An optimisation model for Sustainable Supply Chains following the European Union Emissions Trading Scheme

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Abstract

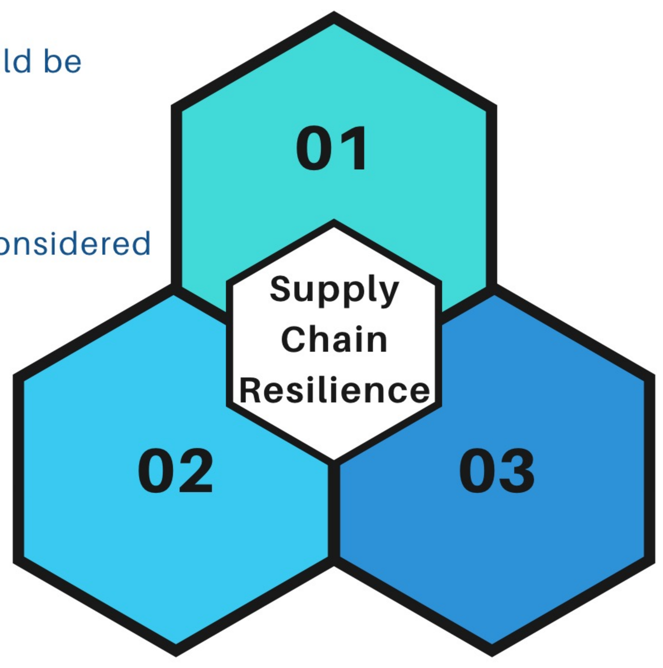
Environmental and resilience are currently vital concerns when managing Supply Chains (SC). Doing so in a competitive setting, with diverse stakeholders' perspectives and dealing with unforeseen disruptive events is challenging. Today, this is a reality where, with the actual COVID-19 pandemic, supply chains face reduced demand and stoppages at different levels, calling for the urgent need to invest in designing and planning resilient SC. But resilience must not leave apart other vital goals as is the environmental goal, which nowadays requires special attention. This is especially critical in the process industries where environmental concerns are often at stake. We address this challenge in the current work by representing the cost associated with CO2 emissions, considering the EU emissions trading system (EU ETS). This system makes the cost associated with emissions a variable value attributed by the market. A Mixed Integer Linear Programming model (MILP) is here presented which allows to understand the supply chain resilience of different supply chain structures. This is done with the objective of maximising the Expected Net Present Value (ENPV) while facing disruptions, and the presence of uncertainty in demand is considered. The results show that our model can help decision-makers to create resilient SC with good environmental behaviour and without compromising financial results.

