Assessing Supply Chain Vulnerabilities on Critical Infrastructure Disruptions: a multilevel modelling approach

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ABSTRACT: Disruptions of Critical Infrastructure systems (CI) have a significant impact on citizens' well-being and daily life, national economic growth and development. These effects are magnified due to the (inter)dependencies between CI themselves and disruption propagation to Key Resources Supply Chains (KRSC; e.g. food).The paper focuses on assessing the impact of CI disruptions to KRSC, the economic losses caused and the potential effectiveness of different strategies to improve KRSC resilience. As no single modelling approach applied to both KRSC and CIs networks could fully meet the objectives of this work, as documented by literature review, an opportunity to build a multi-level model was spotted. A case application is discussed with regard to the Fast Moving Consumer Goods (FMCG) sector in Italy.

1 INTRODUCTION

Critical Infrastructures (CIs) may be defined as those assets or systems that are critical for the maintenance of vital societal functions, providing services that society and citizens rely on in their daily life [1]. Infrastructure services are supplied through networks and assets including electricity grids, roads and communication networks. Disruptions of these CIs have a significant impact not only on citizens' well-being and daily life but also on national economic growth and development. These effects are magnified due to the (inter)dependencies between CIs themselves and disruption propagation to Key Resources Supply Chains (KRSC; e.g. food). In fact, some studies on risks that affect Supply Chains (SC) found that most of the considered risk categories directly or indirectly involve CIs.

Trying to achieve a safer society, one of the emerging issues faced by the most advanced regions is the service continuity of some fundamental services. The main focus of this work is to analyse the impact of CI disruptions to KRSC, the economic losses caused and the effectiveness of different strategies to improve KRSC resilience. For evaluating resilience strategies, consequences (losses) of CI disruptions need to be quantified and this of course requires understanding about the whole propagation mechanism.

In the first step we conducted a literature analysis on the modelling techniques applied to both SC and CIs networks, identifying their main advantages and drawbacks. As no single approach could fully meet the objectives of this work, an opportunity to build a multi-level model was spotted. The proposed multi-level model combines *System Dynamics* method and *Discrete Event Simulation.* It was applied on the case of the Fast Moving Consumer Goods (FMCG) sector, which is one of the most relevant supply chain in the Italian economic context (considering its contribution to the growth of the GDP).

2 THEORETICAL AND METHODOLOGICAL BACKGROUND

2.1 *SC Risks and Resilience*

In general, resilience is understood as the ability of a system to bounce back (return to its original state) from large-scale disruptions [2] [3]. Resilience of a SC can be understood as the ability of a global supply chain to reorganize and deliver its core function continually, despite the impact of external and internal shocks to the system [4]. Sheffi [5] defined resilience as the capacity to be better positioned than competitors to deal with – and even to gain advantage from – disruptions.

SC related risks are classified as [6] [7]:

- *Environmental* – risks caused by natural disasters, extreme weather and pandemics;
- *Geopolitical* – geopolitical upheavals, conflicts, organized crime, corruption;
- *Economical* – currency fluctuations, commodity price volatility, dependency from external production, sudden demand change, export/import restrictions;

- *SC Vital Services* – information and communication disruptions, transport and infrastructure failures.

According to Tang [8] SC issues can be essentially classified into two major groups: supply management and demand management. *Supply management issues* include supplier selection, supplier relationship, supply planning, transportation and logistics, while *Demand Management issues* include new product introduction, product line management, demand planning, product pricing and promotion planning. In his paper [8] he describes nine different robust SC strategies that aim to improve a firm's capability to manage supply and/or demand better under normal circumstances and to enhance a firm's capability to sustain its operations when a major disruption hits. The majority of these best practices deal with the availability of vital services, either as primary subject of intervention or as subsequent object associated to other categories of risks. We can say that Vital Services represent the most important risk category and their improvements enable to protect SC from either CIs disruptions or all the other risk categories closely linked to them. The main focus of supply chain managers is also centred on the Vital Services for the SC [6] because their influence is unclear in terms of impact that they could have, not only in industrial production but also in public services and in movement of goods and people. Still, there is not a wide bibliography about this very significant dependency and relationship between SC and Vital Services (especially with focus on CIs) in quantitative terms.

