CCAHP: A NEW METHOD FOR GROUP DECISION MAKING APPLICATION ON SUPPLY CHAIN DASHBOARD DESIGN

YASSINE EL KHAYYAM & BRAHIM HERROU

*Laboratory of Industrial Techniques, Faculty of Sciences and Techniques of Fez,
Sidi Mohamed Ben Abdellah, Fez University, Morocco*

ABSTRACT

The effective resolution of a problem that concerns several actors requires first of all the involvement of every actor in the choice of the appropriate solution which must be commonly accepted in order to facilitate its implementation. As a result, group decision-making must incorporate a consensus reaching process. In this study, we introduce CCAHP Collaborative and Clustering Analytic Hierarchy Process» method which is a hybrid form of the multi-criteria analysis method AHP that integrates together artificial intelligence and collective intelligence.

Then we apply the proposed method to build a dashboard for supply chain risk and performance management (SCRPM), which allow managing performance (under performance: "normal risks") on one side, and on the other managing abnormal risks (disruption, incidents, etc.).

KEYWORDS: Multi-Criteria Analysis, Group Decision-Making, K-means, SCRPM, CCAHP, Supply Chain, Performance & Risk

Received: Feb 19, 2018; **Accepted:** Mar 09, 2018; **Published:** Apr 05, 2018; **Paper Id.:** IJMPERDAPR2018150

INTRODUCTION

The aim of this article is to propose a new multi-criteria decision analysis method in a multi-actor environment. This approach will allow consensus reaching by using group decision-making, k-means method, and the analytic hierarchy process.

We use the proposed approach "CCAHP" to build a supply chain dashboard which can give rise to effective improvement actions. The effectiveness of improvement actions within a supply chain depends extremely on the consistency between the strategy deployed and the overall context: key factors of competitiveness (costs, quality, delays and level of service), control of uncertainty and risks upstream and downstream of the supply chain.

In the first part, we introduce the different tools used by the proposed method which are k-means method, analytic hierarchy process and consensus reaching process. In the second part, we introduce the supply chain performance and SCOR reference (supply chain operations reference). Then we address risk management by presenting principal frameworks that have been introduced over the last few decades and next we present a range of risks relating to the different parts of the supply chain (upstream, central and downstream). After introducing the two modes of management, performance, and risks, we will highlight the relationship between them, and then we will integrate their life cycles into a single life cycle, the supply chain risk and performance management (SCRPM).

Finally, using a web application developed in our laboratory that will facilitate the CCAHP analysis, we will apply the proposed approach to design a dashboard for the procurement process of a small Moroccan industry.

1. THE CCAHP, A COLLABORATIVE TOOL FOR MULTICRITERIA ANALYSIS

We present in this paragraph the CCAHP method, the aim of this method is consensus reaching in group decision-making. In the following, we introduce the different tools used by the proposed method which are k-means method and the analytic hierarchy process.

1.1. Analytic Hierarchy Process

Multi-criteria decision-making methods are frequently used for decision-making in real problems with several criteria and/or several objectives that are compatible and/or incompatible. These methods are classified into two categories: multi-attribute decision-making (MADM) and multi-objective decision-making (MODM) (Kubler et al., 2016). Multi-attribute decision-making methods involve human intervention to express judgment, yet the human brain is only able to take into account a limited amount of information (Simpson, 1996), which makes the decision-making unreliable solution to complex problems.

The Analytic Hierarchy Process (AHP) introduced by Saaty in 1980 is currently the most used technique for multi-attribute decision making. This technique has its popularity due firstly to its simplicity and secondly to the impartiality and logic offered by its classification system and also to its flexibility of integration with other techniques: linear programming, fuzzy logic, and group decision... (Kubler et al., 2016).

This technique can be described according to the following steps (Vaidya et al., 2006):

- Determine the problem, its objectives, its actors and the expected results.
- Determine the criteria that influence the expected results.
- Structuring the problem, according to a hierarchy of several levels: objective, criteria, sub-criteria and alternatives (Figure. 1).
- Compare the elements of each level, $\frac{n*(n-1)}{2}$ comparisons, in order to construct a pairwise comparison (1).
- Perform the calculations necessary to have the eigenvector of the matrix, the maximum eigenvalue, the consistency index and the consistency ratio.
- If the consistency is acceptable, we take into account the normalized eigenvector as a vector of priorities, otherwise, it is reiterated from step 4.

