A Supply Chain Disruption Framework for Discrete Event Simulation

Andrew Greasley
Dept. of Engineering Systems & Supply Chain Management
Aston University
Birmingham, UK
e-mail: a.greasley@aston.ac.uk

Daniel Chicksand
Dept. of Management
University of Birmingham
Birmingham, UK
e-mail: d.chicksand@bham.ac.uk

Presenter Bio

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Dr Andrew Greasley is a Lecturer in supply chain analytics and modelling at the Department of Engineering Systems and Supply Chain Management (ESSCM). He has extensive experience of the application of discrete-event simulation modelling in industry in the supply chain area. His current research interests include the use of Hybrid Modelling - the combined use of discrete-event simulation and other analytical techniques such as machine learning and the use of a simulation methodology to test supply chain design resilience to external disruptions. He has over 140 publications including a number of 3* and 4* journal articles as the main author. He has supervised to completion 6 PhD, DBA and MPhil students and is a member of the editorial board for the Journal of Manufacturing Technology Management.

Introduction

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- Discrete Event Simulation (DES) is usually considered a stand-alone software tool that is used to assess the steady-state performance of manufacturing and service processes.
- However recently it has been used to undertake the analysis of the effect of transient disruptive events in a variety of supply chain settings.
- The purpose of this article is to review existing work on the use of DES to analyse disruptive events in a supply chain context.
- From this review a framework has been developed that identifies the key attributes of the combination of disruptive events, the supply chain configuration and supply chain resilience factors that lead to supply chain performance.
- By identifying key attributes associated with supply chain disruptions, this framework will provide a basis on which to develop a DES model of disruption events and measure their effect on supply chain performance.

Review of the use of DES to analyse disruptive events in the supply chain

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The review examines supply chain disruption in terms of the following:

- The nature of the disruption event itself,
- the supply chain configuration,
- the supply chain features and relationships that lead to a level of supply chain resilience
- supply chain performance metrics used to assess the response to disruption events.

Disruption Events

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In terms of DES models of the **source** of risks leading to disruption events, Rios (2017) models a combination of the following:

- internal firm risks such as machine breakdowns and internal quality problems
- internal supply chain risks such as delays in contracting with suppliers and raw material shortage
- external supply chain risks such as earthquakes and computer Denial of Service events

In terms of the **characteristic** of a disruption event, MacDonald et al. (2018) provide the following generic attributes:

- length (number of time periods over which the shock manifests itself),
- magnitude (the size of the initial negative impact, and the extent to which the shock subsequently reduces supply chain performance over time,
- shape (the way in which the disruption manifests itself – a step function, a ramp etc.)
- number (number and frequency of disruption that occur during a given event).

Supply Chain Configuration

In terms of the supply chain configuration, this can be described by the use of a supply chain map such as in Moosavi and Hosseini (2021).

Christopher (2016) emphasises the importance of managing the critical nodes and links in the supply chain.

MacCarthy et al. (2022) define the minimum information for a supply chain map as nodes, the participants of the supply chain and links, how the participants are connected.

The primary flows modelled by DES in the review are material flows, such as in (Ivanov, 2019) but information and financial flows could also be modelled.

Supply Chain Resilience Factors

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In terms of factors that impact the resilience of the supply chain to disruption events, Waters (2011) distinguishes between the physical features of a supply chain such as its design matched to demand, shape, stocks, capacity, agility/flexibility and supply chain relationships such as collaboration and visibility.

In addition MacDonald et al. (2018) model the connectivity relationship between supply chain actors.

Supply Chain Performance

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In terms of measuring supply chain performance when submitted to disruption events, MacDonald et al. (2013) define performance measures of speed of recovery, financial cost and customer impact.

Borgos and Ivanov (2021) define performance measures of profit, revenue, costs, delivery time, inventory levels, order backlog (orders lacking products) and late orders.

As well as direct supply chain design and operations measures most studies aim to provide a measure of supply chain resilience which is defined by Melynk et al. (2014) as requiring two capacities of resistance (ability to delay a disruption and reduce the impact once the disruption occurs) and recovery (ability to recover from a disruption).