Rice and Caniato [9] identified *flexibility* and *redundancy* as two methods holding the greatest potential for creating SC resilience. *Flexibility* entails creating capabilities within the organization to redeploy some existing and previously committed capacities from one area to another (to make up for lost or delayed capacity) [9]. *Redundancy*, by contrast, is the additional capacity that would be used to replace the capacity loss caused by a disruption [9]. Both approaches require investments in infrastructure and resources prior to the point of need.

When evaluating effectiveness of resilience strategies applied to specific parts of the SC, we also consider different levels of resilience capacity (Section 4.2), achievable either though flexibility or redundancy, or most typically a mixture.

2.2 *Approaches to SC and CI Modelling and Simulation*

In this chapter we analyse the main approaches used for SC and CI modelling and simulation with a particular focus on the resilience aspect.

The three main simulation approaches in the SC context are: Discrete Event Simulation, System Dynamics and Agent Based Modelling.

Discrete Event Simulation (DES) method models the system as a process, i.e. sequence of operations being performed over entities. The operations include delays, services by various resources, choosing the process branch, splitting, combining, etc. As long as entities compete for resources and can be delayed, queues are present in virtually all discrete event models. *Entities* are the actors in the simulation. Entity is any object or component in the system which requires explicit representation in the model (e.g. clients, physical and electronic documents, parts, products, computer transactions, vehicles, projects, ideas). *Resources* are objects that provide services to entities (e.g. staff, doctors, operators, workers, servers, CPUs, equipment, transport). Service times and entity arrival times are usually stochastic, drawn from a probability distribution, thus discrete event models are stochastic themselves.

System Dynamics (SD) "is a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems... It is also a rigorous modelling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations." [10]. One of the main concepts of SD is the capacity of this methodology to catch the complexity of the problems [10]. In general SD is associated to the use in long-term, strategic models, and it assumes high level of object aggregation. Stocks (the accumulation of resources in a system), flows (the rates of change that alter those resources), and feedback are the central concepts in this methodology. Simulations based on this methodology can provide insight into important causes and effects, which can lead to a better understanding of the dynamic and evolutionary behaviour of a system.

Agent Based Modelling (ABM) is much newer than system dynamics or discrete event modelling. In fact, ABM was largely an academic topic until simulation practitioners began using it in 2002-2003 [11]. It was triggered by:

- desire to gain deeper insights into the systems which traditional modelling approaches don't capture well;
- advances in modelling technology from computer science, including object oriented modelling, UML, and state charts;
- the rapid growth of CPU power and memory – agent based models are more demanding than system dynamics and discrete event models.

It can be said that ABM fits well in situations where the modeller doesn't know how the system behaves, what its key variables and their dependencies might be, but has some insights into how system's objects behave individually. In this conditions, the modeller can start building the model by identifying the objects (agents) and defining their behaviours. Then it may be necessary to connect the agents (there are also agent based models where agents don't interact), let them interact, and put them in an environment which has its own dynamics. The global behaviour of the system then emerges out of (numerous) concurrent individual behaviours.

When it comes to Critical Infrastructures, thanks to Ouyang's [12] review on modelling and simulation of interdependent infrastructure systems, we can classify the approaches of the studies into six types:

- **Empirical approaches** – analyse CI interdependencies according to historical accident or disaster data and expertise experience;
- **Agent based approaches** – a bottom-up method that assumes the complex behaviour or phenomenon emerge from many individual simple interactions of autonomous agents;
- **System dynamics (SD)** based approaches – take a top-down method to manage and analyse complex adaptive systems involving interdependencies;
- **Economic theory** based approaches – analyse CI interdependencies through models of economic interdependencies;
- **Network based approaches** – model single CIs by networks and describe interdependencies by inter-links represents the physic and relational connections among them;
- **Others**

2.3 *Use of SC Modelling in literature*

In this paragraph we shortly analyse how the use of the most popular techniques for the SC modelling have changed over time in terms of diffusion and type of problems treated. Our literature search focused on the simulation approaches applied to analyse SC Resilience.

