Implementation of supply chain management for the optimizationof e-dinar strategies to reduce vulnerabilities:case of the Tunisian post

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Abstract

This contribution aimed to highlight the impact of the supply chain management strategy on the success of the institution and the advantages it provides, and the method of SCM's contribution to the Tunisian Post was presented to confirm that the adoption of the supply chain management strategy, even if it differs from one institution to another, is an essential entrance to achieving competitiveness.

The study found that the strategy of supply chain management depends on (cost control) and increase customer satisfaction. It was also found that improving the smart e-dinar strategy for the purpose of reducing vulnerabilities in the supply chain in the Tunisian Post Office.

Key words:*Supply Chain management, Tunisian POST, QFD,SPSS*
Jel Codes Classification:*E40, F31.*

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اعتماد إدارة سلاسل التوريد لتحسين استراتيجيات الدينار الإلكتروني للحد من نقاط الضعف: حالة البريد التونسي

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ملخص

هدفت هذه المساهمة إلى إبراز أثر إستراتيجية إدارة سلاسل التوريد في نجاح المؤسسة والمزايا التي تقدمها،وتم عرض طريقة مساهمة SCM في البريد التونسي للتأكيد على أن اعتماد إستراتيجية إدارة سلاسل التوريد وان كانت تختلف من مؤسسة لأخرى فإنها مدخل أساسيا لتحقيق القدرة التنافسية .

وقد توصلت الدراسة إلى أن إستراتيجية إدارة سلاسل التوريد تعتمد على (التحكم في التكلفة) وزيادة رضا العملاء. كما تبين أن تحسين استراتيجية الدينار الإلكتروني الذكي لغرض تقليل الضعف في سلسلة التوريد في المكتب البريد التونسي

الكلمات المفاتيح: ادارة سلسلة التوريد، البريد التونسي

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Introduction

With the increase of frequent disruptive events, organizations have become more vulnerable to the consequences of these disruptive events. As a result, the need for a more efficient supply chain (SC) to mitigate vulnerabilities has become paramount.

In this study, we will try to answer three fundamental questions:

What are the supply chain vulnerabilities that the Tunisian postal sector is currently facing?

What are the resilience strategies to mitigate these vulnerabilities?

What is the effective resilient portfolio of e-dinars Smart and e-dinars post strategies to mitigate vulnerabilities under budget constraints?

To answer these questions, we will first of all apply the "Quality Function Deployment" (QFD) to study the effectiveness and relevance of the various strategies proposed in the resolution of problems related to the supply chain and in the minimization of threats and risks. to which it is exposed. With the new smart card of La Poste Tunisienne e-DINAR SMART we can in other words: Prepaid; Personalized a wide range of modern, secure and fast services 7 days a week, 24 hours a day. Payment for your purchases and services via the Internet (payment of invoices, remote reservations in hotels and with travel agencies, registration for the driving license exam, sending of "postal flowers" bouquets, etc.), Safe payment of your purchases from merchants and stores equipped with TPE electronic payment terminals, Withdrawal of money from all postal and bank ATMs. e-DINAR SMART: an instantly rechargeable card. The e-DINAR SMART card can be recharged with an amount ranging from DT 5 to DT 2000: By bank or postal transfer: the postal identity statement of your e-DINAR card. MART which will be given to you upon acquisition allows you to make postal or bank financial transfers,by means of bank payment cards or the Post office and this from all the ATMs of the Tunisian Post,from all computerized post offices,by your creditors or debtors called upon to register transfer or payment transactions on your card by giving them the postal identity statement (RIP) of your e-DINAR SMART card. The e-DINAR SMART card is a smart card secured by two confidential codes. It belongs to the generation of smart cards. It thus presents additional security elements compared to magnetic stripe cards:

An 8-digit confidential code for use on the Internet, A 4-digit confidential code for transactions via ATMs and TPEs.

I. Presentation of the Tunisian Post

As part of the realization of our projetand particularly with the aim of studying the performance of the logistics chain and to what extent they constitute an important factor that should be optimized for the achievement of our objectives. Our choice is to focus on the Tunisian post which is in other words, the National Post Office and precisely the central direction of postal products. The national post office is trade name Tunisian Post, is the Tunisian public operator that provides postal services under the supervision of the Ministry of Communications Technologies and the Digital Economy. Since January 1999, and after the separation from Tunisie Telecom, the Tunisian Post has become a public body of an industrial and commercial nature which has two main professions:

• Postal services:Collection, transport and distribution of mail.

• Financial services:savings and postal checks, money orders in addition to electronic payment services.(Post Office in Tunisia, 2019, p. 23)

I – 1. Strategic axes of the Tunisian Post

La Poste Tunisienne directs its investments and efforts towards four strategic axes as follows:

Strengthen the essential role of the Tunisian Post in the development of the digital economy in Tunisia through modern means of communication such as mobile telephony and the Internet.

Modernize postal services by improving service quality, reliability and speed. Modernize financial services through structural reforms, diversification of financial products and electronic cards. Logistics axis Strengthen the role of the digital post office in a smart logistics system that understands the challenges and modern technologies that can ensure the development of electronic commerce and the “Digital Tunisia” project.

II. The implementation phases of an ERP from A to Z

ERP:An Enterprise Resource Planning (ERP or Integrated Management Software Package) is software that makes it possible to manage all the processes of a company, by integrating all the functions such as human resources management, accounting and financial management, customer relations, purchasing, inventory management, distribution, supply, e-commerce. An ERP software generally induces a rapid response (time to market) to business needs.(Norigeon, 2010, p. 6)

Regarding this phase, it is necessary to study the usefulness of setting up an ERP, the purpose of this software package for the achievement of the strategic objectives of the Tunisian Post, for this it is essential to carry out a diagnosis and an audit of the three levels of the Post Pyramid: operational, tactical and strategic.

II – 1. Problem

The problem with this work is that the Tunisian Post has a set of applications and computer systems (E-Guichet, Postal counter, etc.) for processing mail which are heterogeneous, not integrated, and operating in platforms of different types. This multi-system architecture constitutes an obstacle to meeting the strategic needs of La Poste, which are essentially based on new technologies, and also for meeting customer needs.

For this, and in order to stimulate a sustainable, profitable and systematic growth and to acquire a competitive differentiation, the Tunisian Post decides to refocus its Information System on its large customer base by using the solutions which are in the new technologies..

Thus, the actors of the needs analysis must be chosen from among the best of the central postal products department and have a variety of skills, in this context the following table shows the qualities of each actor for the needs analysis:

Table n°1: Roles and qualities of the actors in the needs analysis

Members	Roles	Skills and qualities
The counter clerks	- Express their needs - Use the service	Serious Realistic
Managers and heads of agencies representing the counter clerks	- The hierarchical manager of the users - He is a user	Fair Neutral Objective
The IT specialist responsible for monitoring the project	- Comprend lebesoin - Formulation dubesoin -Validation du besoin	Attentive Careful
The computer scientist responsible for facilitating the meetings	Animation of meetings -Collection of ideas -Organize meetings	Franc SincèreDynamique
The postal business expert	Translates all the needs of the solution -Qualify functions -Modeling of solutions	Neutral Realistic
The computer expert	Choice and technical solutions. -Computer consulting	Sincere Honest
The person in charge of the specifications	Write the specifications - Validate the specifications	Serious Combative
The committee head	Strategic choices. - Arbitrations among the actors.	Sincere Men Leader