Figure 1: Generic Structure of AHP

A is the pairwise comparison matrix (1), where a_{ij} ($i, j \in N$) reflects the importance degree of the criterion i regarding to criterion j .

$$A_{n \times n} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (1)$$

The pairwise comparison matrix must satisfy the following rules:

- **Uniformity:** The elements must be comparable.
- **Reciprocity:** $a_{ij} = a_{ji}^{-1}, \forall i, j \in N$ (2)
- **Transitivity:** $a_{ik} = a_{ij} * a_{jk} \forall i, k \in N, j \neq i \text{ and } j \neq k$ (3)

Compliance with rules (2) and (3) plays an essential role in the AHP analysis, both of which serve to ensure the consistency of an expert's judgment (Kubler et al., 2016). The rule (2) comes from the fact that comparisons between the attribute i and the attribute j must be equal to the inverse of the comparison between the attribute j and the attribute i , so we compute only the comparison of a_{ij} and we deduce a_{ji} , the comparison matrix is in the form (4).

$$A_{n \times n} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix} \quad (4)$$

Rule (3) means that each direct comparison a_{ik} must be confirmed by the indirect comparisons $a_{ij} * a_{jk} \forall j$. in other words an expert must be able to perform pairwise comparisons without contradicting itself (Brunelli, 2015). Saaty has proved (Saaty, 1977) that a matrix of n -dimensional comparisons are consistent if only the maximal eigenvector λ_{max} is equal to n , he proposes the consistency index (5) and the consistency ratio (6) for taking into account the dimension of the matrix when calculating the consistency.

$$CI(A) = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

$$CR(A) = \frac{CI(A)}{RI_n} \quad (6)$$

RI_n is a random index, which represents an estimation of the average consistency of a sufficient number of randomly generated n -dimensional matrixes; Table 1 presents a set of random indices as a function of dimension. According to (Saaty, 1977), in practice, the acceptance threshold of a comparison matrix is 0.1.

Table 1: Values of RI_n

n	3	4	5	6	7	8	9	10
RI_n	0.5247	0.8816	1.1086	1.2479	1.3417	1.4057	1.4499	1.4854

1.2. Group Decision Making and the Consensus Building Process

Group decision-making takes up a central position in the economic and managerial world, from a macro view point, voting is a form of group decision-making in democratic nations, also the definition of market mechanisms requires group decision-making to solve economic problems. From a micro viewpoint, there are various problems of group

decision-making in which individuals are led to work and decide in groups. Group decision-making is a task that allows us to find a collective solution to a decision problem in a situation in which a group of experts expresses their judgments about several alternatives, Group decision making can be modeled as follows (Dong et al., 2016).

- $X = \{X_1, X_2, \dots, X_m\}$ ($m \geq 2$) a set of alternatives.
- $E = \{E_1, E_2, \dots, E_n\}$ ($n \geq 2$) an expert group.
- op_k ($k = 1, 2, \dots, n$) Is the judgment given by the expert E_k on the set of alternatives X .

The objective of group decision-making is to combine individual preferences (F : aggregation function) in order to obtain a collective preference.

$$F(op^1, op^2, \dots, op^n) = op^c \quad (7)$$

In equation (7), two notions of group decision-making arise; these are the preference representation structure and the aggregation function. Several preference structures are used in group decision making, among which the order preference structure in which each expert expresses his judgment by ordering the different alternatives. We also cite the relation preference structure where the expert expresses his judgment through attribution of a weight to the different alternatives. The aggregation function plays an important role in group decision-making, several aggregation functions are proposed in the literature, the two basic functions proposed by (Yager, 1988) are the weighted average operator (weight Attributed to the experts, equation 8) and the ordered weighted average operator (weight assigned to the order of the alternatives, equation 9).

$$F^{WA}(y_1, y_2, \dots, y_n) = \sum_1^n (w_i \cdot y_i) \quad (8)$$

$$F^{OWA}(y_1, y_2, \dots, y_n) = \sum_1^n (w_i \cdot y_{(i)}) \quad (9)$$

Group decision-making as defined does not guarantee the achievement of a collective solution accepted by all or the majority of experts, hence the need for consensus-building process. Integrating a consensus-building process into group decision making will make the implementation of the chosen solution more effective as the majority will actively participate in the implementation of the commonly chosen solution. The integration of this process will also promote communication between team members and subsequently create synergy within the group.