The search was performed through ScienceDirect, Scopus and Google Scholar looking for papers dealing with classification of simulation methods in SC context, and with a particular focus on the resilience theme. The search used the string 'supply chain' combined with the terms 'resilience', 'modelling' and 'simulation'. The search returned about 140 articles dealing with applications of the modelling methods in real SC cases during the last 20 years, which we further analysed (abstracts and/or full articles). Among the identified papers two important literature reviews on SC modelling approaches analysed application of specific techniques.

With a very stringent approach, Tako and Robinson [13] analysed 127 peer reviewed journal papers published between 1996 and 2006. Their work was based on the belief that SD was mostly used to model problems at a strategic level, whereas DES was used at an operational/tactical level. The aim of the review was to test if this hypothesis was true. The paper explored the frequency of application of DES and SD as modelling tools for decision support systems (DSS) for LSCM (Logistic and SC Management) by looking at the nature and level of issues modelled. The findings suggest that DES has been used more frequently to model SC, with the exception of the bull-whip effect which is mostly modelled using SD. The study concluded that in terms of the level of decision making (strategic or operational/tactical) there is no difference in the use of either DES or SD.

Owen et al. [14] repeated the same research in 2010 using a different taxonomy, i.e. the authors decided to divide the approaches according to three different methodologies: DES, SD and ABM. A total of 439 scholar (peer-reviewed) papers (out of 517 search hits) were identified and then a sample of 100 papers was selected, reviewed and classified [14]. This review revealed that both SD and ABM have been equally used to address strategic and planning problems. DES, on contrary, is more heavily weighted towards planning problem types and is also the only approach to have been used to address operational problems.

We can observe how the SC modelling applications in the period 2007-2010 influenced the picture as a whole. In addition, the results of our search shown examples underlining how the use of SD in the last years mostly focused on the strategic view (see e.g. [15] [16]).

The bibliography dealing with simulation approaches applied to SC Resilience theme is not wide. Our literature search found 8 articles, all written in the last three years. Small number of papers centred on simulation technique approach to study SC resilience and their recent date of publications indicate the novelty of this approach to the field. SD modelling method is the most used to face the Resilience of the SC (4 times, compared to single cases of DES and ABM), but again all of the authors build their model using single method, with all the limitations emphasized before.

3 A MULTI-LEVEL MODELLING APPROACH

As suggested by literature review, the state-of-the-art of simulation is the use of multi-method approach. That happens because systems, in particular complex systems, could be best modelled with not just a single method but combining them creating a hybrid model. Similarly, as no single modelling approach could fully meet the objectives of this work, we resorted to building a multi-level model. We can represent our model as divided in three levels.

3.1 *The first level: Critical service Supply Chain*

In the first level, we can find the Energy Critical Infrastructures and their sub-models of supply. The level was built using System Dynamics methodology (Fig. 1) and is composed by the following CIs:

– Sub-model of fuel supply through pipeline;
– Sub-model of fuel supply through road and rail;
– Sub-model of gas supply through pipeline;
– Sub-model of water supply through pipeline;
– Sub-model of power supply.

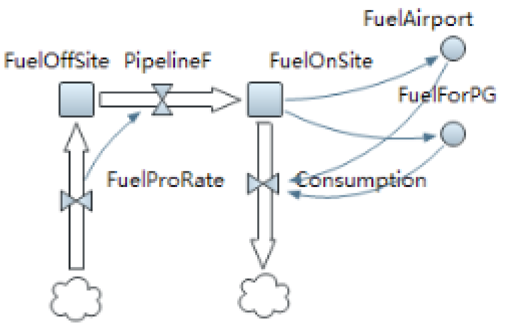

Figure 1. Example: Sub-model of fuel supply through pipeline

3.2 *The second level: service and resource availability*

The second level models the availability of services supplied by CIs and of other resources used either for the FMCGs SC or for the first level needs. This level was built with System Dynamics methodology (Fig. 2).

