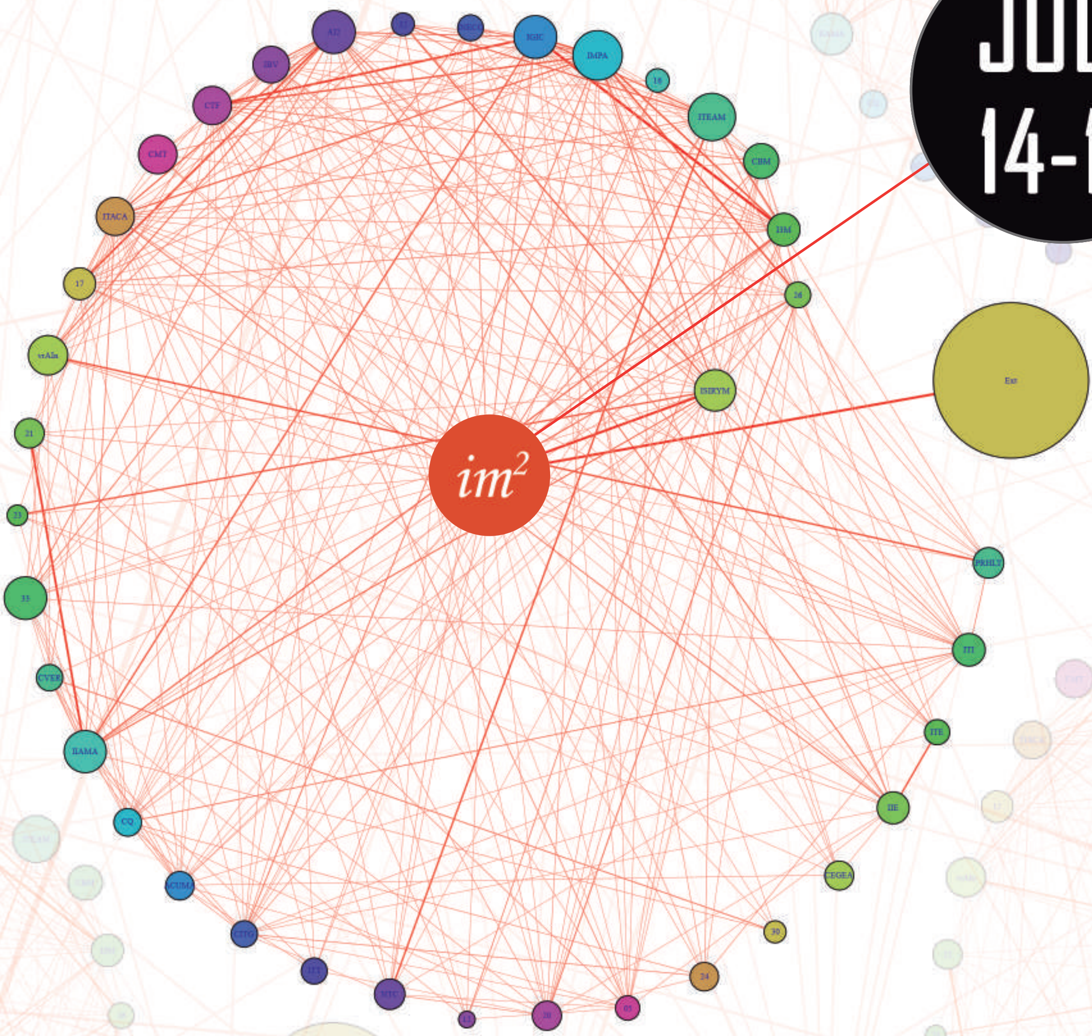
MODELLING FOR ENGINEERING & HUMAN BEHAVIOUR 2021

JULY 14-16



Edited by

Juan Ramón Torregrosa Juan Carlos Cortés Antonio Hervás Antoni Vidal Elena López-Navarro

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

im2 Instituto Universitario de Matemática Multidisciplinar

20

Contingency plan selection under interdependent risks

Ilyas Mzougui[♭], Silvia Carpitella[♮] and Joaquín Izquierdo[♯] [1]

(♭) Faculty of Sciences and Technologies - Abdelmalek Essaadi University, Avenue Khenifra, 93000 Tangier, Morocco;

(♮) Department of Decision-Making Theory, Institute of Information Theory and Automation, Czech Academy of Sciences, Pod Vodárenskou věží 4, 18208 Prague, Czech Republic;

(♯) Fluing-Institute for Multidisciplinary Mathematics, Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia, Spain.

