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Measuring Environmental Performance of Supply Chain

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ABSTRACT
Environmental performance is a hot topic for researchers in management science. It is also one of the major concerns of supply chain leaders. To assess this performance, there are increasingly many management tools. It is then appropriate to wonder the role of these tools in supply chain: are these tools meet real organizational needs? Or they are used to promote supply chain image face institutional constraints increasingly strong?
In this context, many modules and methodologies have been established in literature in order to evaluate environmental performance of supply chain, since it has become an important issue for society. However, few of them analyze environmental impacts. So, this work presents an integrated methodology to perform this evaluation, based on issues which significantly affect the environment. We purpose a module which will allow the assessment of this performance.This module was tested in an automotive supply chain in north of Morocco.

Keywords:*Environmental performance; Supply chain; Performance evaluation; Environmental indicators; Composite environmental index, Mathematical module*

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I. INTRODUCTION

The issue of reducing environmental impacts appears more and more as a collective responsibility shall be ensured in the daily management of companies [1]. This awareness is reflected in practice by the implementation of Environmental Management Systems (EMS), whose ISO 14001 standard constitute a reference model. Indeed, International Organization for Standardization (ISO) 14001(2004) standard invites companies to adoptEMS in order to improve their environmental performance: “A system of this kind enables an organization to develop an environmental policy, to establish objectives and processes to meet the commitments of its policy, to take necessary actions to improve its performance”.

The companies are already involved in various activities aimed at addressing sustainable development, which has been defined as the creation of goods and services using processes and systems that are non-polluting, conserving energy and natural resources, economically viable, safe and healthful for employees, communities and consumers, socially and creatively rewarding for all working people [2].

At the supply chain level, the strategic importance of environment is also well documented in literature. Various studies report the increasing number of organizations that have implemented sustainability documentation or voluntary codes of conduct within their supply chains for reportingpurposes and performance measurements [3-4]. Supply chain design and planning involve major business and industrial activities, such as materials acquisition, manufacturing, packaging, transportation and recycling, all of which can impose negative environmental impacts if not managed appropriately [5-6]. The environmental aspects may include Greenhouse gas (GHG) emissions, hazardous materials, toxic chemicals and other pollutants as well as land use and resource depletion issues [7]. Governments have been trying to mitigate these issues through enacting tighter environmental regulatory legislation.Evaluation of environmental performance of supply chain requires the implementation of tools more or less innovative: green accounts, green dashboard, etc. These tools provide information on the environmental impacts of supply chains and on the measures taken to limit the depletion of natural resources. Among these tools, audits and environmental indicators are increasingly used by companies because, recommended by ISO standards, they allow to leaders to "assess the level of environmental performance of their companies and identify potential areas which need improvement [8]. What about the reality? These tools really reflect the environmental performance of supply chains? They are actually used to improve environmental performance of supply chains?

So,our goal in this article is to provide a tool which will enable the determination of environmental performance of supply chain.

II. LITERATURE REVIEW

2.1 Supply chain

2.1.1 Definition

There are in literatures many definitions of logistic chain. Of these, we adopt the following one: "A supply chain is a system of subcontractors, producers, distributors, retailers and customers between which exchanges the material flows in the sense from suppliers to customers and information flow in both senses" [9]. In supply chain, we distinguish three types of flows: physical, informational and financial. Physical flows relate to all materials that pass through the supply chain from upstream to downstream (raw materials, intermediate products and finished products). Other materials can flow from downstream to upstream, such as containers, packaging, pallets, product returns or end-of-life products in the case of reverse logistics. Informational flows concern exchange of information and data between actors of chain (stocks and outstanding level, customer demand, etc.) which are made in both sense. Finally, financial flows are the cash flows associated with the physical flow.

2.1.2 Types of supply chains

Typologies of supply chains different following the properties of players involved there:

- If the sites are located in different countries, it is called global supply chain.
- If partners all belong to the same legal entity (even if the firm is multi-sites) it is called internal supply chain.
- If several firms are working within supply chain, but one of them plays a dominant and central role, it is called an extended enterprise.
- In case where several firms are working within the supply chain, but where steering is decentralized or at least semi decentralized with bilateral negotiations between pairs of partners, it is called a virtual firm.