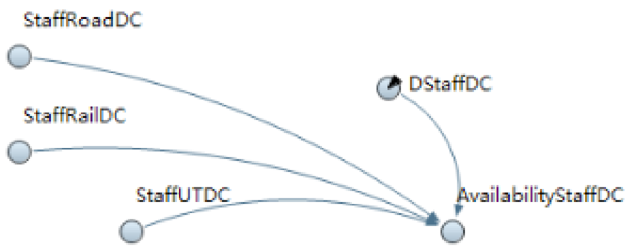

Figure 2. Model of Staff Availability at Distribution Centres (DC)

3.3 *The third level: KRSC model*

The third level represents the KRSC model, i.e. the FMCGs SC in our case application. It embodies the Internal Production and Logistic phases, the Import SC and the connection between Distribution Centres (DC) and Retailers. This level is built with a multi-method approach. Indeed the initial part of the SC, in which we can find the flows of the internal and external productions (import rate), follows a *System Dynamics* approach. The part of the SC between the DC and Retailers is modelled with *Discrete Event Modelling* instead. The rational for adopting a multi-method approach is that, on one hand it assures a continuous systemic view of the dependencies from the upper levels, while, on the other hand, Discrete Event method better models the capacity and lead times involved in the distribution and delivery processes.

3.4 *Multi-level model hypotheses*

There are some key hypotheses at the basis of the overall modelling approach:

– The model is isolated from outer environment, which means it can only be affected by inner entities (concepts);
– The functional dependencies between CIs and other services is linear. For example, if 100 ton per day [t/d] of fuel is required to support 100% of generation capacity of a power plant, then 80 t/d of fuel supports 80% of the same capacity;
– The amount of FMCG demand is constant;
– Staff availability only affects goods distribution rate and purchasing rate. Since most of the processes included in the model are fully automatized, staff might not be the bottleneck, thus the effect of staff availability can be neglected in those processes.

Coherently with the abovementioned hypotheses, the multi-level model is able to implement interdependencies between CIs. In our specific application, power generation plants and airports need fuel and/or natural gas. Furthermore, fuel is also used by road transportation. On the other side, power is used for fuel and gas production, urban train functioning, supply chain, water supply, road, rail and air transportation. Staff availability is influenced by the status of urban transport system, road, and railway systems. As for the FMCG sector, the production rate is influenced by power and fuel, while the distribution process is affected by staff availability and three kinds of transportation: road, railway and air. Finally, the purchasing rate is influenced by staff availability and power.

4 FAST MOVING CONSUMER GOODS (FMCG) SUPPLY CHAIN

FMCG supply chain deals with the delivery of non-durable goods, such as drinks and grocery items. At the consumer side, the main characteristics of these products are: high frequency purchase, low prices and low involvement. Looking from the producers and distributors side, the main characteristics of these products are low contribution margin, extensive distribution network and high stock turnover. A key issue in managing this type of supply chains is the perishability of the products and thus the lead-time that these goods can undergo.

The model of the FMCG supply chain is made of the following elements (Fig. 3):

– *Producers* – can be classified considering both the firm dimensions (Big vs. Small and Medium producers) and the typology of products (Food vs. Health & Care);
– *Distribution Centres (DC)* – retailers' facilities for temporary storage with the main function of receiving daily orders from the retailers and deliver

them to the purchasing organization that will buy the products required (e.g. warehouse or other specialised buildings);
- *Retailers* – subjects who receive goods in large quantities from the Distribution Centre, and then sell smaller quantities to the consumer for a profit (e.g. Supermarket);
- *Clients* – persons who pay for the products intended for private consumption.

The model of FMCG Supply Chain in Anylogic is presented in Figure 7.

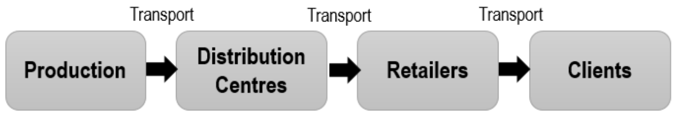

Figure 3. FMCG Supply Chain

In our analysis, we considered that the lead-times between the Distribution Centre and the final Retailers for different product categories vary between 7 and 12 days. These figures represent the expected mean lead-time values assured by logistics service providers for the Italian FMCG sector.

5 SIMULATION CAMPAIGNS

5.1 *Resilience strategies*

In this paragraph, the strategies applied to the FMCG SC to reduce the impact of disruptions occurring at the first level CI – namely ,Gas, Fuel, Power Generated and Water – are presented.