1 Introduction

Managing supply chain risks (SCRs) has become an increasingly strategic key factor over the last decade, aimed at pursuing and maintaining business success. These types of risks clearly pose an important challenge to managers nowadays, and evaluating uncertainty affecting business scenarios is crucial. Indeed, COVID-19 has been dangerously affecting supply chains of global manufacturers, and is indicated as a main trigger cause of supply chain disruptions for a huge number of enterprises. Major effects derived from epidemic outbreaks on supply chains should be further adequately investigated since enterprises have been adopting poor risk management plans [1] to face them. Many companies, for instance, have been assuming a passive attitude towards the management of pandemic effects, simply waiting for the situation to come back to normality at hopefully short notice. On the other side, those companies that are more proactively reacting to the pandemic have been encountering countless difficulties in implementing risk management plans at operational levels [2]. Given these preliminaries, the present contribution is aimed at proposing a way for managing risks due to COVID-19. The main objectives of the present contribution can be formalised as follows:

1. analysing critical supply chain risks and related interdependence relationships to establish priorities on mitigation/prevention actions and most influential risks;

2. proposing a structured method capable to get the vector of risks' weights and ease the selection of the most suitable contingency strategy on the basis of companies' needs.

These objectives are herein addressed by means of a Multi-Criteria Decision-Making (MCDM) approach based on the use of the Analytic Network Process (ANP), suggested to analyse and weight risks by taking into account relations of dependence existing among the same risks and effects. Results will be formalised in the field of automotive industry as offering a significant input for the process of contingency strategy selection while simultaneously considering uncertainty affecting evaluations on the basis of the specific business context features.

[1]jizquier@upv.es

2 The Analytic Network Process

The ANP, first implemented by Thomas Saaty [3] as a follow-up of the Analytic Hierarchy Process (AHP) [4], is a useful tool commonly applied to evaluate sets of decision-making elements (called nodes in the method context). Its purpose is to produce a vector of weights by considering the possible interdependence among the nodes, which are categorised into clusters (namely, criteria, subcriteria and alternatives) to build the hierarchical structure of the decision making problem, whose general goal has been specified previously. Specifically, weights of alternatives are calculated with respect to criteria and subcriteria, weights of subcriteria with respect to criteria and, lastly, criteria weights are determined with respect to the main goal. In the the present paper, however, the ANP application is conducted only to evaluate criteria (i.e. main risks) and subcriteria (i.e. effects) weights. The alternatives (i.e. strategies) of the decision-making process will be ranked in a future research, according to the weights herein calculated. The ANP technique is implemented by performing the following six stages in sequence [5].

1. Representing the decision-making problem by means of a hierarchical structure, clearly defining clusters and nodes. Once the structure has been fixed, relations of interdependence among the nodes (that may occur among nodes belonging to the same clusters and also among nodes belonging to different clusters) have to be established. At this stage, opinions provided by a decision-making team of experts in the field of the problem may highlight any possible relation.

2. Building the influence matrix, in which relations identified during the previous stage are formalised. Specifically, the influence matrix is a square block matrix, whose size equals the total number of nodes, whose blocks correspond to the identified clusters, and whose entries a_{ij} are equal to 1 if a relation of dependence between element j over element i exists, and 0 otherwise. This matrix acts as a template for the non-zero elements of the matrix described next.

3. Building the unweighted supermatrix (following the non-zero-entry structure of the influence matrix) by pairwise comparing those nodes for which a relation of dependence has been identified ($a_{ij} = 1$), and by calculating weights for the corresponding elements in each cluster (the AHP may be applied to calculate those weights). We herein specify that, in our case, comparisons have to be performed: 1) between pairs of criteria, 2) between pairs of criteria and subcriteria, and 3) between pairs of subcriteria. The calculated weights will be the entries of the unweighted supermatrix. The sums of the columns of the unweighted supermatrix must equal the number of clusters for which a comparison has been performed.

4. Producing the weighted supermatrix by means of a normalisation procedure. The sums of the columns of the weighted supermatrix will be equal to one and, in such a way, the matrix gets stochastic.

5. Obtaining the limit matrix by raising to powers the weighted matrix. All the columns of the limit matrix are equal, each one of them representing the global priorities, which will have to be eventually normalised with relation to each cluster to produce meaningful information.

6. Formalising the final vectors of weights, which embody the interdependencies accumulated throughout the successive powering of the weighted matrix. Elements with associated higher values should be preferred and, in any case, will have major prominence in leading the decision-making process.