Source:output of the project meeting

II – 2. The treasury, accounting and management control part

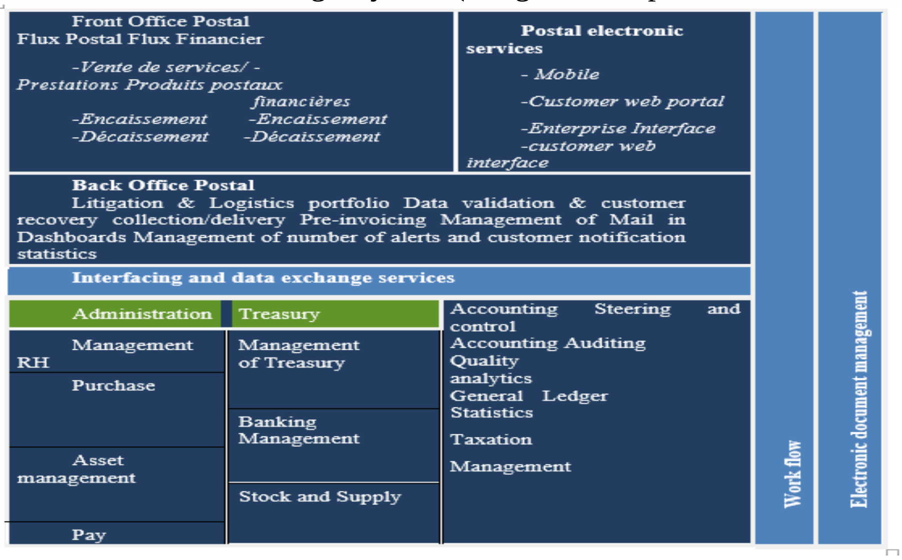
The treasury part concerns the central asset management and the treasury department and is specifically linked to cash management, banking management, stocks and supplies.

The accounting part is directly linked to the central accounting affairs department and concerns cost accounting, general accounting and taxation.

This part is linked to general management and concerns all matters relating to audit quality, statistics and management.

The following figure shows the architecture of the target system and all parts of the ERP:

Figure n°1: Architecture of the target system (Integration of postal services with the ERP)



Source: output of the project meeting

III. SCM implementation in the Tunisian post

III – 1. Choice of research methodology

Our work is enriched by the choice of a single research methodology, for reasons which will be explained later. We use a questionnaire as a research method, in which we treat two types of questions (closed questions and open questions), and this to enrich our investigation. Once the answers are collected, we proceed to software that helps us do our job.

The majority see GCS as important (48%), while others in the middle (32%) consider it very important are senior managers. For the remaining minority, some (12%) think it is a little important while others (8%) see that it is not unimportant.

Figure n°2: Importance of SCM

Importance scale	Frequency	Percentage (%)	Percentage Cumulative
Very important	8	32	32
Important	12	48	80
Unimportant	3	12	92
Unimportant	2	8	100.0
Total	25	100,0	

Source:output from SPSS software

28% of staff, all of whom are senior executives, reason that the approach

SCM is clearly embedded in the company's strategy, with 72% of lower and middle managers denying it.

Table n°2: The SCM approach

Types of responses	Frequency	Percentage (%)	Percentage Cumulative
Yes	7	28	28
No	18	72	100
Total	25	100	

Source:output from SPSS software

All people see that among the technologies used in ONP are:Tel / Fax, PC (computer), Internet network, Intranet network and EDI.

The majority think that SCM does not cover all internal and external flows while the others contradict it.

Table n°3: The scope of the SCM

Types of responses	Frequency	Percentage (%)	Percentage Cumulative
Yes	5	20	20
No	20	80	100
Total	25	100	

Source:output from SPSS software

A majority of 60% think that the effect of the use of technologies and logistics software on the progress of work is very important.

Table n°4: The importance of logistics technologies and software packages

Importance scale	Frequence	Percentage (%)	Percentage Cumulative
Very important	15	60	60
Important	8	32	92
Unimportant	2	8	100
Unimportant	0	0	
Total	25	100	

Source:output from SPSS software

All the people come together on the fact that the SCM is a software package which concerns all the personnel of the company.

III – 2. The contribution of SCM to GPO

100% of people who believe that SCM's contribution to GPO affects strategic, tactical and operational objectives at the same time. GPO:"Group POlicy" A set of settings that automatically apply to users or groups on client workstations or servers.(Valet, 2012, p. 4)

There are 56% of people who see the contribution of SCM to the GPO of very important, 40% say that this contribution is important and the rest qualify it as being somewhat important.

Table n°5: The contribution of SCM to GPO

Importance scale	Frequency	Percentage (%)	Percentage Cumulative
Very important	14	56	56
Important	10	40	96
Unimportant	1	4	100
Unimportant	0	0	
Total	25	100	

Source:output from SPSS software

All staff affirm that the SCM helps in the development of strategic, tactical and operational objectives, by referring to the SCOR model which involves the mobilization of all the company's resources in order to achieve the objectives fixed, it therefore traces the various business processes

the majority of responses focus on two degrees of importance, in fact, 68% think that the contribution of the SCM in the Implementation phase is important and the remaining 32% believe that this contribution is somewhat important.

Table n°6: Development of the contribution of the SCM in the implementation phase

Importance scale	Frequency	Percentage (%)	Percentage Cumulative
Very important	0	0	0
Important	17	68	68
Unimportant	8	32	100
Unimportant	0	0	100
Total	25	100	

Source:output from SPSS software

Almost half who confirm that the contribution of the SCM in the phase of monitoring and evaluation is important (52%) of which the majority they are senior executives, the other half is divided into two unequal percentages, the first of which is 20% representing people who believe that this contribution is a little important and the second percentage is 28% presenting those who think that this input is unimportant and are all lower managers.

Table n°7: Development of the contribution of the SCM in the monitoring and evaluation phase

Importance scale	Frequency	Percentage (%)	Percentage Cumulative
Very important	0	0	0
Important	13	52	52
Unimportant	5	20	72
Unimportant	7	28	100
Total	25	100	

Source:output from SPSS software

III – 3. Results interpretation

Starting from the results obtained by questionnaire, and relying to some extent on observable data in the field, it was achieved that management by objective is an applied process, within the organization in question. We examined first, the phase of the development of objectives and strategies:starting from our sample, there are 4% of people (represents the regional director in our case) who participate in the development of objectives, then that generally.

Therefore, a majority of 60% believe that the relationship between a hierarchical superior and his subordinate, is satisfactory, while this relationship is very satisfactory for 28% of staff and indifferent for a minority of 12% which mainly consists of senior executives who prefer like this relationship to keep their respects and their authorities at work.

For these executives, prefer a formal relationship with subordinates. These, present a minority of 16%, as the other levels, middle and lower, respectively prefer an informal relation to 44% and 40% are indifferent to this relation, that is to say whatever the relation, they give the same work efforts because they believe that in the end it is the general management which is responsible for defining the objectives.

In this phase it is vital to use a management tool to measure the degree of achievement of objectives, by clearing the gap between what is achieved and what is planned. A minority of 16% who are aware of the great importance of this tool are the majority of senior executives, for a majority of 60% consider it important, while some 8% think it doesn't matter, and the rest think it's unimportant.

III – 4. Interpretation of the SCM within the Tunisian post office

Based on the responses collected, the majority (48%) see that SCM is important, since it is based on information systems and logistics software aimed at synchronizing physical and information flows, at the same time. time, and communication between the various partners of the company. A number of senior executives of 32% consider that the SCM is very important, since, in the post office certain software packages and information technologies which support this one are authorized and reserved only for this category of civil servant. For the remaining minority is distributed between 12% who think that this software package is of little importance while 8% neglects it. Among the technologies and software packages most used in the post, according to the responses of its officials, are: landline telephone, fax, computer, Internet network and EDI which are limited to senior executives, and intranet network.