2.1.3 Supply chain functions

The supply chain functions ranging from raw material purchase to sale of finished products through production, storage and distribution:

- Supplying: is the most upstream function of supply chain.Supplied materials and components constitute from 60% to 70% of costs of manufactured products [10] in a majority of firms.
- Production: the production function is central in supply chain, this is the skills hold by firm to manufacture, develop or transform raw materials into products or services.
- Storage: the storage includes all quantities stored throughout the process beginning with raw material, components, work in progress and finally finished products.
- Distribution and transport: transportation of raw materials, transportation of components between plants, transportation of components to storage centers or to distribution centers and delivery of finished products to customers.
- Sale: The sale function is the ultimate function in a supply chain; its effectiveness depends on performance of functions upstream.

2.1.4 Decisions in supply chain

Supply chain management is a widely studied topic in scientific literature. We will approach it from a sustainable point of view, which today is more innovative.

We can classify decisions about supply chain management in three categories [11]:

Strategic decision:concerns decisions taken by senior management on long term (from six months to several years).

Tactical decision: is concerned with decisions taken by the company's executives over the medium term that is to say from a few weeks to few months.

Operational decision: has a more limited scope in space and in time. These are decisions taken by team leaders during day or week.

2.1.5 Supply chain management

Like supply chain, the concept of supply chain management has led to several definitions, among these, we adopt the following one:

"Supply chain management is a set of approaches used to effectively integrate suppliers, producers, distributors, so that merchandise is produced and distributed in the right quantity, at the right place and at the right time in order to minimize costs and ensure the service level required by customer." [12].

2.2. Environmental performance

2.2.1 Environmental performance concept

Environmental performance, like any performance, is a notion largely undetermined, complex, contingent and source of subjective interpretations[13].In environmental management domain, it is defined as: "the measurable results of the environmental management system, in relationship withthemasterly by organization of its environmental aspects on basis of its environmental policy, its environmental objectives and targets." [8].The performance is contingent on each firm since it depends on environmental policy which is unique by definition.Indeed, this policy takes into account mission, values, local and regional conditions of each firm and requirements of its stakeholders [14].

Far from the debate about what the environmental performance, it is conceivable,like performance in general, that environmental performance exists only if it can be measured.Indeed, the performance exists only ifcan be measured and this measure may in no case be limited to the knowledge of a result [15].

2.2.2 Tools for measuring environmental performance

Quantitative measurement of environmental performance (EP) by companies is a difficult task. The most challenging part is the development of a reliable proxy that is widely accepted[16].

To measure environmental performance, firms that adopt an EMS under ISO 14000 standards are establishing indicators systems and environmental audits.The main difference between these two tools is the fact that indicators allow a permanent measure of performance, while environmental audits are conducted periodically to verify the conformity of system to well-defined requirements.But these tools have limitations to assessing environmental performance of firms.

- ***Environmental indicators***

Environmental indicators are magnitudes, established from observable or calculable quantities, reflecting by various possible ways the environmental impact caused by a given activity [17].These indicators can be gathered in an environmental dashboard that organizes them synthetically for an internal use [18].

ISO 14031 standard includes indicators into two categories:

- Environmental Performance Indicators : there are two types of indicators:
  - Management Performance Indicators: provide information on efforts made by leadership to influence environmental performance of company's operations.
  - Operational performance indicators: produce information on environmental performance of company's operations.
- Indicators of environmental condition: give information on local, regional, national or international condition of environment. They allow seeing the link between state ofenvironment at a given time and company's activities.These data may help company to better take into account impact or potential impact of its environmental aspects, and thus facilitate planning and implementation of environmental performance assessment.

- ***Environmental audits***

Environmental audit is a management tool which aims to systematic, documented, periodic and objective evaluation of company functioning from an environmental point of view [19]. Conducting an environmental audit is a mandatory step in certification process of ISO 14001 standards. Audit is a key element in functioning of EMS by strategic information it provides, but also as a proactive tool since it allows detecting latent problems that could degenerate into crisis [14].

In addition, when audit is performed by an independent organization, it can provide assurance to stakeholders that everything is done to meet their expectations.In this context, audit gives credibility to environmental management of company.It helps reduce risks, ensuring reliability of data and is susceptible to affect the company's image.