3 Application and results

The ANP has been applied to a real case study in the field of the automotive industry. The chosen field of application is extremely complex, critical and vulnerable under current conditions, having been particularly affected by the pandemic outbreak. Despite the impact of COVID-19 on supply chain management has been studied in the literature, a proper process of risk identification is crucial to get a comprehensive overview about the main aspects. We have carried out a study aimed at identifying risks related to COVID-19 effects in the automotive industrial sector. Specifically, the following most significant risks have been evaluated by leading several brainstorming sessions with a group of experts in the industrial field of reference: external, operation, organisational, supply-side and demand-side risks. These risks have been codified as $C_i (i = 1, \ldots 5)$, and their brief description is reported next, along with the identification of fifteen main related effects emerging from the literature, herein codified as $E_i (i = 1, \ldots 15)$.

- C_1, external risks, produced by exogenous sources, that is, external to the company, and, as a consequence beyond control, even though broadly predictable. These risks are connected to the following effects:

  E_1 : perturbed supplies [2]: supplies of critical components can be severely affected, something that can likely impact production in a negative way;

  E_2 : shortage of primary resource [6]: the shortage of raw and human resources may lead to possible consequent factory shutdown.

- C_2, operation risks, referring to the prospect of loss resulting from inadequate or failed procedures such as those related to the management of workers, policies or system failures. These risks are connected to the following effects:

  E_3 : perturbed production [7]: the process of raw material supply is less efficient, leading to the strong reduction of production rates as well as to the impossibility of fulfilling orders and to long-term capacity shortage;

  E_4 : unavailable operators due to sickness reasons [1]: one or more operators may be COVID-19 affected.

- C_3, organisational risks, referring to potential losses due to uncertainty including such aspects as material, strategy, reputation, and security. These risks are connected to the following effects:

  E_5 : ineffective supplier contingency plans [2]: supplies of components or modules may suffer from undetected broken supply chain, then showing lack of readiness in responding to perturbation events as well as in limited applicability of the existing plans;

  E_6 : excessive inventory amount [8]: excess on inventory could be caused by sudden cancellations of orders or reductions of ordered quantities;

  E_7 : shortage of Operation, Maintenance, and Surveillance (OMS) workers [9]: one or more OMS workers may be COVID-19 affected and in lockdown areas;

  E_8 : increased level of job cuts [9]: multiple job cuts may occur due to reduction of production and demand;

  E_9 : social problems: tighter sanitary precautions imposed by governments negatively impact workers under the psychological point of view by increasing stressful conditions;

  E_{10} : lack of cash liquidity: the COVID-19 pandemic has induced a sharp drop in cash-flow for many firms so that several companies have become illiquid.

- C_4, supply-side risks, causing problems to inventory, manufacturing, information exchange and general logistic aspects. These risks are connected to the following effects:

  E_{11} : slow shipments and problems with deliveries [1]: having been ports closed during the lockdown periods, distributors' capability to send goods can be seriously affected as well as delivery delayed and related costs inflated;

  E_{12} : impact on international trade [10]: foreign investors may pull their offers out and, in addition, credit flow from banks and non-banking financial companies may be slowed down or even interrupted.

  E_{13} : impact on relationships with suppliers [2]: suppliers have been facing strong pressure caused by COVID-19 disruptions in terms of visibility, communication and flexibility, something that may generally deteriorate the quality of relationships with customers.

- C_5, demand-side risks, that are related to general performance of order processing, also in terms of delivery processes. These risks are connected to the following effects:

  E_{14} : orders cancelled by brands and retailers [2]: only a few orders can correctly be processed, given the difficulties in reaching final customers, the lack of flexible delivery options and peaks of transportation demand.

  E_{15} : change of delivery and order cycle [11]: delivery times may be extremely delayed in COVID-19 scenarios and this may significantly affect the whole order cycle.

The ANP ranks risks by taking into account relationships among them and also those links bonding risks with effects and effects with each other. The unweighted matrix shown in Table 1 has been obtained from the relations of influence established by an expert in automotive logistic, and specifically by pairwise comparing those nodes for which a link has been identified. We have used the AHP to determine the priorities shown in the unweighted matrix, whose columns have been normalised to sum one to get the weighted matrix of Table 2.