IV. Methodology of our research

We have adapted the QFD methodology to identify vulnerabilities and resilience strategies. We then develop an interactive multi-objective methodology to find the portfolio of effective resilience strategies to mitigate vulnerabilities.

We applied our method in the Tunisian post. Our study has three stages:

Identification of vulnerabilities and resilience strategies; Integration with the Analytical Hierarchy Process (AHP); The Analytic Hierarchy Process (AHP) is a general theory of measurement. It is used to derive ratio scales from both discrete and continuous paired comparisons. And finally, to determine the effective resilience capacities (binary nonlinear mathematical program with multiple objectives). Our objective is to choose all the strategies that allow us to maximize the logistics chain resilience indicators while respecting the financial and budgetary constraints available. To achieve such an objective we exploit the responses of officials of the Tunisian post to establish in a first step a modified QFD making it possible to analyze the effectiveness of different actions.

IV – 1. Identification of vulnerabilities and resilience strategies

By referring to reviews of the literature and interviews we identified the different vulnerabilities and resilience in the Tunisian post sector to start filling in the QFD table.

QFD:Quality Function Deployment (QFD) is a product development methodology that “deploys” the voice of the customer (VOC) throughout the product development process. A cross-functional team implements QFD by creating a series of one or more matrices, the first of which is called the House of Quality (HOQ.(John, 2010, p. 2).

Tables 8 and 9 present the vulnerabilities and the supply chain resilience strategies explained. There are 26 vulnerabilities. Among these, 19 vulnerabilities were selected and 13 resilience strategies were selected to mitigate vulnerabilities.

Table n°8: Different vulnerabilities

Factors	**Specific vulnerabilities**
vulnerability	Natural disaster (DV1) Political instability (DV2) Fire and other accidental damage (DV3) Disorders at work (DV4)
Vulnerability to danger:	Non-compliance with social standards and environmental factors (SV1) Customer relationship problem (SV2) Real-time integration and information problem (SV3) Supplier relationship problem (SV4) Localization problem (SV5)
Strategic vulnerability	Currency fluctuation (FV1) Economic recession (FV2) Bankruptcy or Corruption (FV3)
Financial vulnerability	Shortage of skilled workers (OV1) Employee switching and absenteeism (OV2) Planning fault (OV3) Computer system and machinery failure (OV4) Disruption of the public service offer (OV5) Product quality defect (OV6)
Operational vulnerability	Delay in customs clearance (IV1) Delay for congestion and inefficiency in the port (IV2) Workers' strike (IV3) Delay in transport due to poor infrastructure (IV4)
Infrastructure vulnerability	Supplier lead time (DO1) Dependence on imported material and lack of backward link (DO2) Defect or non-conformity (DO3) Fluctuation / uncertainty (DO4)

Source:output from Project Meeting

Table n°9: The different resilience strategies

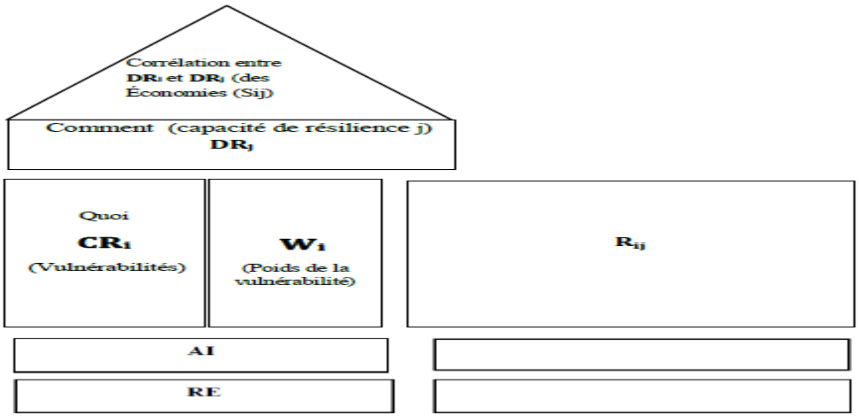
Identification of supply chain resilience capacities
Product differentiation and customization (St1)
Multiple sources of supply (St2)
Channel rerouting, reconfiguration (St3)
Backup capacity (St4)
Quality control and reduction of non-conformities (St5)
Development of skills and efficiency through training and advice (St6)
Improvement of products / services and processes for efficiency and reduction of faults / complaints (St7)
Forecasting and predictive analysis (St8)
Upstream and downstream linkage (St9)
Responsiveness to customers (St10)
Compliance with social and environmental issues (St11)
NICT adoption and information integration (St12)
Cooperation, communication and building relationship with buyers and suppliers (St13)

Source:output from Project Meeting

In step one, we defined the row items **CRi** (what) which represent the vulnerabilities the supply chain is currently facing and the column items **DRj** (how) which represent the resilience strategies or capacities to mitigate the vulnerabilities.

The vulnerabilities and resilience were collected from the literature review and interviews with managers.

Figure n°3: Framework of the QFD method



CRi = Vulnerability i;
wi = Degree of importance of CRi;
DRj = Resilience strategies j;
Rij = Measure the impact of strategy j in solving problem i
AIj = Absolute importance of the resilience strategy j;
REj = Effectiveness of the resilience strategy j
Sij = Correlation between the resilience strategies i and j (measurement in terms of the savings made following the simultaneous implementation of the two strategies i and j).

To find the answers **Rij**, we asked respondents to indicate "the extent of the reduction in vulnerability i to follow up on the implementation of the resilience strategy j" using the widely used scale of 9 (strong attenuation), 3 (moderate attenuation), 1 (weak attenuation) and 0 (no attenuation). (Chan and Wu, 2002; Faisal, 2013;Pujawan et al, 2009).

IV – 2. Integration with the hierarchical analysis process (AHP)

In step two, we applied Saaty's AHP method to find the values of **wi** (importance of each vulnerability). The hierarchical analysis process is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1980s. It aims to refine the decision-making process by examining the consistency and logic of the decision-maker's preferences.

The overall weight of each vulnerability reflects the importance of that vulnerability. To apply the AHP method we used the Super Décisions software. Figure 4 shows the **wiRij** values (in the main body of the matrix) and AIj values for different resilience strategies. The **AIj** are the absolute importance of resilience strategies.

For example: the extent of the reduction of the DV4 vulnerability by the ST2 resilience strategy is equal to 3 so**wiRij** = 3 * 0.026 = 0.078

The magnitude of the reduction in DV4 vulnerability by the ST3 resilience strategy is equal to 9so **wiRij** = 9 * 0.026 = 0.234

Note that in our case, **AIj** is interpreted as a "total resilience" of the resilience strategy to mitigate vulnerabilities.

$$AI_j = \sum_{i=1}^{m} w_i R_{ij} \quad \forall\, j \quad j = 1, \ldots, n \quad (1)$$

For example, for strategy ST1:

AI1 = W1R11 + W2R21 + W3R31 + W4R41 + ……..
= 0 + 0 + 0 + 0.081 + 0.246 + ⋯ +0 + 0.144 = 2.379.
The relative importance (resilience) of the resilience strategy j is determined by:

$$RI_j = \frac{AI_j}{\sum_{i=1}^{n} AI_j} \quad \forall\, \mathrm{j} \quad \mathrm{j} = 1, \dots, \mathrm{n} \quad (2)$$

In step two, we collected the quantitative data (**wiRij**) to find the values **AIj**and**RIj** (see equations (1) and (2)). We also collected data on the costs **Cj** of implementing resilience strategies to find resilience effectiveness **REj** and the savings achieved when two resilience strategies i and j are implemented simultaneously.

