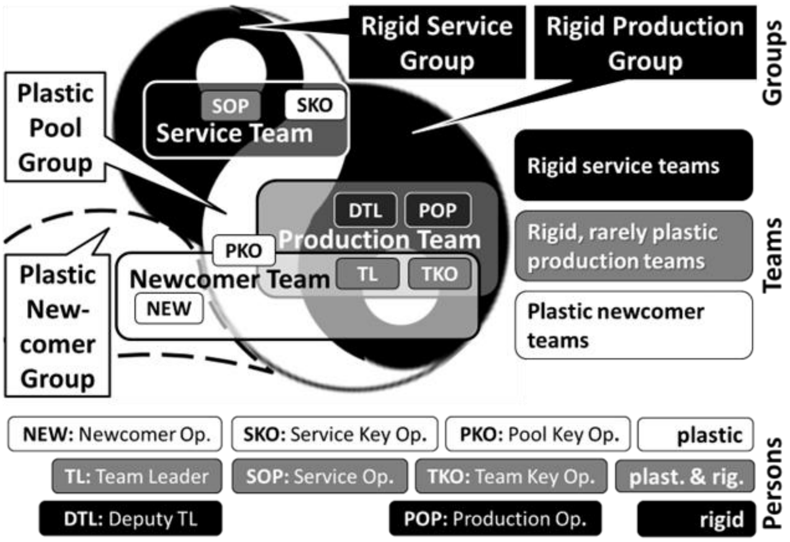

Figure 4: Embedded plasticity at three organizational levels creates resilience and adaptability

The embedded plasticity of a large organization is shown, enabling the organization to anticipate the large disruptive demand perturbations and some of the internal ones. The plastic and/or rigid behaviors occur in different combinations at the different organizational hierarchical levels. A higher-level rigid entity may consist of rigid-, but even plastic- or dual behavioral entities, and vice versa. The dual plastic-and-rigid behavior is separated in space-time, and – as a rule – the rigid behavior dominates the shorter-time plastic behavior.

The rigid Production Group with clear, standard processes lasting for years can guarantee high repeatability, quality, and productivity. But the new product development frequently required radical changes, especially at the introduction of a new product family.

Therefore, the building entities of the rigid Production Group, the production teams (PT), must have dual behavior, i.e., dominantly rigid function and structure – guaranteeing the high quality and productivity, while during learning a new product family, the team turns to plastic mode. Plasticity at the team level ensures quick learning and adaptation since the knowledge is managed at the team level, not at the person level. Later, step-by-step, the team develops the intra-team multiskilling regarding the new product family. Thanks to the several months of experience, the deep product knowledge is acquired and kept by the rigid team members: Production Operators (POP) and Deputy Team Leaders (DTL) who work together safely for years. The Production Team corresponds to the family nucleus or larger family of Dunbar (1993). The safety to PT during learning is created by the plastic-rigid team members – the Team Leader (TL) and the Team Key Operator – who are imported to the learning PT during the ramp-up days. In the PT exporting the TL and TKO, the DTL steps up to TL function, and the vacancy is filled in by a plastic Pool Key Operator (PKO).

With such dynamics, 80-90 % of the production-related persons (POP, DTL) keep their safe, stable small-world (Csermely, 2009) thanks to the small population who sacrifices its stability (TL, TKO, PKO). But those latter persons are remunerated separately, and they prefer working in diverse teams.

Pool Key Operators (PKO) and Service Key Operators (SKO) form the Plastic Pool Group. That group is about 10-30 % of the entire population. PKOs in the Pool Group enable a swift move between two production teams (PKO to PT) within a single minute. Service Key Operators (SKO) can change their function day-by-day, e.g., Monday working as a forklift driver, Tuesday as a production operator, as the demand changes. During the low season, SKOs work for several months in production. In that way, the organization can keep and protect the higher value knowledge in the low season and immediately scale up when needed.

The other plasticity serving group is the Plastic Newcomer Group, consisting of plastic Newcomer Teams (NT). Newcomer Teams were formed by newcomer persons (NEW), ensuring that they could develop together at the same good speed. The development and the safe environment were guaranteed by the dedicated Team Leader (TL) and Team Key Operator (TKO). Please note that a learning production team is supported by 2 persons of different personal profiles – a leader and a teacher/helper.

The fourth group is the Rigid Service Group, consisting of rigid Service Teams covering such functions as quality, factory logistics, maintenance, testing, etc. Ensuring deep knowledge and high performance, those teams also last for years. But the large external perturbation would either break those (e.g., hire and fire) or cause the wasting of valuable capacity. Therefore, the daily fluctuations were anticipated by Plastic Service Key Operators (SKO). Concerning the large seasonal perturbations, some Service Operators (SOP) had to work also for several months as Production Operators.

In sum, understanding the demand patterns of the external world and the main characteristics of our organization's networked structure, we could create a resilient, adaptive organization where:

- Entire teams can move, keeping their internal integrity and getting appropriate help
- 10-20 % of the population – scarifying its stability – can create a safe small world for the majority
- Production Teams work dedicated for weeks
- Production Team migrates to another Product Family if long-term demand requires
- Not needed capacity in Services and Pool is channeled into Production Teams
- Long-term excess capacity is channeled out to the time bank or headcount reduction of temporary workers

In that way, stability-seeking employees find safe stability, while change-tolerating employees enjoy diverse work. More valuable positions are more protected. Added value is respected and remunerated. That guarantees the organization's sustainable healthiness, resilience to disruptions, and continuous adaptation to changes.

5. Conclusions

This study introduces a novel framework that connects organizational network topology with the dynamic mechanisms of resilience through the concept of embedded plasticity–rigidity cycles. While previous research has examined supply chain fragility and cascading failures, this paper uniquely demonstrates how right-sized, localized plasticity – when systematically embedded across organizational subnetworks – can actively dissipate disruptions and prevent systemic breakdowns. The work extends classical network science by identifying specific structural motifs (bi-fans and bi-parallels) responsible for the amplification of cascading failures and by proposing practical design principles to counteract these effects. The concept was empirically validated in its early phase in small, mid-size, and large organizations, resulting in two-digit improvements in key performance indicators, such as COTD, inventory cost, attrition, etc.

A further innovation lies in translating the biological principle of plasticity–rigidity cycling into an organizational engineering context. The concept of dual plastic–rigid team architecture offers a scalable model for maintaining both operational stability and flexibility in complex, human–material–machine networks.

In summary, this work advances a new systems-theoretical foundation for building resilient, self-learning organizations, bridging the gap between network theory and practical supply chain design in the era of highly interconnected, IoT-driven enterprises.

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