In face of a disruption, resilience capabilities can exploited at three levels of the SC. The downstream segment, which includes the part of SC between DC and Retailers, the midstream segment dealing with the logistics from Producers to DC, and the upstream segment, dealing with production planning and management within the Producers. We assume that the part of SC dealing with import is not modifiable in the short range, thus its contribution to SC resilience is negligible.

The strategies represent the package of actions that SC Managers and other company managers can actuate in order to sustain the business continuity of a specific segment of the SC. In particular, four basic strategies were identified and investigated:

- **Strategy 1**, exploiting resilience capabilities located in the downstream segment; it is used to sustain business continuity of DC and Retailers only;
- **Strategy 2,** exploiting resilience capabilities located in the midstream and downstream segments. This strategy includes all the capabilities of Strategy 1;
- **Strategy 3,** includes all the capabilities of Strategy 2 and embodies the exploitation of additional capabilities needed to support transport services from Producers' facilities to DC (e.g., fuel tanks to avoid fuel disruptions);
- **Strategy 4,** expands on resilience capabilities to overcome disruptions affecting Producers' production facilities, in addition to the capabilities activated under Strategy 3.

5.2 *Resilience capacities under different strategies*

A further dimension covered by the simulation campaign deals with the capacity level (or strength) of the resilience capabilities activated under different strategies. In particular, three levels of resilience capacity were considered for each strategy:

- Resilience capacity of 20% – i.e. a capacity able to mitigate up to 20% reduction of critical services due to some CI disruption;
- Resilience capacity of 50% – i.e. a capacity able to mitigate up to 50% reduction of critical services due to some CI disruption;
- Resilience capacity of 90% – i.e. a capacity able to mitigate up to 90% reduction of critical services due to some CI disruption.

Consequently, a 20% reduction of critical services at some point of the FMCG SC is the minimum "trigger level" for the activation of the available strategies and capacities along the entire SC.

5.3 *Data specification and collection*

The initial set of data were collected from Eurostat (Directorate-General of the European Commission), namely:

- European shares of electricity, gas and water supply;
- European shares of railway, road and pipeline transportation;
- Input-output data related to:
  - Manufacture of coke, refined petroleum products and nuclear fuels;
  - Electricity, Gas, Steam and hot water supply;
  - Land transport and transport via pipelines;
  - Air transport;
- Total turnover per single infrastructure sectors in Italy;
- Input value of single infrastructure sectors to the Fast Moving Consumer Goods supply chain in Italy;
- Consumption (per year) of Electricity, Fuel, Gas and Water by DC, Retailers and Transport infrastructures;
- Flow rates (per year) of Fuel, Gas, Water and Goods through pipelines and/or roads, rails and air;
- Production and procurement rates (per year) in FMCG supply chain in Italy;

– Desired staff at different segments of the FMCG supply chain.

From Eurostat data, the convert factors for each CIs were also estimated, i.e. coefficients to transform physical units, such as litre gas per year, kg fuel per year, electricity per year, litre water per year, into a common unit of ***€ per year***. This computational approach enabled the merging of sub-models and the definition of a unique economic indicator to measure the performance of the entire system-of-systems in terms of annual turnover.

5.4 *Simulation plan*

Four simple crisis scenarios were defined, dealing with the disruption of each one of the CIs at the first level:

– 50% Gas Disruption for 5 Days;
– 50% Fuel Disruption for 5 Days;
– 50% Power Generation Disruption for 5 Days;
– 50% Water Disruption for 5 Days.

For each disruption scenario the four strategies were applied independently at different capacity levels (20%, 50%, and 90%), thus generating 48 different crisis scenarios to be simulated. The reference scenario (baseline), corresponding to the full availability of all the services and CIs, were finally added to complete the simulation campaign.

Due to the presence of stochastic processes in the FMCG SC, introduced by triangular distributions of lead-times, 20 replications covering a time window of 100 day were used to estimate the average performance values of each scenario.

6 SIMULATION RESULTS

6.1 *Reference scenario*

Under standard demand and nominal operational conditions, the Italian FMCG supply chain generates an average daily turnover of 37649 M€, according to our model (baseline). Referring to the contribution of FMCG sector to the Italian GDP in the years 2008-2012 [17] the absolute percentage error ranges from -2.3% to +2.9%, with the MAPE of -0.2%.