Table 1: Unweighted matrix produced within the ANP procedure

	G	$\mathbf{C}_1$	$\mathbf{C}_2$	$\mathbf{C}_3$	$\mathbf{C}_4$	$\mathbf{C}_5$	$\mathbf{E}_1$	$\mathbf{E}_2$	$\mathbf{E}_3$	$\mathbf{E}_4$	$\mathbf{E}_5$	$\mathbf{E}_6$	$\mathbf{E}_7$	$\mathbf{E}_8$	$\mathbf{E}_9$	$\mathbf{E}_{10}$	$\mathbf{E}_{11}$	$\mathbf{E}_{12}$	$\mathbf{E}_{13}$	$\mathbf{E}_{14}$	$\mathbf{E}_{15}$
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\mathbf{C}_1$	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00
$\mathbf{C}_2$	0.13	0.25	0.00	0.50	0.00	0.00	0.30	0.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
$\mathbf{C}_3$	0.07	0.25	0.00	0.00	0.00	0.00	0.30	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50
$\mathbf{C}_4$	0.19	0.25	0.50	0.25	0.00	1.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50
$\mathbf{C}_5$	0.32	0.25	0.50	0.25	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
$\mathbf{E}_1$	0.03	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.46	0.00	0.00
$\mathbf{E}_2$	0.06	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\mathbf{E}_3$	0.07	0.00	0.80	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
$\mathbf{E}_4$	0.07	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\mathbf{E}_5$	0.02	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.09	0.19	0.00
$\mathbf{E}_6$	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
$\mathbf{E}_7$	0.04	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\mathbf{E}_8$	0.07	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00
$\mathbf{E}_9$	0.14	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.88	0.00	0.00	0.00	0.23	0.00
$\mathbf{E}_{10}$	0.16	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.40	0.00
$\mathbf{E}_{11}$	0.07	0.00	0.00	0.00	0.71	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\mathbf{E}_{12}$	0.04	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.11	0.00
$\mathbf{E}_{13}$	0.06	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\mathbf{E}_{14}$	0.12	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00
$\mathbf{E}_{15}$	0.03	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.11	0.00	0.00	0.00	0.00

Table 2: Weighted matrix produced within the ANP procedure

	G	**C**$_1$	**C**$_2$	**C**$_3$	**C**$_4$	**C**$_5$	**E**$_1$	**E**$_2$	**E**$_3$	**E**$_4$	**E**$_5$	**E**$_6$	**E**$_7$	**E**$_8$	**E**$_9$	**E**$_{10}$	**E**$_{11}$	**E**$_{12}$	**E**$_{13}$	**E**$_{14}$	**E**$_{15}$
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C$_1$	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.33	0.00	0.00	0.00
C$_2$	0.07	0.13	0.00	0.25	0.00	0.00	0.15	0.25	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00
C$_3$	0.04	0.13	0.00	0.00	0.00	0.00	0.15	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
C$_4$	0.10	0.13	0.25	0.13	0.00	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
C$_5$	0.16	0.13	0.25	0.13	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.00	0.00
E$_1$	0.02	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.00	0.00	0.00	0.00	0.00	0.00	0.33	0.23	0.00	0.00
E$_2$	0.03	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E$_3$	0.03	0.00	0.40	0.00	0.00	0.00	0.00	0.50	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
E$_4$	0.03	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E$_5$	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.05	0.09	0.00
E$_6$	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
E$_7$	0.02	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E$_8$	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00
E$_9$	0.07	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.88	0.00	0.00	0.00	0.12	0.00
E$_{10}$	0.08	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.20	0.00
E$_{11}$	0.04	0.00	0.00	0.00	0.36	0.00	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E$_{12}$	0.02	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.06	0.00
E$_{13}$	0.03	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E$_{14}$	0.06	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00
E$_{15}$	0.01	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.05	0.00	0.00	0.00	0.00

The limit matrix has been eventually obtained by raising the weighted matrix to successive powers until achieving convergence. By performing a normalisation operation of any of these (identical) columns it is possible to express the final vector of criteria weights. The values of any of the columns of the limit matrix are shown in Table 3 with relation to risks and effects. Their weights expressed in percentage are also indicated.

