**CASE STUDY**

**Resilience in Complex Systems: An**

**Agent-Based Approach**

PART 1

The paper explains that complex systems evolve from other complex systems and as the complexity of the system increases, so does the chance of system failures or service disruptions. It puts forward the points on how to avoid disruptions in a system. Modifications to enable success in a particular environment are being discussed in the paper and to increase the robustness of a complex system, a model has been put forward for research. Fast, proficient, and complete rebuilding of the framework after an interruption is a critical need of framework proprietors A maximum flow algorithm has been used in the model to analyze the available paths and calculate the most efficient paths across the network. The model takes network configurations, the performance of the system, network disruptions, and events as inputs and processes the performance and time measures. The basic objective behind this agent-based model research, if put into simple words, is to measure the resilience, i.e. the ability of the system to survive and recover from critical conditions as may be faced by a complex system, based on the time and performance parameters.

PART 2

The behavior of complex systems after a disruptive event becomes more complex and the possibility of system interruptions or even failure becomes more likely. To avoid such events the paper presents a combination of network analysis and agent-based modeling for the restoration in case of any failure or disruptive scenario. System resilience is one of the key presentation measurements for proprietors and administrators of complex systems. The paper investigates from a CAS (complex adaptive systems) perspective using ABM (agent-based modeling) and thus model events that harm the performance of the entire network or infrastructure. The agent-based model addresses the conditions under which the infrastructure operates before and post the disruption. It leads to a network-flow data output presenting the flow during the restoration effort at specific time intervals. This network-flow data is crucial in determining the loss in system performance at each time interval. It is applied to quantify system resilience by using a function for the speed of system recovery. Various restoration strategies, principles of network theory, and complexity theory have been discussed, applied, and interpreted for their usage to operate and restore the network after a disruption. There are two main objectives of this research process under study. The first is to expand the systems engineering practice related to complex systems by comprehending complex system behavior. The other objective is to provide the stakeholders and the management with a way to better comprehend the complex adaptive nature of the system. CAS provides a system whose structure modifies promoting success in its environment. Complex adaptive systems follow the traits of non-linearity, emergence, adaptiveness, simple rules and, self-organization. The model discussed in the paper applies a maximum flow algorithm to calculate the most efficient paths (one at a time) to push flow across a network. Model inputs are processed using system response, restoration strategies, and recovery mode to result in the measures of resilience in terms of time and performance. These maximum flow data and other time-dependent performance data output from the simulation is used to calculate the resilience metrics of the system. In this study, disruption events result in a complete loss of flow through arcs that are impacted, and perturbation events increase the difficulty of repairing an arc. To calculate the maximum flow, this model uses the shortest augmented path method which is closely related to the Ford Fulkerson algorithm. The paper calculates the resilience and the illustrative model leads to the result.

PART 3

The paper is repetitive as far as the theoretical information is considered. There could have been a more detailed explanation for the practical application of the algorithm under consideration. The scenarios that have been considered provide limited information as there has been less focus in discussing the scenarios individually in a vivid manner. There has been no discussion of the adverse events and how well can this resilience system handle an extreme condition. The research is a little too stringent about the study presented. Considering that everything would fall in line as discussed by the authors would be quite idealistic to consider.

The paper identifies another problem of being based upon a single performance measure and states that the results may vary in case of a different interpretation of resilience or system function. The model in this paper is limited to the study of capacitated networks for which performance is characterized by a max flow solution. As mentioned, prioritizing the work or the repairs based on the criticality and assigning specialized repair agents could be the further enhancement or possibility of the system.

PART 4

The future applications could be identifying the problems as discussed above and providing an extensive study into those areas or scenarios which may have been missed under this study. The model could be extended to other types of network flow problems. Evaluating the different network sizes and topologies could be another extension of the paper where the relationship between resilience metrics and network topology could be explored. Restoration task dependencies and restoration procedures with specialists dependent on the worth of a curve corresponding to how the bend upholds other complex infrastructure systems. In achieving these objectives, the theoretical concepts could be summarized and greater stress could be laid on further elaborating the network flow problems and the various scenarios related to them.