The consensus building process, Figure 2, consists of three phases (Dong et al., 2016):

- Use the aggregation function to obtain a collective preference from the individual preferences.
- Use a consensus measurement method to measure the degree of consensus among experts, usually we try to minimize the distance between individual preferences and collective preference.
- Use a feedback mechanism to help experts change their preferences in order to improve the degree of consensus.

The clustering of the different expert's preferences into different classes can help in the measurement of consensus and in the feedback mechanism; the following section introduces clustering methods and particularly K-means method.

Figure 2: Consensus Building Process

1.3. Clustering Methods

In recent decades, clustering methods have played an important role in several fields like social sciences, market analysis, marketing, finance, biology... etc. The aim of classification methods is to group together into homogeneous classes a set of individuals by using a classification criterion (similarity or dissimilarity).

We distinguish the non-hierarchical classification methods aimed at classifying into k classes a studied set (like k -means), These methods are efficient for the treatment of bulky sets but require that we impose the number of classes at the start. Hierarchical classification, for its part, consists in providing a set of partitions in less and less fine classes obtained by successive groupings of partitions (Wu, 2012). In our study ,we are interested in the K -means method, this method applies when we know in advance how many classes we want to get, let us call k this number of classes the algorithm is the following:

- **Step 0:** To initialize the algorithm, randomly select k individuals belonging to the population, these are the k initial centers. The following two steps will then be repeated several times:
- **Step 1: Establishment of Classes:** We divide the set of individuals into k classes by grouping around each center the set of individuals closer to it than to the other centers.
- **Step 2: New Centers Computation:** The gravity centers of the k classes obtained are determined and these points are designated as the new centers.
- **Repetition of Steps 1 and 2:** these two steps are repeated until the algorithm is stabilized, that is to say until the division into classes obtained is (almost) no longer modified by additional iteration.

To evaluate the classification obtained, the Davies-Bouldin (DB) and Dunn indexes can be used (Soares et al., 2017). DB index takes into consideration the centers of the groups to calculate inter and intra-group distances.

$$DB = \frac{1}{n} \sum_{i=1}^n \max_{j \neq i} \left(\frac{\sigma_i + \sigma_j}{d(c_i, c_j)} \right) \quad (10)$$

Where n is the number of groups, c_i is the center of group i , σ_i is the average distance between the elements of group i and $d(c_i, c_j)$ is the distance between group i and group j . The quality of the grouping is better when the index DB is small. This index doesn't provide valid evaluation when the data is very dense or very scattered. This limitation can be avoided by using the Dunn index:

$$D = \frac{\min_{1 \leq i < j \leq n} d(i, j)}{\max_{1 \leq k \leq n} d'(k)} \quad (11)$$

Where $d(i, j)$ is the distance between the group i and the group j , $d'(k)$ is the distance between the elements of the

group k . For an efficient grouping, the intra-group distance should be as small as possible and the inter-group distance should be as large as possible. The quality of the grouping is better when the index D is significant.

1.4. The CCAHP Method

In the proposed method we use in addition to the AHP method, collaborative decision-making (first C of CCAHP) and clustering method (second C of CCAHP). In our context, the structure of preference is in relation where the experts assign a weight to the different alternatives using the analytic hierarchy process. We have also opted for the weighted average operator as an aggregation function. The proposed approach consists of (Figure 3):

- Determine the importance (weight) of each expert in the group.
- Each expert makes the necessary comparisons between the different alternatives and then we determine the priority vector and the consistency ratio of the pairwise comparison matrix expressed by the expert.
- If the consistency ratio is unsatisfactory, invite the expert to adjust his judgments in order to reduce the inconsistency until reaching a well-defined threshold.
- Calculate the new weights associated with the different experts according to the consistency ratio (equation 10).
- Classify the expert's judgments into two classes using the k-means method. If we have a majority class we go to the next step, otherwise we cluster the judgments into $k + 1$ classes (initially $k = 2$) until obtaining a majority class or reaching the iteration limit K . If none of the classes obtained is a majority class, we consider the densest class as the majority class.
- Aggregate the experts' priority vectors belonging to the majority class.
- Suggest to the experts belonging to the classes of least cardinal to modify their judgments by proposing them the previously calculated priority vector.
- If there are changes, check the consistency ratio to invite the expert to adjust his judgments in order to reduce the inconsistency until reaching a certain threshold.
- Calculate the new weights associated to the different experts according to the consistency ratio (equation 10).
- Aggregate the priority vectors using the newly calculated weights.