We are talking about the supply chain resilience efficiency: SCREF if

- The resilience capacity must be resource efficient (e.g. minimum cost of implementation), and
- The portfolio of resilience capacities chosen must be effective (or not dominated) from the point of view of several objectives (Larbani et al, 2011).

According to Vugrin et al. (2011), the effectiveness of resilience **REj** is calculated as follows:

$$RE_{ij} = \frac{AI_j}{c_J}$$

Where **REij** = measures the effectiveness of strategy j in solving the problem related to vulnerability i, and **Cj** is the cost of implementing the resilience strategy.

For example: $RE1 = 2.379/10 = 0.2379$

It can be noted that the resilience strategies ST6 (Development of skills and efficiency through training and advice), ST7 (Improvement of products / services and processes for efficiency and reduction of defects), ST5 (Control quality and reduction of defective products), ST4 (Backup capacity) and ST2 (Multiple sources supply) have the highest AIs of (3.822; 3.643; 3.63; 3.117 and 3.027 respectively).

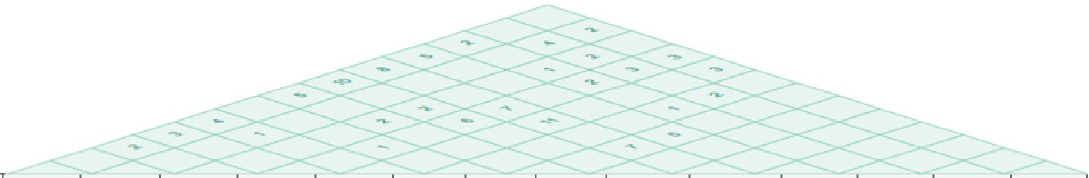
It should be noted that the ST6 resilience strategy (development of skills and efficiency through training and advice) has the highest RE value, i.e. 1.911 followed by the ST11 resilience strategy (Compliance with social and environmental issues) with 0.826 and the ST2 (Multiple Sources of Supply) strategy of 0.756.

The triangle at the top of the house represents savings **Sij**following the simultaneous application of strategies **STi** and **STj** or the degree of correlation between these two strategies. An empty square indicates a zero correlation between the two strategies that is, there are no savings and the total cost of applying both strategies is the sum **Ci** + **Cj**.

However, a non-zero correlation indicates that the realization of the two strategies allows to have a saving in the cost of an amount **Sij** such that the cost of the simultaneous implementation of the two strategies will be equal to **Ci** + **Cj**-.

For example, the implementation of the two strategies ST1 and ST10 simultaneously saves an amount of the order of 5 MD.

Figure n°4: Supply chain resilience model before coronavirus



	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	weights
DV2	0	0	0	0	0	0.129	0	0	0	0	0.387	0	0	0.129
DV3	0	0.027	0.027	0	0.081	0.081	0.027	0	0	0	0	0.027	0	0.009
DV4	0	0.234	0.234	0	0.234	0.234	0.078	0.078	0.078	0	0.078	0.078	0.078	0.026
SV1	0.081	0.081	0.027	0.027	0.081	0.081	0.081	0.027	0.027	0.081	0.027	0.081	0.081	0.009
SV2	0.246	0	0.246	0.246	0.738	0.738	0.738	0.246	0.246	0.246	0.738	0	0.246	0.082
SV3	0141	0.423	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.423	0.047
SV5	0.243	0	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.243	0.027
FV1	0.099	0.033	0	0.033	0	0	0	0	0	0	0	0	0	0.011
FV2	0.201	0.201	0	0.201	0	0	0	0	0	0	0	0	0	0.067
FV3	0.126	0.126	0	0.126	0.378	0.126	0	0	0.378	0	0.126	0	0	0.042
OV1	0.111	0	0.111	0	0.111	0.333	0.111	0	0	0	0.037	0	0	0.037
OV2	0.063	0	0.063	0.063	0.063	0.189	0.063	0	0	0	0.021	0	0	0.021
OV3	0.324	0.972	0.324	0.972	0.972	0.972	0.972	0.324	0.324	0	0	0.972	0	0.108
IV1	0	0.375	0	0.375	0	0	0.375	0.375	0.375	0	0	0.125	0.375	0.125
IV2	0	0.123	0	0	0.123	0	0.123	0.123	0.123	0	0	0.041	0.123	0.041
DO1	0.195	0.195	0.195	0.585	0.195	0.585	0.585	0.195	0.195	0.195	0	0.195	0.585	0.065
DO2	0.078	0.078	0.078	0.234	0.078	0	0.078	0.078	0.078	0.078	0	0.234	0.078	0.026
DO3	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0	0.033	0.033	0.011
DO4	0	0	0	0	0.141	0	0.141	0.141	0.141	0.141	0	0.047	0.141	0.047
AI	2.379	3.027	1.608	3.117	3.63	3.822	3.643	1.986	2.4	1.272	1.652	2.071	2.567	
Coût	10	4	3	8	8	2	25	20	9	5	2	15	5	
RE	0.2379	0.7567	0.536	0.389	0.4537	1.911	0.145	0.099	0.267	0.2544	0.826	0.138	0.513	

Source:Output Quality Function Deployment Software

AI = Absolute importance;**Tj** = Resilience strategy j; DV, SV, FV, OV, IV, DO = various vulnerabilities; RE = Effectiveness of resilience.

Using QFD's step-by-step procedure, we found the vulnerabilities and the corresponding resilience strategies. In terms of the importance of these vulnerabilities, four principles of vulnerabilities have been identified:Failure in production planning and inventory management (OV3), Delay in customs clearance (IV1), Non-compliance with social and environmental standards (SV2) and Political instability (DV2).

IV – 3. Proposed methodology to determine effective resilience capacities in QFD

The concept of efficiency and the generation of effective solutions is prevalent in a decision-making domain with multiple objectives. A general multi-objective decision problem is represented as follows:

$$\left.\begin{aligned} &\mathbf{Max(min)}\ f_i(\mathbf{X}) = C^i(\mathbf{X})\ \mathbf{i} = \mathbf{1}, \dots, \mathbf{p} \\ &g_j(\mathbf{X}) \leq b_j \quad j = \mathbf{1}, \dots \dots \dots \dots \dots \dots \dots q \end{aligned}\right\} \qquad (3)$$

Where $X = (x1., \dots\dots\dots,)$: are n-dimensional decision variables;

fi (): Represent P contradictory and linear objective functions p i = 1, 2,…, p

gj (): The constraint j, j = 1, 2,…, q.

A feasible solution $X*$ to problem (3) is said to be efficient (for a maximization problem) if there is no other feasible solution X such that for all $i = 1,..., p$,

$fi\ (X) \geq fi\ (X*)$ and $fi\ (X) > fi\ (X*)$ for at least one i.

The following formulation can be used to maximize the resilience of the supply chain.

$$\left.\begin{aligned} &\mathbf{Max}\ \ f_1(\mathbf{X}) = \sum_{j=1}^{n} RE_j\, x_j \\ &\mathbf{Max}\ \ f_2(\mathbf{X}) = \sum_{k \in n, k \neq j} RE_k\, x_k \\ &\dots\dots\dots \\ &\mathbf{Max}\ \ f_p(\mathbf{X}) = \sum_{l \in n,\ k \neq j}^{m} RE_l\, x_i \\ &\textbf{sous contraintes} \sum_{j=1}^{n} C_j\, X_j - \sum_{i=1}^{n} \sum_{j=1}^{n} S_{ij}\, x_i x_j \leq Bx \in X \\ &\qquad x_i \in \{0; 1\} \end{aligned}\right\} \qquad (4)$$

Where n: The number of resilience strategies

: The effectiveness of the resilience strategy j;

: Equal to one or zero, depending on whether the corresponding resilience strategy j is selected or not; (decision variable)

The cost of implementing the resilience strategy j;

: The savings achieved if the resilience strategies i and j are implemented simultaneously;

B is the available budget devoted to managing the risk of the supply chain.