III. PROPOSAL OF A MATHEMATICAL MODULE TO ASSESS ENVERONMENTAL PERFORMANCE OF SUPPLY CHAIN

3.1 Modeling of supply chain by activities

The majority of supply chains affect negatively the environment. The findings reveal that stakeholders perceive mining impacts on social and environmental domains negatively in contrast to a positive perception about economic impacts [20].

To assess environmental performance of supply chain and plan operations of this one, it is necessary to describe production system used.The level of abstraction of model describing this production system depends, of its characteristics, level decisions, elements that we want to study and accuracy of performance measurement that we want to get.

We retain the approach by activities that considers an activity consumes more resources such as labor, energy, water etc. to transform a product (s) coming into product (s) outgoing (s) using a certain type of technology (several alternative technologies can be used) which specifies how inputs are transformed into outputs [21]. Undesirable products such as waste, CO_2 and other emissions can also be generated (Fig. 1).This approach provides a finer and more realistic modeling of production system.Characteristics of this latter are better taken into account on the one hand, and quality of performance measurement is improved on the other hand.

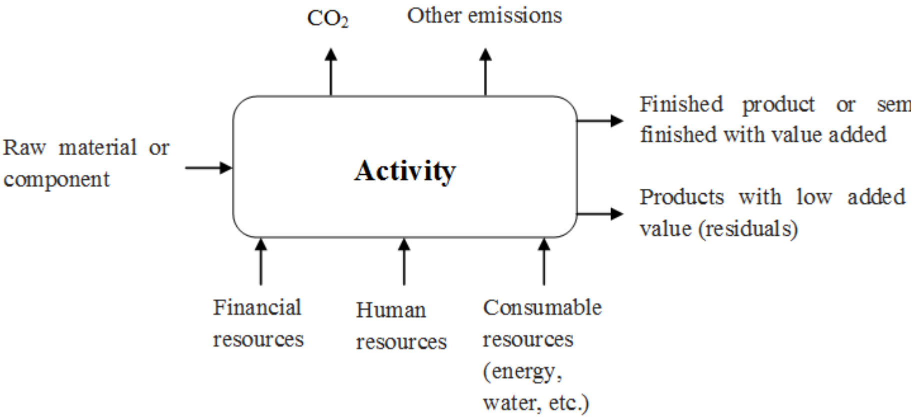

Fig. 1.Activity description

3.2 Mathematical module for environmental planning of supply chain

Customer demand and resource capacity being known, how supply chain could be configured and exploited optimally, to meet customer demand without exceeding the capacity of available resources while guaranteeing a "good" environmental performance?

We consider the case of a multi-echelon supply chain which is composed from several potential suppliers and subcontractors, several production sites and several clients. Production sites are differentiated by the consumption of resources (energy, water, labor, etc.) and pollutant emissions (gases, liquids, solids etc.). Furthermore, different modes of transport (train, truck, etc.) can be used between supply chain links. Finally, we consider several regions where production sites are located (Fig. 2). The assumptions of mathematical module are as follows:

1. Supply chain is managed centrally by a single entity which coordinates all operations.
2. Planning horizon is multi-periods.
3. Part of production can be outsourced on one or more periods.
4. Suppliers and subcontractors are assumed to be logistics partners usual of the supply chain.
5. Supply chain does not have its own transport fleet and use external providers.
6. Production processes are convergent: more incoming products are mixed or assembled together to get the outgoing product (automotive industry for example).

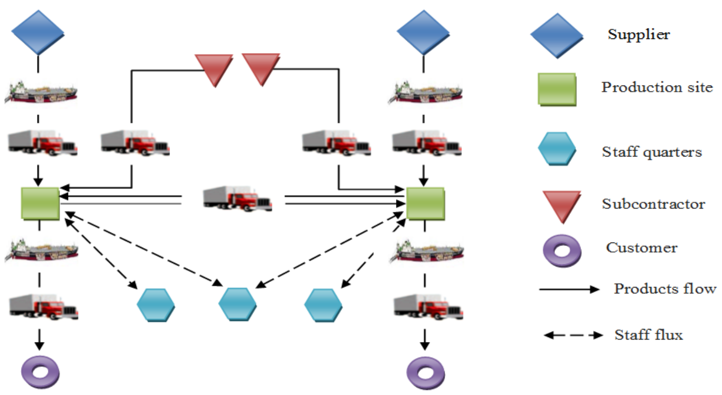

Fig. 2.A supply chain example

3.3 Identification of environmental performance indicators which we need to assess

We based our selection of indicators on the three recommended requirements by Roy (1985)[22]:

- **Completeness**: we must not it has too few criteria; otherwise, it means that some assessment elements were not taken into account.
- **Non-redundant**: it should not be that there are indicators that are duplicated, thus more than necessary.
- **Consistency**: global preferences (all indicators) are consistent with local preferences (for single indicator).

Table 1 presents environmental indicators of our module:

Table 1. Environmental indicators of supply chain

Environmental criteria	Symbol	Unit
Liquid pollutants	M_{liquid}	Cubic meter (m^3)
Solid pollutants	M_{solid}	Kilogram (kg)
Greenhouse gas	M_{ghg}	Kilogram (kg)
Noise pollution	D_{noise}	Decibel (dB)
Energy consumed	E_{energy}	Joule (J)
Water consumed	V_{water}	Cubic meter (m^3)
Raw material consumed	$M_{raw\ mat}$	Kilogram (kg)
Environmental budget	E_{budget}	Euro (EUR)

3.4 Determination of environmental indicators values

3.4.1 Decision variables of mathematical module

Decision variables of mathematical module are as follow:

- R: all employee residences
- S: all suppliers
- SC: all subcontractors
- F: all production sites
- C: all customers
- N: all supply chain links such as $N = S \cup SC \cup F \cup C$

We consider that supply chain contains:

- R_N employee residences
- S_N suppliers
- SC_N subcontractors
- F_N production sites
- C_N customers

Such as: $R_N, S_N, SC_N, F_N, C_N \in [1, +\infty[$

3.4.2 Environmental indicators values

- *Solid wastes*

A waste is a material that is discarded after it has performed a work. It is therefore something which become useless. Solid adjective, mentions what is solid or firm. A solid body retains its volume due to high cohesion of molecules. In this way, it differs from other aggregation states of matter such as liquid or gas states. Solid wastes are therefore those who are in this state. Supply chain is one of the major generators of this type of waste.

For supply chain, we propose to determine the amount of this waste through the summing of solid waste generated by all production sites of this chain following the equation (1) below.

$$M_{solid,t} = \sum_{a=1}^{a=F_N} M_{solid,a} \qquad (1)$$

- *Liquid wastes*

Liquid waste can be defined as such fluids as wastewater, fats, oils or grease, used oil, and hazardous household liquids, to name a few.All other types of liquid waste, including those generated by a business, must be properly disposed of by a licensed waste hauler. Disposal of such waste, such as transmission fluid, cooking oil, fats, or grease, should not be improperly disposed of by throwing it on the ground, down manholes or storm drains, or down any household drains as these items can contaminate the groundwater or negatively impact the wastewater system.

$$M_{liquid,t} = \sum_{a=1}^{a=F_N} M_{liquid,a} \qquad (2)$$

- *Greenhouse gas*

Greenhouse Gases (GHG) are gases that absorb some sunlight redistributing them in the form of radiation within the Earth's atmosphere, called greenhouse phenomenon.
Over forty of greenhouse gases were identified, including the ones shown in Table 2.

Table 2.Main greenhouse gas

Greenhouse gas	Relative percentage
Carbon dioxide (CO_2)	70%
Methane (CH_4)	13%
Nitrous oxide (N_2O)	16%
Hydro fluorocarbons (HFC)	
Per fluorocarbons (PFC)	2%
Sulfur hexafluoride (SF_6)	

Amount of greenhouse gas generated by displacements between: production sites, production sites and employee residences, productionsites and suppliers, production sites and subcontractorsand production sites and customers represent the total of greenhouse gas generated by supply chain (Equation (3)).