We calculate the new weights associated with the different experts according to the inconsistency, the weight of an expert is subject to decrease if the latter's judgments are inconsistent. The maximum value of the weight is the initial weight p_0 , and the minimum value is 0 if the judgment is completely inconsistent. We have chosen to reduce the weight exponentially following the increase of inconsistency and to make the weight zero if the consistency ratio is greater than or equal to 1 (the fact that $CR = 1$ is interpreted according to (Saaty, 1980) by the fact that all judgments relative to a pairwise comparison matrix are randomly given). The three conditions below allow us to formulate the relationship between the consistency and the revised weight of an expert according to equation (12):

- Weight decrease exponentially with the increase of inconsistency and for $CR = 1/2, P_r = P_0/8$
- P_0 is the maximum value reached when $CR = 0$.

- Weight is Null from $CR = 1$

$$P_r(c) = P_0 * 8^{-2c} \text{ and } P_r(c) = 0 \text{ if } c > 1 \quad (12)$$

Figure 3: The CCAHP Approach

2. THE SCRPM : SUPPLY CHAIN RISK AND PERFORMANCE MANAGEMENT

2.1. The Supply Chain Performance

Performance measurement provides visibility on the compliance of activities and products with client expectations and operational and strategic objectives. It is used to determine improvement needs in low-performance domains (Bhagwat et al., 2007). The performance of the supply chain downstream part can be described mainly by the performance of the order management, the performance of the after-sales service and the level of customer satisfaction. The performance of order management is characterized by (Bhagwat et al., 2007):

- Order-taking efficiency: the ability to provide accurate and well-timed customer requirements.
- Delivery lead time: The time elapsed between receipt of an order and the delivery of this order.
- Distribution costs.
- Order treatment efficiency: Order treatment can be improved by eliminating non-value-added activities and optimizing processing times along the supply chain from order registration to order delivery.

The performance of the after-sales service and the customer satisfaction can be described mainly by:

- The efficiency and responsiveness of after-sales service.
- Flexibility that reflects a company's ability to satisfy changes in customer requirements, volumes, and lead times (Agarwal et al., 2006).
- Response time of requests for information: for planning purposes, customers may express requests for information

about the feasibility or the status of an order or availability of products (Bhagwat et al., 2007).

As to the upstream part of the supply chain, performance can be described mainly by procurement performance (Gruat La Forme et al., 2007) which is characterized by:

- The quality, cost and lead times of products or components delivered by suppliers.
- The responsiveness and flexibility of suppliers.

And finally for the central part of the supply chain "production", performance is characterized by:

- Costs, lead times, quality (rejects and nonconformities) and availability of products.
- Capacity utilization ratio: capacity used versus maximum possible capacity, this ratio directly impacts the degree of flexibility and lead times.
- Control of inventory management costs.
- The accuracy of the production planning.
- The variety of products which is an information that impacts the supply chain strategy choice, according to (Fisher, 1997) the improvement of performance depends on the choice of the strategy most adapted to the type and variety of products.

For performance measurement within the supply chain, we will base our case study on the indicators provided by the SCOR reference, it is a model for the supply chain management operations, developed by the Supply Chain Council (SCC) on the basis of industry best practices, benchmarking studies and existing IT solutions. SCOR subdivides every supply chain into five types of processes: Planning, Procurement, Manufacturing, Delivery and Returns.

Regarding performance indicators, the model proposes a large number of indicators that are grouped into five criteria: reliability (measured by accuracy of replenishment, lead times on the due dates, perfect orders execution, etc.), the responsiveness (appreciated by the time of replenishment, the delivery times, etc.), agility (reaction time, flexibility of production, etc.), costs (total operations cost, value-added productivity, warranty costs, etc.) and asset management efficiency (Naciri et al., 2015). Each performance axis is composed of one or more level-1 indicators. In order to analyze and improve a performance axis, each level-1 indicator is broken down into a set of level-2 and level-3 indicators (Table 2 source: SCOR, 2012). The model provides to each performance criterion all the activities in relation to it and a set of good practices that can improve it (SCOR, 2012).