Introduction

I. What is the first thing we think of when dealing with SC Resilience?

II. Why SC Resilience should be treated as a field of SC Managment?

III. Everything should be considered in SC Resilience?



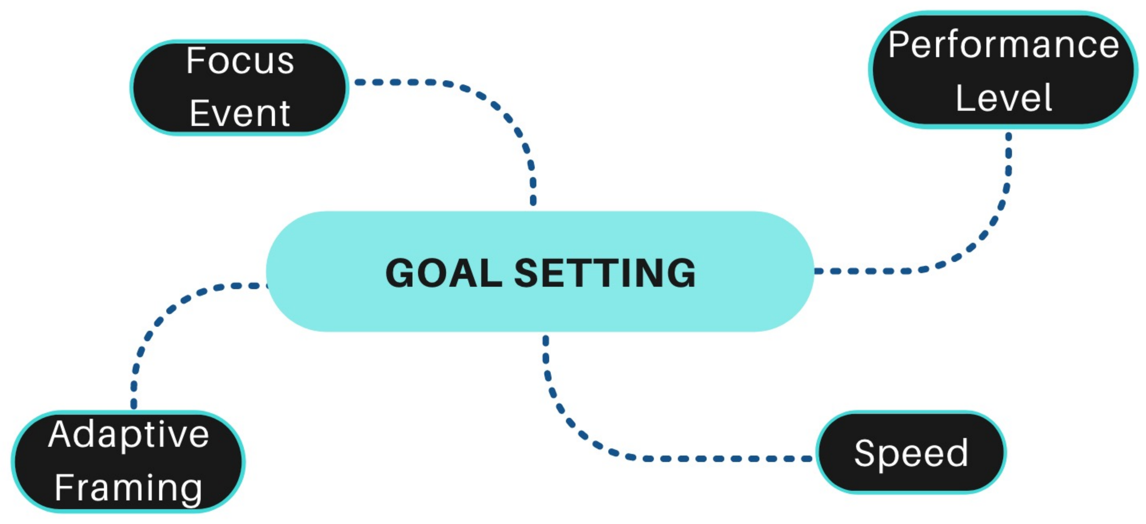
01 Catastrophic Events

02 Low probability

03 Endanger continuity

"A resilient supply chain should be able to prepare, respond and recover from disturbances and afterwards maintain a positive steady state operation in an acceptable cost and time."

Pires Ribeiro, J., & Barbosa-Povoa, A. (2018). Supply Chain Resilience: Definitions and quantitative modelling approaches – A literature review. Computers & Industrial Engineering, 115(January 2018), 109-122. https://doi.org/10.1016/j.cie.2017.11.006



An opportunity for green resilient SC

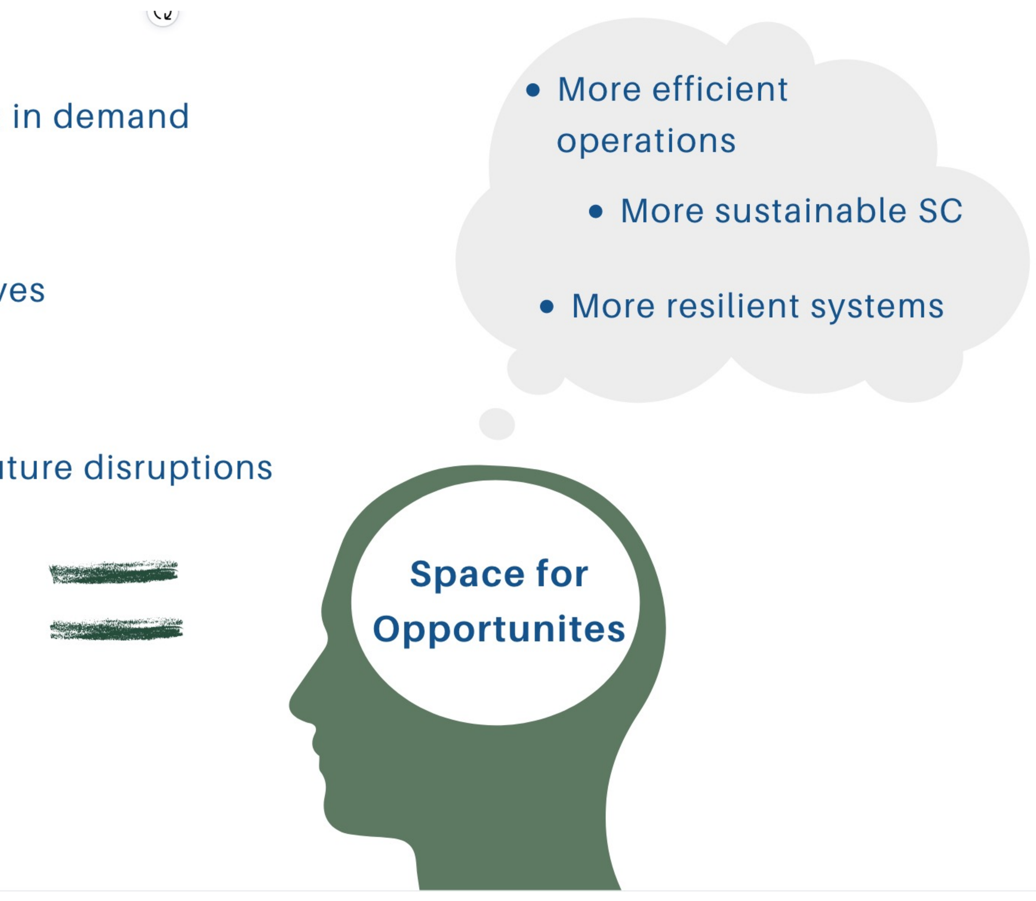
I. Temporary stoppages, reduction in demand