$$M_{ghg,t} = \sum_{a=1}^{a=F_N} M_{ghg,a} + \sum_{b,b'=1}^{b=F_N,b'=R_N} M_{ghg,bb'} + \sum_{c,c'=1}^{c=F_N,c'=S_N} M_{ghg,cc'} \text{❶} + \sum_{d,d'=1}^{d=F_N,d'=SC_N} M_{ghg,dd'} \text{❷}$$
$$+ \sum_{e,e'=1}^{e=F_N,e'=C_N} M_{ghg,ee'} \text{❸} \qquad (3)$$

- *Noise pollution*

The concept of noise pollution generally includes noises, and pollutions caused by sound. They can be caused by various sources and the consequences can range from temporary gene to serious impacts on the health and quality of life of humans, but also to impaired functioning of ecosystems, can range up to kill animals, or prevent their normal reproduction.
We adopt the same trajectories as in greenhouse gas case; value of sound pollution generated throughout supply chain is calculated basing on equation (4) below:

$$D_{noise,t} = \sum_{a=1}^{a=F_N} D_{noise,a} + \sum_{b,b'=1}^{b=F_N,b'=R_N} D_{noise,bb'} + \sum_{c,c'=1}^{c=F_N,c'=S_N} D_{noise,cc'} \text{❶} + \sum_{d,d'=1}^{d=F_N,d'=SC_N} D_{noise,dd'} \text{❷} + \sum_{e,e'=1}^{e=F_N,e'=C_N} D_{noise,ee'} \text{❸} \qquad (4)$$

- *Energy consumed*

Energy refers to an ability to act: put in motion, heat, light,etc. It is obtained by fuels combustion (petrol, diesel, coal, wood, etc ...), by use of electricity or natural forces like wind or solar energy.Each supply chain consumes energy, so in order to evaluate this energy consumed by supply chain; we propose the following equation (5) which takes into account the same trajectories as in greenhouse gas and noise pollution cases.

$$E_{energy,t} = \sum_{a=1}^{a=F_N} E_{energy,a} + \sum_{b,b'=1}^{b=F_N,b'=R_N} E_{energy,bb'} + \sum_{c,c'=1}^{c=F_N,c'=S_N} E_{energy,cc'} \text{❶} + \sum_{d,d'=1}^{d=F_N,d'=SC_N} E_{energy,dd'} \text{❷} + \sum_{e,e'=1}^{e=F_N,e'=C_N} E_{energy,ee'} \text{❸} \qquad (5)$$

N.B: Elements ❶, ❷ and ❸ can be annulled or not according to contract signed between supply chain leaders on one hand and suppliers, subcontractors and customers on the other hand.

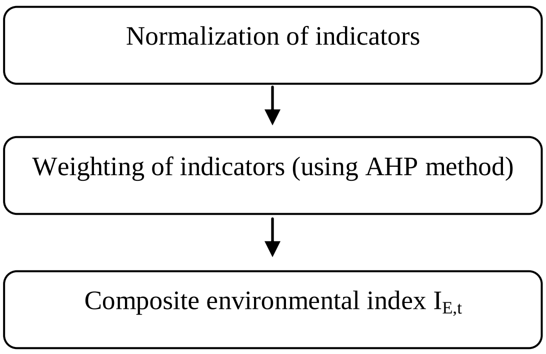

Fig. 3. Calculation procedure of $I_{E,t}$

- *Water consumed*

Water consumed by supply chain is the quantity of water consumed by all production sites which constitute this chain (Equation 6).

$$V_{water,t} = \sum_{a=1}^{a=F_N} V_{water,a} \qquad (6)$$

- *Raw material consumed*

A raw material is a product in its raw state or having undergone primary processing at production place to make it fit for international exchange,used in the production of finished products or as an energy source. For those intended to food, we talk instead of commodities.
Raw material consumed by supply chain is the total of Raw material quantity consumed by all production sites which constitute this chain (Equation 7).

$$M_{raw\ mat,t} = \sum_{a=1}^{a=F_N} M_{raw\ mat,a} \qquad (7)$$

- *Environmental budget*

The environmental budget is the translation expressed in monetary (Euro, Dollars…) value of funds dedicated to improving environmental performance of supply chain during a specified period.