Table 3: Risks and effects weights

Risk	**Limit matrix value**	**% Weight**	**Effect**	**Limit matrix value**	**% Weight**
C$_1$	0.0484	10.68%	**E**$_1$	0.0346	60.65%
			E$_2$	0.0225	39.35%
C$_2$	0.0894	19.71%	**E**$_3$	0.0680	84.54%
			E$_4$	0.0124	15.46%
C$_3$	0.0732	16.13%	**E**$_5$	0.0430	23.36%
			E$_6$	0.0031	1.70%
			E$_7$	0.0070	3.79%
			E$_8$	0.0179	9.72%
			E$_9$	0.0676	36.71%
			E$_{10}$	0.0455	24.72%
C$_4$	0.1254	27.65%	**E**$_{11}$	0.0960	70.82%
			E$_{12}$	0.0172	12.66%
			E$_{13}$	0.0224	16.52%
C$_5$	0.1172	25.83%	**E**$_{14}$	0.0669	74.88%
			E$_{15}$	0.0225	25.12%

Results derived from the ANP procedure show as prominent importance is attributed to supply-side and demand-side risks. Operation and organisational risks have associated weights representing intermediate importance, while external risks has the lower weight for the selection of contingency plans contemplating COVID-19 effects. Future research will perform the selection of the strategy representing the most suitable trade-off to minimise COVID-19 related risks. Risks will be considered as evaluation criteria of the decision-making problem, and the weights herein calculated through the ANP will be treated as part of the set of input data.

4 Conclusions

The COVID-19 pandemic is strongly affecting the performance of worldwide supply chains. In such an uncertain and precarious context, the present contribution intends to propose a MCDM approach based on the use of the ANP to deal with the decision-making problem of weighting risks relevant for contingency strategy selection. The research need is clear, since many companies are struggling from a managerial point of view to cope with the current situation.

In this context, the ANP has been suggested to calculate risks' weights on the basis of various relations of interdependence, and also by taking into account relationships existing with regard to the occurrence of potential COVID-19 effects. The procedure attributes higher values of weights to supply-side and demand-side risks, while external risks show the lower degree of importance. Lastly, operation and organisational risks have associated intermediate weights. Results also quantitatively formalise the contribution of the considered effects to each weight.

Future developments of this work refer to a journal paper aimed at proposing a hybrid MCDM approach to rank a set of contingency strategies. The ranking will be performed by considering as evaluation criteria the risks and their weights herein evaluated. Specifically, the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) is going to be suggested and applied in order to simultaneously consider uncertainty affecting evaluations.

References

[1] Kumar, A., Luthra, S., Mangla, S. K., & Kazançoğlu, Y., COVID-19 impact on sustainable production and operations management. *Sustainable Operations and Computers*, 1:1–7, 2020.

[2] Van Hoek, R., Research opportunities for a more resilient post-COVID-19 supply chain–closing the gap between research findings and industry practice. *International Journal of Operations & Production Management*, 40(4): 341–355, 2020.

[3] Saaty, T.L., Fundamentals of the Analytic Network Process. *Proceedings of the* 5^{th} *International Symposium on the Analytic Hierarchy Process, Kobe, Japan, August 12-14*, 1–14, 1999.

[4] Saaty, T.L., A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15(3):234–281, 1977.

[5] Carpitella, S., Mzougui, I., Benítez, J., Carpitella, F., Certa, A., Izquierdo, J., La Cascia, M., A risk evaluation framework for the best maintenance strategy: the case of a marine salt manufacture firm. *Reliability Engineering & System Safety*, 205:107265, 2021.

[6] Pradhan, S., Ghose, D., Shabbiruddin., Present and future impact of COVID-19 in the renewable energy sector: a case study on India. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 205:1–11, 2020.

[7] Sánchez-Ramírez, C., Ramos-Hernández, R., Mendoza Fong, J.R., Alor-Hernández, G., García-Alcaraz, J.L., A system dynamics model to evaluate the impact of production process disruption on order shipping. *Applied Sciences*, 10(1):208, 2020.

[8] Tang, C.S., Zimmerman, J., Information and communication technology for managing supply chain risks. *Communications of the ACM*, 56(7):27–29, 2013.

[9] Taqi, H., Ahmed, H., Paul, S., Garshasbi, M., Ali, S., and Kabir, G., Paul, S.K., Strategies to Manage the Impacts of the COVID-19 Pandemic in the Supply Chain: Implications for Improving Economic and Social Sustainability. *Sustainability*, 12(22):9483, 2020.

[10] Vidya, C.T., Prabheesh, K.P., Implications of COVID-19 pandemic on the global trade networks. *Emerging Markets Finance and Trade*, 56(10):2408–2421, 2020.

[11] Anderson, H., COVID-19: Preparing Your Supply Chain in Times of Crisis. *https://www.publicissapient.com/insights/coronavirus_and_managing_the_supply_chain_amid_a_crisis*, 2020, Publicis Sapient.