We notice that there are different conflicting goals that need to be optimized simultaneously. It is therefore necessary to find an efficient and satisfactory solution to the problem (4) by interacting with the decision maker.

Note that any solution to problem (4) will offer a portfolio of resilience strategies to mitigate vulnerabilities.

To find the optimal portfolio of strategies, we need to reformulate problem (4) as follows:

$$\left.\begin{array}{l} \text{Max} \quad \sum_{i=1}^{P} \lambda_i \, f_i(X) \\ \\ \text{sous contraintes} \sum_{j=1}^{n} C_j \, X_j - \sum_{i=1}^{n} \sum_{j=1}^{n} S_{ij} \, x_i x_j \leq Bx \in X \\ \qquad\qquad\qquad\qquad x_i \in \{0;1\} \end{array}\right\} \quad (5)$$

P: Number of objective functions in the program

Where λ**i** (i = 1,…, p) are positive values representing the weights (importance) given by the decision maker to the different objective functions. The theorems of the multi-objective optimization domain suggest that any solution of the problem (5) ci above is an effective (non-dominated) solution to the problem (4).

It should be noted that the large weights λ**i** are only necessary to find the first efficient solution to the problem (4)

We propose an interactive procedure which finds a satisfactory strategy, to explore other efficient solutions by modifying the weightings by the decision maker.

We now provide an interactive procedure for finding a satisfactory portfolio of effective resilience strategies to mitigate vulnerabilities.

1: Optimize each objective function of the problem (4). We obtain p optimal solutions. The decision makers will act according to the maximum value of each individual goal. An effective solution can be a compromise of solutions.

2: Formulate the problem (5) where each λ**i** = **1** (i = 1,…, p). Solve the problem (5). The solution will be effective (not dominated) for problem (4). Offer it to the decision maker.

3: If the decision maker is satisfied with this solution (after comparing it to the solutions found in step 1), it will be retained. This solution offers the satisfying portfolio of resilience strategies to mitigate vulnerabilities. If the decision maker is not satisfied, go to step 4.

4: Discuss with the decision maker to adjust the values of λ**i** and find new values representing his preferences for the objective functions.

5: Formulate and solve the problem (5) with the new values of λ**i**, Go to step 3.

We developed a multi-objective binary program and applied the step-by-step procedure to find the satisfactory portfolio of effective resilience strategies. We have defined three objectives to be maximized:

- Maximize the resilience of "Procurement" processes by applying at least one of the strategies ST2, ST4, ST9 and ST13.
- Maximize the resilience of "Processing (transformation)" processes by applying at least one of the strategies ST5, ST6, ST7, ST11 and ST12.
- Maximize the resilience of "Distribution" processes by applying at least one of the strategies ST1, ST3, ST8, and ST10.

The existence of a budget constraint makes it impossible to apply all the strategies at the same time and to achieve a maximum level of resilience for the 3 processes at the same time. According to the official, the B budget can be set at 80 million dinars.

The total cost of implementing the strategies is equal to the sum of the costs of the different strategies to be implemented minus the savings made following the simultaneous application of the two interrelated strategies. This cost should not exceed the B budget spent by the company to improve the resilience of the supply chain.

$Maxf1\ (X) = RE2x2 + RE4x4 + RE9x9 + RE13x13$

$Maxf2\ (X) = RE5x5 + RE6x6 + RE7x7 + RE11x11 + RE12x12$

$Maxf3\ (X) = RE1x1 + RE3x3 + RE8x8 + RE10x10$

$Maxf1\ (Approvisionnement) = 0.756x2 + 0.389x4 + 0.267x9 + 0.513x13$

$Maxf2\ (Traitement) = 0.453x5 + 1.911x6 + 0.145x7 + 0.826x11 + 0.138x12$

$Maxf3\ (Distribution) = 0.237x1 + 0.536x3 + 0.099x8 + 0.254x10$

We followed the step-by-step process to find the satisfying portfolio of effective resilience strategies. We used LINGO as optimization software.

To solve the program we use the LINGO program writing:

Table n°10: Optimal portfolio of resilience strategies (before COVID-19)

```
MAX=1*(0.756*x2+0.389*x4+0.267*x9+0.513*x13)+0*(0.453*x5+1.911*x6+0.145*x
7+0.826*x11+0.138*x12)+0*(0.237*x1+0.536*x3+0.099*x8+0.254*x10);10*x1+4*x2+
3*x3+8*x4+8*x5+2*x6+25*x7+20*x8+9*x9+5*x10+2*x11+15*x12+5*x13-
0.2*x1*x3-0.3*x1*x4-0.4*x1*x5-0.5*x1*x7-1*x1*x8-0.8*x1*x9-0.5*x1*x10-
0.2*x1*x11-0.1*x2*x5-0.4*x2*x12-0.2*x2*x13-0.2*x3*x7-0.2*x3*x8-0.1*x3*x11-
0.2*x3*x12-0.1*x4*x6-0.6*x4*x8-0.7*x4*x9-0.2*x4*x11-0.3*x4*x12-0.3*x4*x13-
1.1*x5*x9-0.3*x5*x13-0.1*x6*x11-0.2*x6*x12-0.7*x7*x9-0.5*x7*x10
<=80;@BIN(x1);

@BIN(x2);

@BIN(x3);

@BIN(x4);

@BIN(x5);

@BIN(x6);

@BIN(x7);

@BIN(x8);

@BIN
(x9);

@BIN
(x10;

@BIN
(x11);

@BIN
```

Programme(λ_1, λ_2, λ_3)	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	Z_1	Z_2	Z_3	Z_4	Z_5
P1 (1,0,0)	1	1	1	1	1	1	0	1	1	0	1	1	1	1.925				
P2 (0,1,0)	1	1	0	1	1	1	1	0	0	1	1	1	1		3.473			
P3 (0,0,1)	1	0	1	1	1	1	0	1	1	1	1	1	1			1.126		
P4 (1/3, 1/3, 1/3)	1	1	1	1	1	1	1	0	1	1	1	0	1				2.095	
P5 (0.35, 0.55, 0.1)	0	1	1	1	1	1	1	0	1	0	1	1	1					2.637

Source:output from LINGO optimization software.

If the business objective is to maximize the degree of resilience of the procurement process independent of the resilience of other processes, it should opt for the implementation of all strategies except the ST7 and ST10 strategies. This makes it possible to achieve an optimal level of resilience $\boldsymbol{Z1}$ = 1.925. In this case, the resilience indicators of the treatment and distribution processes are equal to 3.328 and 0.872 respectively.

On the other hand, if the objective is to maximize the degree of resilience of the treatment process independently of the resilience of other processes, it must opt for the implementation of all strategies except strategies ST3, ST8 and ST9. This makes it possible to achieve an optimal level of resilience $\boldsymbol{Z2}$ = 3.473. In this case, the indicators of resilience of the procurement and distribution processes are equal to 1.658 and 0.491 respectively.

Then, if the business objective is to maximize the degree of resilience of the distribution process regardless of the resilience of other processes, it should opt to implement all strategies except ST2 and ST7. This makes it possible to achieve an optimal level of resilience $\boldsymbol{Z3}$ = 1.126. In this case, the resilience indicators of the supply and processing processes are equal to 1.169 and 3.328 respectively.