3.5 Measuring environmental performance of supply chain

Integrated information on environmental performance of a supply chain is very essential for decision-making, but it is very difficult to evaluate because of too many indicators. The proposed model reduces the number of indicators by aggregating them into a composite environmental index ($I_{E,t}$) which reflects environmental performance of supply chain (Fig. 3).

Environmental indicators are divided into two groups:

- Indicators whose increasing value has a positive impact (I_A^+) on environmental performance of supply chain:
  - Liquid wastes
  - Solid wastes
  - Greenhouse gas
  - Noise pollution
  - Energy consumed
  - Water consumed
  - Raw material consumed
- Indicator whose increasing value has a negative impact (I_A^-) on environmental performance of supply chain:
  - Environmental budget

For example, increased value of air emissions per unit of production clearly has a negative impact, while increased environmental budget has a positive impact.
The main problem of aggregating indicators into$I_{E,t}$ is the fact that indicators are expressed in different units. One way to solve this problem could be normalizing each indicator i by dividing its value over time t with its average value over all the time measured (Equations (8) and (9)).

$$I_{N,it}^{+} = \frac{I_{A,it}^{+}}{\bar{I}_{A,i}} \qquad (8)$$

$$I_{N,it}^{-} = \frac{I_{A,it}^{-}}{\bar{I}_{A,i}} \qquad (9)$$

Where $I_{N,it}^{+}$ is the normalized indicator i (with positive impact) over the time t and $I_{N,it}^{-}$ is the normalized indicator i (with negative impact) over the same time t.Thus the possibility of incorporating different kinds of quantities, with different units of measurement is offered. Among the advantages of the proposed normalization of indicators is the clear compatibility of different indicators, since all indicators are normalized.

Next procedural part of calculation of$I_{E,t}$ involves determining weights, which should be combined with each indicator. The weights of environmental indicators can be obtained from environmental expert surveys or from public surveys about environmental themes. Therefore, to derive the weights practically, the Analytic Hierarchy Process (AHP) was used in this module.

We build a matrix *A*= (n x n) (in our case n=8); where indicators are compared 2 by 2 by the decision maker. The comparisons are made by posing the question which of two indicators i and j is more important from environmental point of view. The intensity of preference is expressed on a factor scale from 1 to 9 (Table 3).

Table 3. Comparison scale of AHP method [23]

Preference factor, p	Importance definition
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance of one over another
7	Very strong or demonstrated importance of one over another
9	Extreme importance of one over another
2,4,6,8	Intermediate values
Reciprocal, 1/p	Reciprocal for inverse comparison

The value of 1 indicates equality between the two indicators while a preference of 9 indicates that one indicator is nine times more important than the one which it is being compared. This scale was chosen, because in this way comparisons are being made within a limited range where perception is sensitive enough to make a distinction. In the matrix A, if indicator i is “p-times” the importance of indicator j, then necessarily, indicator j is “1/p-times” the importance of indicator i, where the diagonal $a_{ii} = 1$ and reciprocal property

$$a_{ji} = \left(\frac{1}{a_{ij}}\right) \ \textit{such as}\ i, j = 1.., n.$$

Weight of indicators i $(W_i)$is given by the formula:

$$W_i = \frac{\sum_{k'=1}^{n} \frac{a_{ik'}}{\sum_{k=1}^{n} a_{kk'}}}{n} \qquad (10)$$

One disadvantage of AHP method outlined in literature [24] is the problem ofintransitivity preferences. Indeed, pair wise comparison may lead to the non-transitivity that cannot be removed as part of AHP method. However, perfect consistency rarely occurs in practice. In AHP method the pair wise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10% [25]. CR coefficient is calculated as follows: first a consistency index (CI) needs to be estimated. This is done by adding the columns in the judgment matrix and multiply the resulting vector by the vector of priorities (i.e., the approximated eigenvector) obtained earlier. This yields an approximation of the maximum eigenvalue, denoted byλ_{max} . Then, CI value is calculated by using the formula:

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (11)$$

Next, CR is obtained by dividing CI by random consistency index (RI) as given in table 4.