6.2 *Full disruption (worst case) scenarios*

The aim of the second scenario simulated is to assess the impact on the FMCG supply chain of a disruption occurring to each of the CIs belonging to the first level, where 50% of service is lost for 5 consecutive days. Results are shown in Table 1. The Δ Turnover is referred to the reference scenario (baseline = 37649 M€).

Table 1. Average turnover of 100 days with 5 days of Energy CIs Disruptions

Disrupted service	**Gas**	**Fuel**	**Water**	**PG**
Avg. turnover for 100 days [M€]	33070	33508	33495	34376
ΔTurnover [M€]	4579	4141	4154	3273

It can be seen that the CI with the heaviest impact on the FMCG SC is Gas, causing the major amount of turnover loss. On the contrary, PG presents the less severe consequences. Finally, Fuel and Water unavailability have the same impact on the economic performance of the FMCG SC.

6.3 *Severe disruption of CIs with application of resilience strategies and different capacity levels within the FMCG SC*

In this final step, the application of the four strategies with different resilience capacities (20%, 50% and 90%) on SC of FMCGs are simulated to estimate the expected benefits. Similarly to the previous step, each simulation run lasted 100 days with a 50% unavailability of a single critical service during 5 consecutive days; the results related to a disruption of the gas infrastructure are depicted in Figures 4-6.

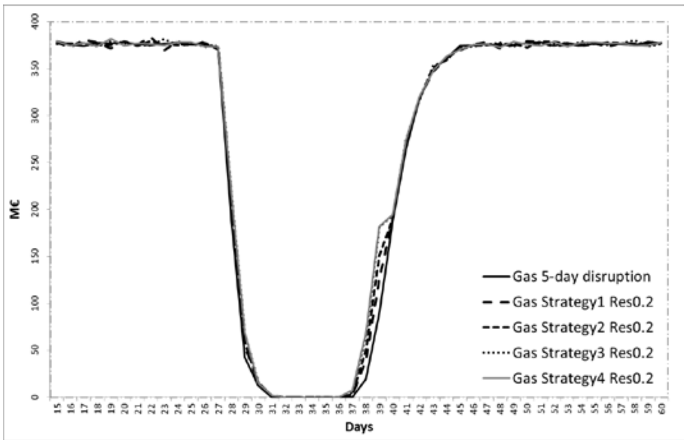

Figure 4. Average daily turnover with 5-day Gas disruption and 20% resilience capacity

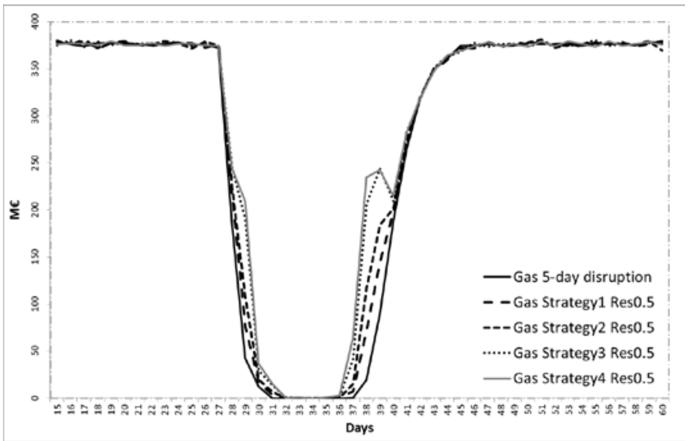

Figure 5. Average daily turnover with 5-day Gas disruption and 50% resilience capacity

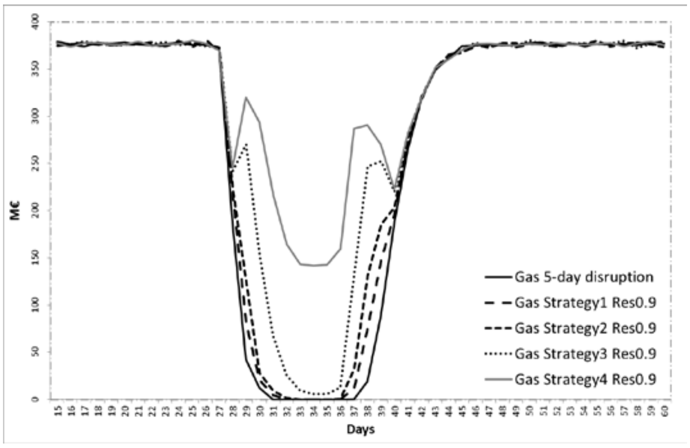

Figure 6. Average daily turnover with 5-day Gas disruption and 90% resilience capacity

The summary of all the simulation results is given in Table 2.