2.2. Supply Chain Risk Management

Supply Chain Risk Management is the implementation of a coordinated set of activities to manage risks throughout the chain by means of the efficient identification of risks, the assessment and management of all significant risks with the objective of reducing vulnerability, ensuring business continuity (Schlegel et al., 2015) and improving performance. Like enterprise risk management, the supply chain risk management consists of four stages, first, the identification of risks, then the analysis and evaluation of these risks, afterwards treatment and managing incidents through communication and coordination and finally monitoring and review of risks (Sodhi et al., 2012) Depending on the context of the supply chain and the severity of the impact of risks, several treatment approaches are possible:

- Risk mitigation means taking action to reduce both the probability of occurrence and the risk impact.
- Risk Prevention: means taking steps to reduce the likelihood of risk occurrence.
- Avoiding risk involves avoiding activities that increase the likelihood of risk occurrence.
- Acceptance of a risk: in this case no action is taken as the impact of the risk is either negligible or the cost/benefit analysis reveals that the cost of the risk treatment exceeds the risk impact.
- Risk Sharing: The transfer of risk management to a third party, the purchase of insurance is a method of risk sharing.

Table 2: SCOR Model Indicators

	performance attributes	Level-1 Metric	Calculation	Level-2 Metric
customer focused attribute	Reliability	Perfect Order Fulfillment	$[\text{Total Perfect Orders}] / [\text{Total Number of Orders}] \times 100\%$	% of Orders Delivered In Full Delivery Performance to Customer Commit Date Documentation Accuracy Perfect Condition
	Responsiveness	Order Fulfillment Cycle Time	$[\text{sum actual cycle times for all order delivered}] / [\text{Total Number of Orders delivered}] \text{ in day}$	source cycle time make cycle time deliver cycle time delivery retail cycle time
	Agility	Upside Flexibility	Supply Chain Flexibility is the minimum time required to achieve the unplanned sustainable increase when considering Source, Make, and Deliver components	Upside Source Flexibility Upside Make Flexibility Upside Deliver Flexibility Upside Source Return Flexibility Upside Deliver Return Flexibility
		Upside Adaptability	The maximum sustainable percentage increase in quantity delivered that can be achieved in 30 days.	Upside Source Adaptability Upside Make Adaptability Upside Deliver Adaptability Upside Source Return Adaptability Upside Deliver Return Adaptability
		Downside Adaptability	Downside Source Adaptability + Downside Make Adaptability + Downside Deliver Adaptability	Downside Source Adaptability Downside Make Adaptability Downside Deliver Adaptability
		Overall Value-at-Risk	$\text{VAR } \$ (\text{Plan}) + \text{VAR } \$ (\text{Source}) + \text{VAR } \$ (\text{Make}) + \text{VAR } \$ (\text{Deliver}) + \text{VAR } \$ (\text{Return})$. VAR: Probability of Risk Event (P) x Monetized Impact of Risk Event (I)	Supplier's/Customer's/Products's Risk Rating Value at Risk (Plan) Value at Risk (Source) Value at Risk (Make) Value at Risk (Deliver) Value at Risk (Return)
internal focused attribute	Cost	Total Cost to Serve	sum of : planning cost, sourcing cost, material landed cost, production cost, Order management cost, fulfillment cost, returns cost	planning cost sourcing cost material landed cost production cost Order management cost fulfillment cost returns cost
	Asset Management Efficiency	Cash-to-Cash Cycle Time	$[\text{Inventory Days of Supply}] + [\text{Days Sales Outstanding}] - [\text{Days Payable Outstanding}] \text{ in days}$	Days Sales Outstanding Inventory Days of Supply Days Payable Outstanding
		Return on Fixed Assets	$[(\text{Supply Chain Revenue}) - (\text{Total Cost to Serve})] / [\text{Supply-Chain Fixed Assets}]$	Supply Chain Fixed Assets
		Return on Working Capital	$[(\text{Supply Chain Revenue}) - (\text{Total Cost to Serve})] / ([\text{Inventory}] + [\text{Accounts Receivable}] - [\text{Accounts Payable}])$	Accounts Payable (Payables Outstanding) Accounts Receivable (Sales Outstanding) Inventory

After studying and analyzing the context, the first step in all approaches of risk management is the identification, there are several ways to identify and classify risks, we classify risks in order to distinguish between these risks and establish priorities for risk treatment (Sodhi et al., 2012).

Several methods of risk categorization have been proposed in recent decades. Among these methods is the one that considers two types of supply chain risks, Delays in material flows that are generally predictable, and material flow disruptions throughout the chain that are generally unpredictable and cause considerable damage (Sodhi et al., 2012). A second approach involves two other types of supply chain risk: internal risks (such as capacity, regulations, manufacturing efficiency, costs, and delays) and external risks (market prices, actions of competitors, quality of suppliers, socio-political environment) (Olson, 2014). The third approach is to consider four categories of risks, strategic risks that affect the ability to execute corporate strategy and preserve assets and branding, random risks (random disruption, some of which involve

natural disasters), financial risks and operational risks (Schlegel et al., 2015). The last method is a method based on the organization of the supply chain; we categorize the risks, according to the main processes of each supply chain.