Moreover, if the objective is to simultaneously maximize the resilience of the three processes with the same budgetary constraints and of which the same importance to the processes, the optimal solution consists in implementing all the strategies with the exception of the ST8 and ST12 strategies. This makes it possible to achieve an optimal level of overall resilience of 2.095 (i.e. a level of resilience of 1.925 for the procurement process, 3.335 for the treatment process, 1.027 for the distribution process).

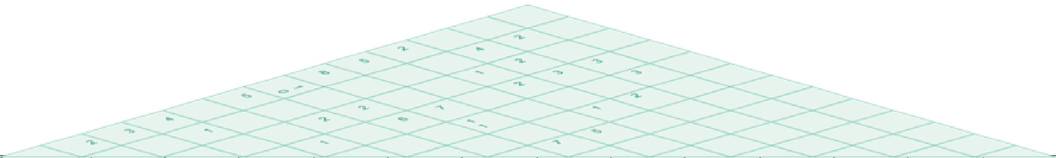
Likewise, if the objective is to simultaneously maximize the resilience of the three processes with the same budgetary constraints and including a different importance to the processes (0.35 for the procurement process, 0.55 for the treatment process, 0.1 for the distribution process), the optimal solution consists in implementing all the strategies except strategies ST1, ST8 and ST10. This makes it possible to achieve an optimal level of overall resilience of 2.637 (i.e. a level of resilience of 1.925 for the procurement process, 3.473 for the treatment process, 0.536 for the distribution process).

Finally, we can notice that the optimal portfolio of strategies depends on the process for which it aims to maximize the loss of resilience and on a general change in the importance given to each process in terms of maximizing its level of resilience.

V. Assessment of the impact of resilience strategies on vulnerabilities : Durant coronavirus case)

We have adapted the same QFD methodology (vulnerabilities and resilience are similar to Study 1). Then, we developed the same interactive multi-objective methodology approach to find the portfolio of effective resilience strategies during covid-19.

Figure n°5: Supply chain resilience model (Durant covid-19)



	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	weights
DV2	0	0	0	0	0	0	0	0	0	0	0.129	0	0	0.129
DV3	0	0.009	0.009	0	0.027	0.009	0.027	0	0	0	0	0.027	0	0.009
DV4	0	0.026	0.026	0	0.026	0.026	0.078	0.078	0.026	0	0.026	0.078	0.078	0.026
SV1	0.081	0.081	0.027	0	0.009	0.009	0.027	0.027	0	0.009	0.009	0.081	0.009	0.009
SV2	0.082	0	0.082	0.082	0.246	0	0.246	0.246	0.082	0.082	0.246	0	0.082	0.082
SV3	0.047	0.141	0.141	0.047	0.047	0.047	0.141	0.141	0.047	0.047	0.141	0.047	0.047	0.047
SV5	0.027	0	0.027	0.027	0.027	0.027	0.027	0.081	0.027	0.027	0.027	0.027	0.027	0.027
FV1	0.033	0.011	0	0.011	0	0	0	0	0	0	0	0	0	0.011
FV2	0.134	0.067	0	0.067	0	0	0	0	0	0	0	0	0	0.067
FV3	0.042	0.042	0	0.042	0.126	0.126	0	0	0.126	0	0.042	0	0	0.042
OV1	0.037	0	0.037	0	0.037	0.111	0.037	0	0	0	0.037	0	0	0.037
OV2	0.021	0	0.021	0.021	0.021	0.021	0.021	0	0	0	0.021	0	0	0.021
OV3	0.108	0.324	0.108	0.324	0.324	0.324	0.324	0.324	0.108	0	0	0.972	0	0.108
IV1	0	0.125	0	0.125	0	0	0.125	0.375	0.125	0	0	0.125	0.125	0.125
IV2	0	0.041	0	0	0.041	0	0.041	0.123	0.041	0	0	0.041	0.041	0.041
DO1	0.065	0.065	0.065	0.195	0.065	0.195	0.195	0.195	0.065	0.065	0	0.195	0.195	0.065
DO2	0.026	0.026	0.026	0.078	0.026	0	0.026	0.078	0.026	0.026	0	0.234	0.026	0.026
DO3	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.033	0.011	0.011	0	0.033	0.011	0.011
DO4	0	0	0	0	0.047	0	0.047	0.141	0.047	0.047	0	0.047	0.047	0.047
AI	0.828	1.029	0.596	1.03	1.14	0.939	1.389	1.986	0.791	0.406	0.694	1.923	0.753	
Coût	10	4	3	8	8	2	25	20	9	5	2	15	5	
RE	0.082	0.2572	0.1987	0.1287	0.1425	0.4695	0.0555	0.099	0.0878 9	0.0812	0.347	0.1282	0.1506	

Source:Output Quality Function Deployment Software

AI = Absolute importance;**STj** = Resilience strategy j; DV, SV, FV, OV, IV, DO = various vulnerabilities; RE = Effectiveness of resilience.

Step 1: In step 1, we have the elements of row **CRi** (what) which represent the vulnerabilities that the supply chain is currently facing and the elements of column **DRj** (how) which represent strategies or resilience capacities to mitigate vulnerabilities.

To find the answers of **Rij**, we asked respondents to indicate "the extent of the reduction in vulnerability i as a result of the implementation of the resilience strategy j" after the coronavirus using a widely used scale. of 9 (strong attenuation), 3 (moderate attenuation), 1 (weak attenuation) and 0 (no attenuation).

Step 2: Integration with the hierarchical analysis process (AHP)

As in study 1 of step 2, we applied the AHP method to find the values of **wi** (importance of each vulnerability). Figure 16 shows the **wiRij** values (in the main body of the matrix) and AIj values for different resilience strategies during coronavirus.

Example: The magnitude of the reduction in DV3 vulnerability by the ST2 resilience strategy is equal to 3 so **wiRij** = 1 * 0.009 = 0.009

The magnitude of the reduction in DV4 vulnerability by the ST3 resilience strategy is equal to 9 so **wiRij** = 1 * 0.026 = 0.026

Note that in our case, **AIj** is interpreted as a "total resilience" of the resilience strategy to mitigate vulnerabilities. $AIj = \Sigma wiRijmi = 1$ ∀ j j = 1,…, n (6)

For example, for strategy ST1:

AI1 = w1R11 + w2R21 + w3R31 + w4R41 +…. = 0 + 0+ 0+ 0.081+ 0.082 + ⋯…. + 0 + 0.016 = 0.828

The relative importance (resilience) of the resilience strategy j is:$RIj = AIj\Sigma AIjni = 1$ ∀ j j = 1,..., n (7)

For example, $\boldsymbol{RI1 = AIj1\Sigma AI1ni = 1 = 0.82813.504 = 0.061}$

According to Vugrin et al. (2011), the effectiveness of resilience **REj** is calculated as follows:

$\boldsymbol{REj = AIj/cj}$

Where **REij** = degree of effectiveness of strategy j in solving the problem related to vulnerability i, and **Cj** is the cost of implementing the resilience strategy.

$RE1 = 0.828 / 10 = 0.0828$

It can be noted that the resilience strategies ST12 (ICT adoption and information integration), ST8 ,ST7 (Product and process improvement for efficiency and waste reduction) and ST5 (Quality control and reduction of defective products) have the highest AIs of (1.923; 1.986; 1.389 and 1.14 respectively).