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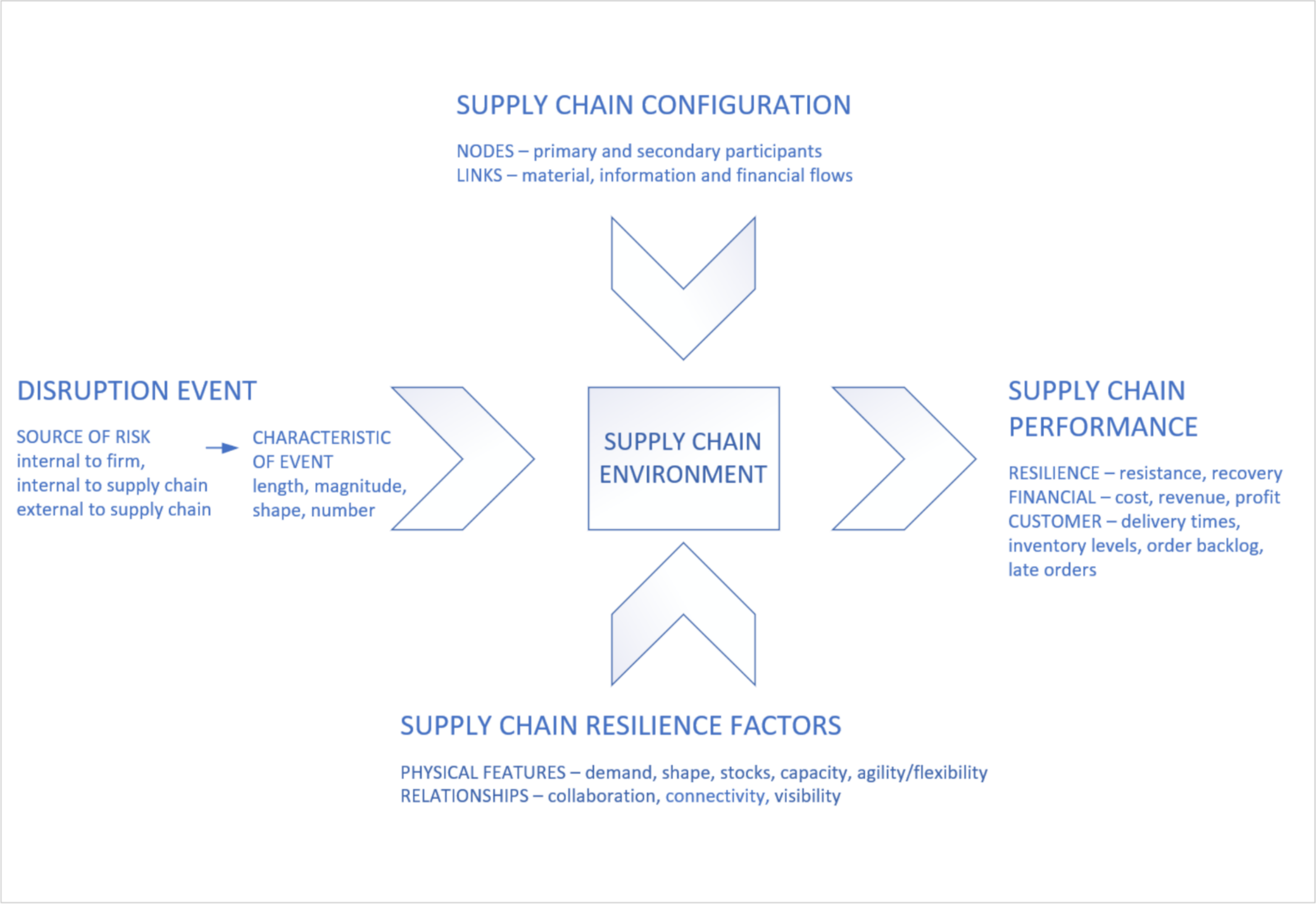

Deploying the framework for DES

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If we wish to model a disruption event that has been derived from a source of risk, we will need to operationalise this event by characteristics of its length, magnitude, shape and number.

We will require high level supply chain and supply network maps to be decomposed to the process map level to enable modelling of material flows by the DES.

The current resilience of the supply chain can be assessed for a range of disruption events. In addition, the use of simulation scenarios incorporating either physical or relationship design changes can be employed.

Supply chain performance can be expressed using traditional DES measures such as financial and customer-oriented metrics. These can be reported by simulating over multiple replications to provide confidence intervals around average performance across these metrics. In terms of the concept of resilience this metric will require operationalising. Resilience may also require a time-based analysis to identify the nature of the recovery from the disruption event in terms of its magnitude and length.

Summary

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The framework identifies the elements that need to be incorporated into the DES model and provides a roadmap for determining suitable methods for operationalising these elements in the DES.

However, further work is needed to meet the challenge of modelling supply chain disruption using DES.

For example, the representation of rare disruption events, the impact of the ripple effect, supply chain mapping decomposition at the conceptual modelling stage and time-series interpretation of disruption events at the experimentation stage.