+

II. Changes in production's objectives

+

III. Concerns on consequences of future disruptions



I. EPS or ReCiPe allow for monetization of impacts

II. Drawbacks: Constant in time and dependent on the method and data available

III. CO2 as a commodity, easy implementation, interpretation. Ease the task of uncertainty concerns.

Our approach towards an optimization model for Green Resilient SC

- Strategic and Tactical decision level
- 15 years timespan, 3 periods of 5 years

Model Objective Function

$$\max \text{ENPV} = \sum pb_s \times NPV_s$$

CO2 monetization

$$\text{Transp}CO_2 = \sum_t (CO_2Cost_t \cdot (\sum_{s,v,w,p,t} (\text{QPL}_{v,w,p,s,t} \cdot \text{FIPL}_{v,w} \cdot \text{envfactorforward}) + \sum_{s,v,w,p,t} (\text{QNC}_{v,w,p,s,t} \cdot \text{FIPL}_{v,w} \cdot \text{envfactorreverse}) + \sum_{s,v,w,p,t} (\text{QEL}_{v,w,p,s,t} \text{FIPL}_{v,w} \cdot \text{envfactorreverse})))$$

$$CO_2\text{eachp}_p = \sum_{s,v,w,t} (\text{QPL}_{v,w,p,s,t} \cdot CO_2\text{prod}_p) + \sum_{s,v,w,t} (\text{QNC}_{v,w,p,s,t} \cdot CO_2\text{prod}_p) + \sum_{s,v,w,t} (\text{QEL}_{v,w,p,s,t} \cdot CO_2\text{prod}_p)$$

Uncertainty

A scenario tree is implemented. Demand can assume three directions each time period: Pessimistic, Realistic and Optimistic.

The case study is implemented into 4 operational conditions, representative of 3 disruptive scenarios and one reference case where no disruptions occurs.

Three scenarios for the evolution of CO2 emissions cost.

Table 1: Expected Net Present Value (ENPV) for all scenarios and disruptions

Case A - Forward Supply Chain				Case E - Closed-Loop Supply Chain			
	CO_2 emissions cost scenarios				*CO_2 emissions cost scenarios*		
ENPV (€)	**Stable**	**Up & Up**	**Up & Down**	**ENPV (€)**	**Stable**	**Up & Up**	**Up & Down**
No disruption	1,74E+07	1,32E+07	1,42E+07	No disruption	1,86E+07	1,51E+07	1,61E+07
Disruption 1	1,49E+07	0,99E+07	1,12E+07	Disruption 1	1,74E+07	1,33E+07	1,42E+07
Disruption 2	1,40E+07	0,89E+07	1,03E+07	Disruption 2	1,72E+07	1,35E+07	1,41E+07
Disruption 3	1,74E+07	1,32E+07	1,42E+07	Disruption 3	1,77E+07	1,43E+07	1,52E+07

Table 2: Total CO_2 cost for all scenarios and disruptions

Case A - Forward Supply Chain				Case E - Closed-Loop Supply Chain			
	CO_2 emissions cost scenarios				*CO_2 emissions cost scenarios*		
CO_2 Prod (€)	**Stable**	**Up & Up**	**Up & Down**	**CO_2 Prod (€)**	**Stable**	**Up & Up**	**Up & Down**
No disruption	1,86E+06	6,15E+06	5,13E+06	No disruption	1,46E+06	5,38E+06	4,50E+06
Disruption 1	1,91E+06	8,07E+06	6,54E+06	Disruption 1	1,54E+06	5,51E+06	4,66E+06
Disruption 2	1,90E+06	8,03E+06	6,51+06	Disruption 2	1,50E+06	5,53E+06	4,86E+06
Disruption 3	1,86E+06	6,16E+06	5,13E+06	Disruption 3	1,41E+06	5,21E+06	4,26E+06

- Closed-loop SC show better economic performance under disruptive events and in steady state conditions.
- Circular economy principles add flexibility to the SC and allow for better responsiveness
- The monetization of environmental impacts by corresponding it to the European Union Emissions Trading Scheme seems to be a sound and replicable approach.
- Meeting demand appears to be a relevant objective for SC and should be taken into consideration when discussion SC Resilience.

- Further development of the model, with increased applied case studies and uncertainty approaches.
- Provide strategies for SC to become better prepared for the things we cannot precisely predict
- Compare these results with other monetization approaches

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