It should be noted that the ST6 resilience strategy (development of skills and efficiency through training and advice) has the highest RE value, i.e. 0.469 followed by the ST11 resilience strategy (Compliance with social and environmental issues) with 0.347 and the ST2 (Multiple Sources of Supply) strategy of 0.257.

The cost of implementing resilience strategies is more elaborate. Each respondent is asked to give their most probable, optimistic and pessimistic estimates of **Cj**.

The costs of implementing the strategies are the same.

Step 3: Proposed methodology to determine effective resilience capacities in QFD during coronavirus

In step 3, we developed the multi-objective nonlinear binary problem and applied the step-by-step procedure to find the satisfactory portfolio of effective resilience strategies during coronavirus.

A general multi-objective decision problem is represented as follows:$\textbf{Max}\ (\textbf{min})\ \boldsymbol{fi}\ (\textbf{X}) = \boldsymbol{Ci}\ (\textbf{X})\ \textbf{i} = \textbf{1},\ldots,\ \textbf{p}\boldsymbol{gj}\ (\textbf{X}) \leq \boldsymbol{bjj} = \textbf{1},\ \ldots\ldots\ldots\ldots\ldots\ldots\ \boldsymbol{q}\}\ (\textbf{8})$

Where $X = (x1,\ldots..,)$: are n-dimensional decision variables;

fi (): Represent P contradictory and linear objective functions p i = 1, 2,…, p

gj (): The constraint j, j = 1, 2,…, q.

A feasible solution $X*$ to problem (8) is said to be efficient (for a maximization problem) if there is no other feasible solution X such that for all $i = 1,..., p$,

$fi\ (X) \geq fi\ (X*)$ and $fi\ (X) > fi\ (X*)$ for at least one i.

In other words, $X*$ is not dominated by any other solution in terms of achieving the objective function.

According to Chowdhury et al. (2015), the following formulation can be used to maximize the resilience of the supply chain.

$$\left.\begin{array}{r}\textbf{Max } f_1(X) = \sum_{j=1}^{n} RE_j\, x_j \\ \textbf{Max } f_2(X) = \sum_{k\in n, k\neq j} RE_k\, x_k \\ \ldots\ldots\ldots \\ \textbf{Max } f_p(X) = \sum_{I\in n,\ k\neq j}^{m} RE_I\, x_i \\ \textbf{sous contraintes } \sum_{j=1}^{n} C_j X_j - \sum_{i=1}^{n}\sum_{j=1}^{n} S_{ij}\, x_i x_j \leq Bx \in X \\ x_i \in \{0; 1\}\end{array}\right\} \quad (9)$$

Where n: The number of resilience strategies

: The effectiveness of the resilience strategy j;

: Equal to one or zero, depending on whether the corresponding resilience strategy j is selected or not; (decision variable)

: The cost of implementing the resilience strategy j;

: The savings achieved if the resilience strategies i and j are implemented simultaneously;

B is the available budget devoted to managing the risk of the supply chain.

We notice that there are different conflicting goals that need to be optimized simultaneously. It is therefore necessary to find an efficient and satisfactory solution to the problem (9) by interacting with the decision maker.

Note that any solution to problem (9) will offer a portfolio of resilience strategies to mitigate vulnerabilities.

To find the optimal portfolio of strategies, we need to reformulate problem (9) as follows:

$$\left.\begin{array}{r}\textbf{Max } \sum_{i=1}^{p} \lambda_i\, f_i(X) \\ \\ \textbf{sous contraintes } \sum_{j=1}^{n} C_j X_j - \sum_{i=1}^{n}\sum_{j=1}^{n} S_{ij}\, x_i x_j \leq Bx \in X \\ x_i \in \{0; 1\}\end{array}\right\} \quad (10)$$

P: Number of objective functions in the program

It should be noted that the large weights λ**i** are only necessary to find the first efficient solution to the problem (9).

1: Optimize each objective function of the problem (9). We obtain p optimal solutions. The decision makers will act according to the maximum value of each individual goal. An effective solution can be a compromise of solutions.

2: Formulate the problem (10) where each λ**i** = **1** ($i = 1,\ldots, p$). Solve the problem (10). The solution will be effective (not dominated) for the problem (9). Offer it to the decision maker.

3: If the decision maker is satisfied with this solution (after comparing it to the solutions found in step 1), it will be retained. This solution offers the satisfying portfolio of resilience strategies to mitigate vulnerabilities. If the decision maker is not satisfied, go to step 4.

4: Discuss with the decision maker to adjust the values of λ**i** and find new values representing his preferences for the objective functions.

5: Formulate and solve the problem (10) with the new values of λ**i**, Go to step 3.

In step 3, we developed a multi-objective binary program and applied the step-by-step procedure to find the satisfactory portfolio of effective resilience strategies. We have defined three objectives to be maximized:

- Maximize the resilience of "Procurement" processes by applying at least one of the strategies ST2, ST4, ST9 and ST13.
- Maximize the resilience of "Treatment" processes by applying at least one of the strategies ST5, ST6, ST7, ST11 and ST12.
- Maximize the resilience of "Distribution" processes by applying at least one of the strategies ST1, ST3, ST8, and ST10.

$Maxf1\ (Approvisionnement) = 0.257x2 + 0.128x4 + 0.087x9 + 0.150x13$

$Maxf2\ (Traitement) = 0.142x5 + 0.469x6 + 0.055x7 + 0.347x11 + 0.128x12$

$Maxf3\ (Distribution) = 0.082x1 + 0.198x3 + 0.099x8 + 0.081x10$

Under constraints

$10x1 + 4x2 + 3x3 + 8x4 + 8x5 + 2x6 + 25x7 + 20x8 + 9x9 + 5x10 + 2x11 + 15x12 + 5x13$

$-0.2x1x3-0.3x1x4-0.4x1x5-0.5x1x7-1x1x8-0.8x1x9-0.5x1x10-0.2x1x11-0.1x2x5-0.4x2x12-0.2x2x13-0.2x3x7-0.2x3x8-0.1x3x11-0.2x3x12-0x1x4x8-0.6-0 \quad -0.7x4x9-0.2x4x11-0.3x4x12-0.3x4x13-1.1x5x9-0.3x5x13-0.1x6x11-0.2x6x12-0.7x7x9-0.5x7x10 <= 80$

- **Program during covid-19:**

MAX = $(0.257x2 + 0.128x4 + 0.087x9 + 0.150x13) + (0.142x5 + 0.469x6 + 0.055x7 + 0.347x11 + 0.128x12) + (0.082x1 + 0.198x3 + 0.099x8 + 0.081x10)$;

$10x1 + 4x2 + 3x3 + 8x4 + 8x5 + 2x6 + 25x7 + 20x8 + 9x9 + 5x10 + 2x11 + 15x12 + 5x13$

$-0.2x1x3-0.3x1x4-0.4x1x5-0.5x1x7-1x1x8-0.8x1x9-0.5x1x10-0.2x1x11-0.1x2x5-0.4x2x12-0.2x2x13-0.2x3x7-0.2x3x8-0.1x3x11-0.2x3x12-0x1x4x8-0.6-0 \quad -0.7x4x9-0.2x4x11-0.3x4x12-0.3x4x13-1.1x5x9-0.3x5x13-0.1x6x11-0.2x6x12-0.7x7x9-0.5x7x10 <= 80$