We proposed in (EL Khayyam et al., 2016) a risk management approach related to the supply chain. For each process, there is a risk category: sourcing risks, production risks, and delivery risks. Table 3 summarizes some of the supply chain risks based on supply chain processes. This database should be updated after analyzing context or following the monitoring and risk review.

Table 3: Supply Chain Risks

Supply Risks	Process Risks	Demand Risks	Corporate level Risks
Supplier lead times	Manufacturing yield	Forecast error	Currency exchange rates
Supplier quality	Capacity	Time delays	Political environment
Transportation lead time	Information delays	Outbound transit times	Customs regulations
Subcontractor availability	Time delays	change customer requirements	Weather/acts of God
Supplier pricing	Disruption	Customer pricing	Environmental regulations
Time delay	Systems breakdown	Customer promotions	Industry regulations
Disruption	Receivables	Customer bankruptcy	Country regulations
Import delays	Payables	Product failure	Counterfeiting
Supplier insolvency	Inventory	Warranty issues	Fraud/corruption
Fraud/corruption	Intellectual property	Customer loss	supply chain visibility
Counterfeit material	Human/process error	New product introduction	
Supplier delivery	Planning		
	Product failure		
	Equipment failure		
	Organizational management		
	safety(worker accidents)		

To assess risk, companies use different methods using quantitative models or qualitative methods. Risk analysis generally requires two parameters, the likelihood, or frequency of the risk and the impact of the consequences resulting from it, the combination of these two parameters forms the risk intensity (Sodhi et al., 2012). In practice, the evaluation of the parameters involves assigning a value using a scale from 1 to 4; the intensity of a risk can be calculated according to the following formula.

Risk Intensity (RI) = Impact x Frequency, impact and frequency are between 1 and 4. A risk is considered:

- Low, if $0 < IR \leq 4$
- Medium, if $4 < IR \leq 8$
- Strong, if $8 < IR \leq 12$
- Blocking, if $12 < IR \leq 16$

2.3. Supply Chain Risk and Performance Management (SCRPM)

The relationship between risk, processes, and performance measurement is highlighted in Figure 4. The performance measurement is in relation with the achievement of the objectives of the various supply chain processes, Figure 1 shows the different measurement classes used to quantify the achievement of supply chain objectives (performance axes introduced by the SCOR model (Table 2)). The occurrence of a risk impact one or more supply chain assets, processes are also assets. Risk can be monitored by one or more measures if it is measurable (currency increases, production unavailability...), if not we can reduce the risk occurrence probability, by implementing one or more controls (example: unexpected stock control to avoid the risk of fraud).

Figure 4: The Relationship between Risk and Performance Measurement

The performance management and risk management are both centered on value, the aim of the first is to create value and the objective of the second is to preserve it (Sienou, 2009). These two management approaches seem to be independent nonetheless a recent preoccupation is initiated in the industrial field which tries to combine them by studying:

- What are the different relationships between the concepts of the two management models?
- What are the different relationships between the life cycles of the two management models?

We propose a brief answer to these questions in Figure 4 and Figure 5. The interactions between risk management and performance management dwell on the fact that risk management influences engineering decisions and operational monitoring and similarly, process engineering influences the company's behavior in front of risks.

As for the life cycles of the two management modes, it is clear that the supply chain context analysis is the starting point for the two management modes, next we choose the most appropriate strategy in the context and then we prioritize the indicators according to the context, strategy and highest risks. A prior supply chain risk assessment is necessary for the prioritization of the indicators.

The risk assessment must also take into account the adopted strategy, since the impact of a given risk differs according to the supply chain context and according to the adopted strategy, for example, the impact of the customer requirements changes is high in a lean supply chain while it is moderated in an agile supply chain.

Risk and performance management are used to detect needs for improvement in order to deal with an under performance or a risk alert (risk indicator that reaches the alert threshold). Monitoring is also implemented to detect changes that impact the overall context of the supply chain (Figure 5).