Table 4. RI values for different values of n

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Otherwise matrix A should be evaluated:

$$CR = CI/RI \qquad (13)$$

Finally, composite environmental index $(I_{E,t})$ in period t can be derived as shown in equation (14):

$$I_{E,t=} W_{budget,t} \times I^{+}_{N,budget,t} + \sum_{i=1}^{7} W_i \times I^{-}_{N,it} \quad \text{where} \quad \sum_{i=1}^{8} W_i = 1 \ \text{ and } \ W_i \geq 0 \quad (14)$$

IV. APPLICATION

The reliability of the proposed module has been tested in a case study. We chose an automotive supply chain installed in north of Morocco (Tangier). Its principal business activity is electrical harnesses for cars.
Achieving environmental leadership of its branch is therefore a core principle at the supply chain. This chain, addresses environmental risks, at strategic level with its own standards and guidelines. All production sites of this supply chaincover the entire life cycle of products and have integrated ecological aspects in product innovation with the goal of achieving competitiveadvantage. The data needed have been obtained from department of environment.
This supply chain is constituted of:

- Three of production sites (in Tangier)
- Eight suppliers (in Tangier)
- Three customer (In United Kingdom,France and United States)

To evaluate environmental performance, the proposed module was applied to the case chain and $I_{E,t}$ was delivered for the three years 2013, 2014 and 2015.

4.1 *Creating the composite environmental index for a case supply chain*

The environmental dimension of sustainability concerns impacts of the company on living and non-living natural systems, including ecosystems, land, air and water. Environmental metrics should give a balanced view of the environmental impact of inputs – resource usage, and outputs – emissions, effluents and waste, and the products and services produced. Of the three types of sustainability indicators, environmental measures of performance are most developed and have achieved the highest degree of consensus among experts [26]. Table 5 presents environmental indicators of the case supply chain.

Table 5. Indicators of the case supply chain

Indicator	Symbol	Unit	2013	2014	2015	Average
Solid pollutants	M_{solid}	t	52.663	49.176	51.238	51.026
Liquid pollutants	M_{liquid}	m^3	1.499	1.568	1.244	1.437
Greenhouse gas	M_{ghg}	t	0.872	0.922	0.727	0.840
Noise pollution	D_{noise}	dB	94	97	102	97.667
Energy consumed	E_{energy}	GJ	14.686	17.528	15.197	15.804
Water consumed	Wwater	m^3	20.045	17.572	15.122	17.580
Raw material consumed	$M_{raw\ mat}$	t	172.117	212.356	192.548	192.340
Environmental budget	E_{budget}	EUR	70000	82000	85000	79000

To determine the weights of the indicators, pair-wise comparisons of indicators according to their impact to environmental performance assessment of the supply chain have been performed. Priorities are assumed and may vary as to opinion of decision-makers of the supply chain. The results are shown in Table 6.

Table 6. Pair-wise comparison matrix for evaluation of estimated weights of indicators

Indicators	M_{solid}	M_{liquid}	M_{ghg}	D_{noise}	E_{energy}	V_{water}	$M_{raw\ mat}$	E_{budget}	Weights
M_{solid}	1	1	1/2	1	1/2	1	1/2	1	
M_{liquid}	1	1	1/2	1	1/2	1	1/2	1	
M_{ghg}	2	2	1	2	1.000	3	1	2	
D_{noise}	1	1	1/2	1	1/3	1	1/3	1/2	
E_{energy}	2	2	1	3	1.000	2	1	2	
V_{water}	1	1	1/3	1	1/2	1	0.5	1/2	
$m_{raw\ mat}$	2	2	1	3	1.000	2	1	2	
E_{budget}	1	1	1/2	2	1/2	2	1/2	1	
$\sum$	11.000	10.000	5.333	14.000	5.333	13.000	5.333	10.000	
M_{solid}	0.091	0.100	0.094	0.071	0.094	0.077	0.094	0.100	0.090
M_{liquid}	0.091	0.100	0.094	0.071	0.094	0.077	0.094	0.100	0.090
M_{ghg}	0.182	0.200	0.188	0.143	0.188	0.231	0.188	0.200	0.190
D_{noise}	0.091	0.100	0.094	0.071	0.062	0.077	0.062	0.050	0.076
E_{energy}	0.182	0.200	0.188	0.214	0.188	0.154	0.188	0.200	0.189
V_{water}	0.091	0.100	0.062	0.071	0.094	0.077	0.094	0.050	0.080
$M_{raw\ mat}$	0.182	0.200	0.188	0.214	0.188	0.154	0.188	0.200	0.189
E_{budget}	0.091	0.000	0.094	0.143	0.094	0.154	0.094	0.100	0.096