- **To solve the program we use the LINGO program writing:**

Table n°11: Effective portfolio of resilience strategies (during coronavirus)

```
MAX=1*(0.257*x2+0.128*x4+0.087*x9+0.150*x13)+0*(0.142*x5+0.469*x6+0.055*x7+0.347
*x11+0.128*x12) +0*(0.082*x1+0.198*x3+0.099*x8+0.081*x10) ;
10*x1+4*x2+3*x3+8*x4+8*x5+2*x6+25*x7+20*x8+9*x9+5*x10+2*x11+15*x12+5*x13
-0.2*x1*x3-0.3*x1*x4-0.4*x1*x5-0.5*x1*x7-1*x1*x8-0.8*x1*x9-0.5*x1*x10-0.2*x1*x11-
0.1*x2*x5-0.4*x2*x12-0.2*x2*x13-0.2*x3*x7-0.2*x3*x8-0.1*x3*x11-0.2*x3*x12-
0.1*x4*x6-
0.6*x4*x8-0.7*x4*x9-0.2*x4*x11-0.3*x4*x12-0.3*x4*x13-1.1*x5*x9-0.3*x5*x13-
0.1*x6*x11-0.2*x6*x12-0.7*x7*x9-0.5*x7*x10
<=80; @ BIN(x1) ;
@BIN(x2);
@BIN(x3);
@BIN(x4);
@BIN(x5);
@BIN(x6);
@BIN(x7);
@BIN(x8);
@BIN(x9);
@BIN(x10);
@BIN(x11);
@BIN(x12);
@BIN(x13);
```

Programme ($\lambda_1, \lambda_2, \lambda_3$)	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	Z1	Z2	Z3	Z4	Z5
P1 (1,0,0)	1	1	1	1	1	1	0	1	1	0	1	1	1	0.622				
P2 (0,1,0)	1	1	0	1	1	1	1	0	0	1	1	1	1		1.141			
P3 (0,0,1)	1	1	1	0	1	1	0	1	1	1	1	1	1			0.460		
P4 (1/3,1/3,1/3)	1	1	1	1	1	1	0	1	1	0	1	1	1				0.695	
P5 (0.35,0.55,0.1)	0	1	1	1	1	1	1	0	1	0	1	1	1					0.865

Source:output from LINGO optimization software.

LINGO is a comprehensive tool designed to make building and solving mathematical optimization models easier and more efficient. LINGO provides a completely integrated package that includes a powerful language for expressing optimization models, a full-featured environment for building and editing problems, and a set of fast built-in solvers capable of efficiently solving most classes of optimization models.[1]

We have followed the step-by-step process to find the satisfying portfolio of effective resilience strategies during Covid-19. We used LINGO as optimization software. The optimal solutions and the portfolio of resilience strategies are presented in Table 11.

If the business objective is to maximize the degree of resilience of the procurement process independent of the resilience of other processes, it should opt to implement all strategies except ST7 and ST10. This makes it possible to achieve an optimal level of

[1] LINDO Systems Inc. 1415 N. Dayton St, June 2020, book: LINGO, the modeling language and optimizer; volume:989,p-7, https://www.lindo.com/downloads/PDF/LINGO.pdf

resilience $Z1$ = 0.622. In this case, the resilience indicators of the processing and distribution processes are equal to 1.086 and 0.329 respectively.

On the other hand, if the objective of the Tunisian post is to maximize the degree of resilience of the processing process independently of the resilience of other processes, it must opt for the implementation of all the strategies except strategies ST3, ST8. and ST9. This makes it possible to achieve an optimal level of resilience $Z2$ = 1.141. In this case, the resilience indicators of the procurement and distribution processes are equal to 0.535 and 0.163 respectively.

Then, if the business objective is to maximize the degree of resilience of the distribution process regardless of the resilience of other processes, it should opt to implement all strategies except ST4 and ST7. This makes it possible to achieve an optimal level of resilience $Z3$ = 0.460. In this case, the indicators of resilience of the procurement and processing processes are equal to 0.494 and 1.086 respectively.

Moreover, if the objective is to simultaneously maximize the resilience of the three processes with the same budgetary constraints and of which the same importance to the processes, the optimal solution consists in implementing all the strategies with the exception of the ST7 and ST10 strategies. This makes it possible to achieve an optimal level of overall resilience of 0.695 (i.e. a level of resilience of 0.622 for the procurement process, 1.086 for the treatment process, 0.379 for the distribution process).

Likewise, if the objective is to simultaneously maximize the resilience of the three processes with the same budgetary constraints and including a different importance to the processes (0.35 for the procurement process, 0.55 for the treatment process, 0.1 for the distribution process), the optimal solution consists in implementing all the strategies except strategies ST1, ST8 and ST10. This makes it possible to achieve an optimal level of overall resilience of 0.865 (i.e. a level of resilience of 0.622 for the procurement process, 1.141 for the treatment process, 0.198 for the distribution process).

Finally, by comparing the two tables of efficient portfolio of resilience strategies before covid-19 and during covid-19, we can conclude that during covid-19 the company must opt for the same portfolios to separately optimize the resilience of the supply and treatment processes.. On the other hand, maximizing the total resilience of the three processes simultaneously with the same importance to the processes will give us new solutions. In general, resilience levels have seen significant declines during covid-19 compared to the pre-covid-19 period.

Conclusion

In this study, we developed the effective resilience capacities of the Tunisian Post's logistics chain in order to mitigate vulnerabilities.

With the increase in frequent external events, Tunisian companies have become more vulnerable to the consequences of these events. Any organization must properly manage the risks of the logistics chain in order to face the harmful effects of globalization and its side effects and to guarantee its sustainability and development. The Tunisian economy went through an acute crisis, because the shock was important and strong, and upset all the fundamentals. Several sectors of economic activity have been blocked in recent years.

The current socio-political situation in Tunisia has created enormous management and development difficulties in most Tunisian companies, which prevents the managers of these companies from developing conceptions of supply chain risk management. The increase in different types of risks has prevented Tunisian companies from becoming aware of supply chain risk management.

SCRM is collaboration with partners by applying tools and strategies to reduce the vulnerability of the supply chain. Recently, the disruptive effects of COVID-19 have impacted the global economy and crippled several sectors and this crisis has affected all activities of all types of companies. In fact, everyone is affected on all fronts and on all levels.

Logistics chains have experienced various incidents such as the Tunisian revolution, the Corona Virus, the devaluation of the Tunisian dinar, the recession in tourism, strikes, changes in employee values, conditions that have pushed companies to seek new avenues. to reduce failures and also deal with unexpected upheavals. Therefore, developing supply chain resilience becomes crucial. Supply chain resilience is about the ability of businesses to recover operations from unforeseen disruptions and reduce the impact of those disruptions.

As a result, the need for a more efficient supply chain (SC) to mitigate vulnerabilities has become paramount. Our research methodology is based on the principle of field experimentation. The socio-economic approach therefore constitutes the methodological basis of our research, it is a management method integrating the social dimension of the company and its economic performance. We must provide an analysis model that meets our observation objective.

The common thread of our work is the shift from directive management to participatory management by objectives, by integrating a new production process, synchronizing the different information and physical flows between the different players in a logistics chain.

The economic context, in which companies had evolved, did not allow neither to produce efficiently, nor to have a good profitability for the company. As a result, it is not only management, which is the solution for setting up such an enterprise. The main objective has been to identify the existing vulnerabilities related to the postal sector in Tunisia and find the optimal strategy of effective resilience strategies in order to mitigate the vulnerabilities of the supply chain.

Indeed, the postal sector remains one of the levers of Tunisian economic growth. By the end of the 1990s, this sector had slowed down and Tunisia's world rank deteriorated slightly. This sector is exposed to several types of vulnerabilities:vulnerability to danger, strategic vulnerability, financial vulnerability, operational vulnerability, infrastructure vulnerability, and demand and supply vulnerability.

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