Figure 5: Supply Chain Risk and Performance Management (SCRPM)

To build a dashboard for integrated supply chain management, we propose, as indicated in the preceding paragraphs, to:

- Determine the most appropriate strategy for the supply chain, taking into account demand variability, supply control and key competitiveness factors (cost, quality, lead time and level of service).
- Identify, analyze and evaluate the studied supply chain risks and determine the associated mitigation plans.
- Determine the risk indicators associated with risks that have a high RI.
- Prioritize the different supply chain performance attributes (Table 1) taking into account the adopted strategy and then prioritize within each axis the various associated indicators.
- Gather by performance axis the various indicators resulting from risk analysis and prioritization.

In phases 1, 2 and 4, a decision-makers group is led to choose between several alternatives taking into account a set of criteria, this led us to propose the CCAHP method which will be detailed in the following paragraph.

3. CASE STUDY

We have implemented the proposed approach to build an integrated supply chain dashboard. For this reason, we conducted several interviews with the director of a small footwear industry; the interview was aimed at determining the overall context of the company. The data collected are used in the CCAHP analysis. The group that carried out the context analysis, the risk assessment and the prioritization of the indicators consists of the members of the executive board (five directors). In order to facilitate the computation of the priority vectors, consistency ratios, and the consensus-building process, we have developed, using Java / J2EE technology, a web-based application to collect online and independently the experts' Judgments.

First, we determined the strategy most adapted to the supply chain of the studied company by taking into account the key factors of competitiveness and the uncertainty level upstream and downstream of the chain (Figure 6).

Figure 6: Determination of the Most Adapted Strategy to the Context

We then assessed the risks related to this company's supply chain. Figure 7 presents risks that can impact the supply chain of the studied company, it is mainly concerned with a set of risks organized according to the three main categories of risks: supply, production, and demand risks (see diagram below).

Figure 7: Risks Related to the Supply Chain of the Studied Company

After performing pairwise comparisons and obtaining the aggregate priority vectors for the aggregate preferences of executive board members on two occasions, one for establishing the relations between the frequencies of the different risks and the other for establishing relationships between impacts. We have determined the value of the impact of a single risk, preferably a risk that we can determine its impact accurately and we do the same for a frequency value of a risk (not necessarily the same risk).

We assign the value 4 for the impact of the customer loss (highest impact) and the value 1 for the frequency of product failure rate (lowest frequency). To facilitate the computation of the priority vectors and the consistency ratios, we have developed, using Java/J2EE technology, a web application allowing collecting online and independently the judgments of the different members of the group (EL Khayyam et al., 2017). We obtain the results listed in Table 4.

In conclusion, changes in customer requirements, product failure, delays, and lack of supplier quality, supply chain disruption, and customer loss are the average risks of this company and all the other risks are considered as low risks.

Table 4: Results of the Risk Analysis

Risks	Impact priority	Impact	Frequency priority	Frequency	Risk Intensity
Change customer requirements	8%	2	15%	4	8
Disruption	14%	4	3%	1	4
Customer loss	19%	4	2%	1	4
Time delays	10%	2	9%	2	4
Supplier quality	9%	2	7%	2	4
Product failure	9%	2	7%	2	4
Human/process error	2%	1	9%	2	2
Product failure: process	3%	1	8%	2	2
Systems breakdown	3%	1	8%	2	2
Supplier pricing	7%	2	3%	1	2
Equipment failure	2%	1	7%	2	2
Inventory	2%	1	5%	2	2
Manufacturing yield	1%	1	6%	2	2
Supplier delivery	5%	1	5%	2	2
Customer pricing	2%	1	3%	1	1
Safety(worker accidents)	3%	1	1%	1	1
Capacity	1%	1	3%	1	1

Then we started a survey within the purchasing and procurement department to collect the data needed to build a supply dashboard adapted to the company's strategy and context. The indicators subject to prioritization are derived from the company's indicators and from SCOR reference.

By applying the CCAHP prioritization approach, we prioritize the purchasing process indicators of the studied company. The group involved in this collaborative decision-making is made up of the procurement and supply service members and some heads of other services. Finally, we have combined the indicators derived from risk analysis and those derived from performance analysis (Table 5).

Table 5: Proposed Indicators for Procurement and Supply Service

Indicator	weight	Source
Number of deliveries overdue by supplier	3	Performance and Risk Analysis
Rate of change satisfaction by supplier	3	Risk Analysis
Number of changes sent to suppliers before delivery	3	Risk Analysis
Stock rotation	3	Risk Analysis
Satisfaction Level by supplier	1	Performance Analysis
Number non-compliant delivered products	1	Performance and Risk Analysis
Reduction of the purchase price (compared to the old price)	1	Performance Analysis
Market share	1	Performance Analysis

CONCLUSIONS

In this study, we have proposed a new multi-criteria analysis method in a multi-actor environment that allows reaching consensus among several decision-makers. We used this method for collaborative risk analysis and for prioritizing indicators in order to design a dashboard adapted to the context of the supply chain.