7 DISCUSSION

At general level, the results of the study show a very limited responsiveness of the FMCG SC when hit by the unavailability of some critical services, despite the resilience strategies implemented and the capacities mobilised. It can be concluded that there is a structural rigidity of the FMCG SC, mainly due to the strong dependability of all transport systems on energy and the limited amount of stocks in DCs. Efficiency and lean strategies implemented in the sector made it more vulnerable and fragile to CI disruptions.

In particular, at the minimum level of resilience capacity, the use of Strategy 4 brings no additional benefits compared to the less challenging Strategy 3. The strategies are a bit more effective when the CIs affected by a severe disruption are Gas or Power Generation, but the effectiveness is low in general.

When it comes with a higher level of resilience capacities (50%), the benefit of all the strategies are far more significant compared to the previous scenario; in particular, the benefit of Strategy 1 is comparable to the one achievable with Strategy 4 (the most complex) with a 20% of capacity. The percentage of turnover that can be recovered with the strategies has wider range, reaching the maximum of 15%. Looking at these results it appears that, in a context of high system rigidity and fragility and limited resources, it is better to concentrate the available resilience capacities, and decouple the SC (e.g. Strategy 1), than distribute them along the entire SC (Strategy 3 or 4).

When it comes to the best scenario, involving the highest level of resilience capacities (90%) under all the available strategies, improvements range from a minimum of around 4%, when Strategy 1 is implemented, to a maximum of almost 53% for Strategy 4. Comparing strategies 3 and 4, significant differences emerge, which means that the resilience capacity presents a relevant factor here. Finally, observing the impact of the strategies on the CI disruptions, we note that effectiveness of Strategy 3 varies across the CIs, from 19% in case of Fuel disruption, up to 32% in case of Water disruption.

8 CONCLUSIONS

Research on the analysis and modelling of the dependencies between Key Resource Supply Chains (KRSC) and CIs is still limited, mostly if we consider the resilience dimension. The majority of modelling techniques require a large amount of detailed data that are difficult to collect, or model the propagation of consequences in a poorly detailed way. A Multi-method approach, that uses a combination of *System Dynamics* and *Discrete event technique*, could represent a good trade-off and a better choice. However, the proposed modelling approach still suffer for some limitations:

– Some of the hypotheses at the basis of the model are strong and not fully realistic (e.g. neglecting staff factor in power, water and gas facilities), so the quantity may not be accurate;
– Detailed data of confidential nature should be used to quantify the KRSC model (e.g., stock location and coverage, quantity of goods per mode of transport); alternatively, secondary and sector related data could be used (as it was in the present study), resulting in a degraded precision and reliability of results.

The preliminary results achieved with the present study encourage further developments from both the theoretical and the application sides, such as:

– Extension of the model to incorporate a cost index for different strategies and resilience capacities;
– Development of an integrated set of resilience indicators for a better comparison of disruption scenarios and response strategies;
– In-depth investigation of cascading effects between CIs and the FMCG SC and the dynamics of bottlenecks within the FMCG SC under different scenarios and response strategies.