At the same time we have proposed an integrated supply chain management approach, we highlighted the link between risk and performance management and we proposed a framework that integrates the life cycle of risk management and the one of performance management.

REFERENCES

1. R. Bhagwat, M.K. Sharma, *Performance measurement of supply chain management: A balanced scorecard approach*, *Computers & Industrial Engineering* 53 pp. 43–62, 2007
2. A. Agarwal et al., *Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach*, *European Journal of Operational Research* 173 pp.211–225, 2006
3. F.-A. Gruat La Forme et al., *A framework to analyse collaborative performance*, *Computers in Industry* 58 pp. 687–697, 2007
4. M. Fisher, *What is the right supply chain for your product?* *Harvard Bus. Rev.* 75 pp. 105-116, 1997
5. O. Naciri, A. Alami, B. Herrou. *Contribution au pilotage des processus d'une chaine logistique Etude de cas du processus approvisionnement d'une PME marocaine*. *Xieme Conférence Internationale : Conception et Production Int*, Tanger, Maroc, 2015
6. SCOR, *SCOR Version 11.0 Overview*, URL: <http://www.supply-chain.org>, 2012
7. G.L.Schlegel and R.J.Trent, *Supply Chain Risk Management, An Emerging Discipline*. CRC PressTaylor & Francis Group, 2015
8. Antriksh Mutha et al., *Supply Chain Management: A Review*, *International Journal of Industrial Engineering & Technology (IJIET)*, Volume 7, Issue 3, November - December 2017, pp. 1-4
9. M.S.Sodhi and C.S.Tang, *Managing Supply Chain Risk*. *International Series in Operations Research & Management Science* 172, Springer Science+Business Media, LLC 2012

10. L.Olson, *supply chain risk management, tools for analysis*. Business Expert Press, LLC, 2014
11. Y.EL Khayyam and B.Herrou, *Analytical hierarchy process based framework for supply chain risk management*. Volume 7, Issue 7, July 2016 pp 1167-1172 Edition *International Journal of Scientific and Engineering Research (IJSER)* - (ISSN 2229-5518).
12. T.Aven, *Risk Analysis, Assessing Uncertainties beyond Expected Values and Probabilities*. John Wiley & Sons, 2008
13. A. SIENOU, *Proposition d'un cadre méthodologique pour le management intégré des risques et des processus d'entreprise*, Thèse de doctorat en systèmes industriels, sous la direction de Hervé PINGAUD, Toulouse, université de toulouse, 263 p, 2009
14. S.Kubler et al., *A state of the art survey and testbed of fuzzy AHP Applications*. *Expert Systems with applications* 65 pp 308-42, 2016
15. L.Simpson, *Do decision makers know what they prefer?: Mavt and electre ii*. *Journal of the Operational Research Society*, 47 (7), 919–929, 1996
16. T.L.Saaty, *The analytic hierarchy process*. New York: McGraw-Hill, 1980
17. O.Vaidya and S.Kumar, *Analytic hierarchy process: An overview of applications*. *European Journal of operational research*, 169 (1), 1–29, 2006
18. M.Brunelli, *Introducion to the analytic hierarchy process*. Springer-Briefs in Operations Research, 2015
19. T.L.Saaty, *A scaling method for priorities in hierarchical structures*. *Journal of Mathematical Psychology*, 15(3):234–281, 1977
20. Y.Dong and J.Xu, *Consensus Building in Group Decision Making*. Springer Science+Business Media Singapore, 2016
21. R.R. Yager, *On ordered weighted averaging aggregation operators in multicriteria decision making*. *IEEE Trans. Syst. Man Cybern.* 18, 183–190, 1988
22. J. Wu, *Advances in K-means Clustering*, Springer Theses, DOI: 10.1007/978-3-642-29807-3_1, 2012
23. F. Soares and A. Souza - *Neural Network Programming with Java*, 2nd Edition, Birmingham B3 2PB, UK. Packt Publishing, 2017
24. Y. El Khayyam and B. Herrou, "Risk assessment of the supply chain: Approach based on analytic hierarchy process and group decision-making," 2017 *International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*, Rabat, 2017, pp. 135-141. ©2017 IEEE doi: 10.1109/LOGISTIQUA.2017.7962887