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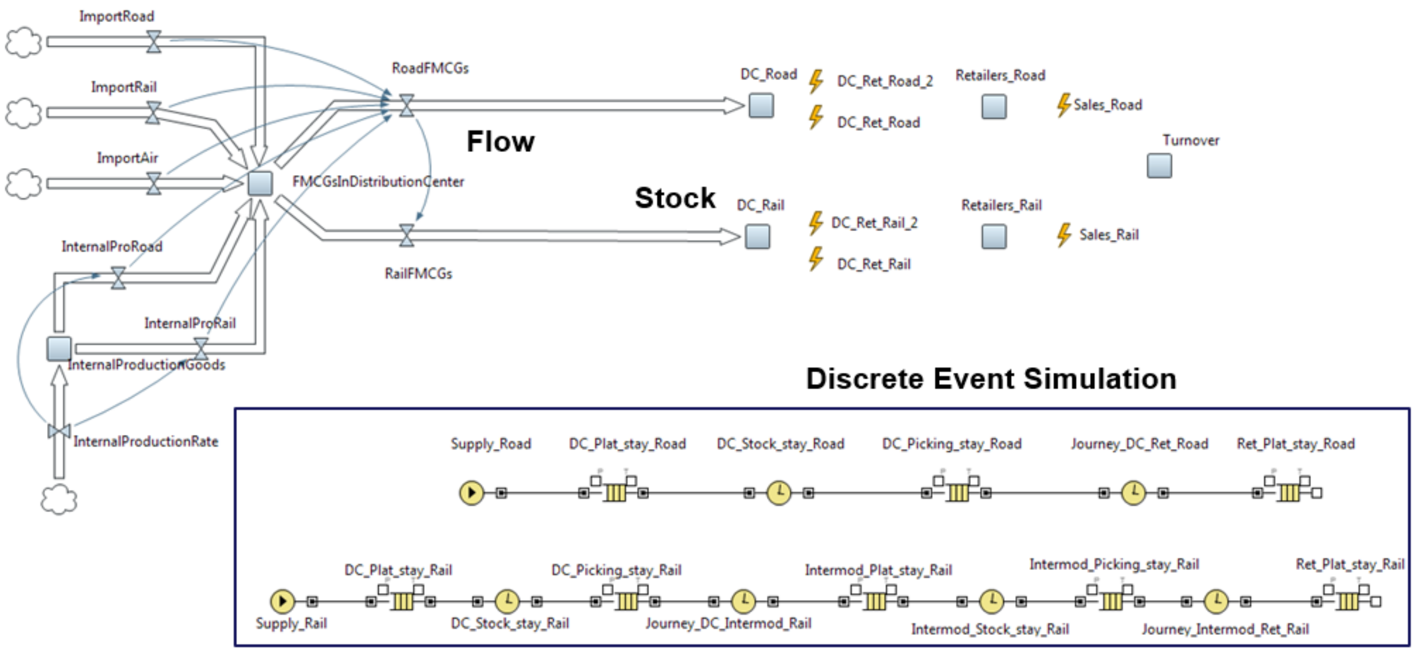

Figure 7. FMCG Supply Chain model in Anylogic

Table 2. Summary of the simulation results – 5 days of 50% service loss from different Energy CIs

Level of resilience capacity in the FMCG SC	Average Turnover [M€] (100 days; 20 repetitions)	Fuel	Gas	Power-Gen	Water	Average value
	Baseline – Absolute value	37649	37649	37649	37649	
	Worst case – Absolute value	33508	33070	34376	33495	
	Worst case – Absolute loss	4141	4579	3273	4154	
0.2	Strategy 1 - % Turnover recovery	1.40%	2.19%	2.20%	1.78%	**1.89%**
	Strategy 2 - % Turnover recovery	2.30%	3.25%	3.51%	2.72%	**2.94%**
	Strategy 3 - % Turnover recovery	3.29%	4.78%	5.11%	3.98%	**4.29%**
	Strategy 4 - % Turnover recovery	4.12%	4.85%	5.13%	4.08%	**4.55%**
0.5	Strategy 1 - % Turnover recovery	3.00%	4.46%	4.55%	3.58%	**3.90%**
	Strategy 2 - % Turnover recovery	5.26%	7.65%	8.10%	6.16%	**6.79%**
	Strategy 3 - % Turnover recovery	10.36%	14.49%	15.28%	11.27%	**12.85%**
	Strategy 4 - % Turnover recovery	14.10%	16.26%	17.19%	12.68%	**16.06%**
0.9	Strategy 1 - % Turnover recovery	3.36%	4.83%	5.11%	3.83%	**4.29%**
	Strategy 2 - % Turnover recovery	6.17%	8.96%	10.05%	7.17%	**8.09%**
	Strategy 3 - % Turnover recovery	19.35%	24.50%	28.92%	32.40%	**26.29%**
	Strategy 4 - % Turnover recovery	52.53%	51.86%	54.82%	51.71%	**52.73%**