Data of the case supply chain does not measure all environmentalindicators usingcommon units. However, that is neither expected nor possible. To get rid of units the normalizationof indicators was performed using equation 1 and 2. In that wayindicators became combinable and the derivation of $(I_{E,t})$ was possible. Normalized results are presented in Table7.

Table 7. Normalized indicators of the case supply chain

I	Indicator	Symbol	Weight	2013	2014	2015
1	Solid pollutants	M_{solid}	0.090	1.032	0.964	1.004
2	Liquid pollutants	M_{liquid}	0.090	1.043	1.091	0.866
3	Greenhouse gas	M_{ghg}	0.190	1.038	1.098	0.865
4	Noise pollution	D_{noise}	0.076	0.962	0.993	1.044
5	Energy consumed	E_{energy}	0.189	0.929	1.109	0.962
6	Water consumed	Wwater	0.080	1.140	1.000	0.860
7	Raw material consumed	$M_{raw\ mat}$	0.189	0.895	1.104	1.001
8	Environmental budget	E_{budget}	0.096	0.886	1.038	1.076

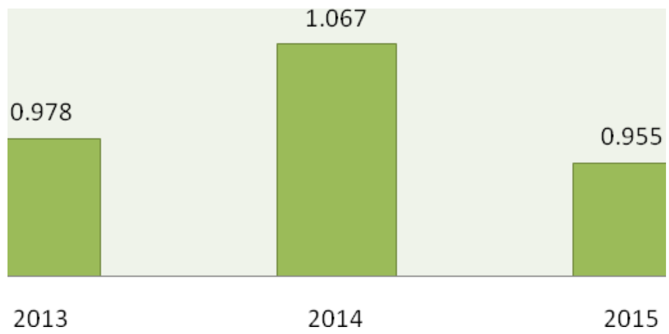

Fig. 4. Variation of composite environmental index $I_{E,t}$of the case supply chain over a time interval 2013–2015.

To calculate the composite environmental index $I_{E,t}$in time t, the normalized value of each indicator was multiplied by itsweight (Equation (14)). The normalized indicators with positive/negative impact were chosen from the perspective of sustainability as follows:

$$I^{+}_{N,it} = E_{budget}$$

$$I^{-}_{N,it} = M_{solid}, M_{liquid}, M_{ghg}, D_{noise}, E_{energy}, V_{water}, M_{raw\ mat}$$

Table 8. Values of composite environmental index $I_{E,t}$

	2013	2014	2015
$I_{E,t}$	0.978	1.067	0.955

4.2. Interpretation of results

Eight environmental indicators were aggregated into composite environmental index $I_{E,t}$ for a case supply chain for the three period of time (t = years) (Table 8). Figure 4 shows the variation of composite environmental index $I_{E,t}$for the case supply chainover a time interval of years 2013–2015.

$I_{E,t}$ of the case supply chain reached the highest value in the year 2014, but in the year 2015 it decreased.Following these results, the case supply chain is not on a truly environmental path.Environmental performance of this supply chain has been increasing between 2013 and 2014 with a small decrease in year 2015. It had some issues on which its environmental performance was not progressing like it should. We can explain this decrease in environmental performance between 2014 and 2015 by the increasing of solid wastes levels and noise generated by this supply chain (Table 5). Increasing and decreasing in environmental performance between 2013 and 2015 indicate that this supply chain should improve its environmental performance more than its level of 2014.

4.3 Contribution of composite environmental index and its pertinence

The importance of environment in our daily life requires the measure of our impact on it. So, by this composite environmental index, we can get a simplified and quantified expression of environmental performance of any supply chain. This index (composite environmental index), can be used to inform decision-makers about environmental performance achieved throughout their supply chain, and then the determination of actions which should be applied. However, it may also be used toprovide informationto critical decision processes.$I_{E,t}$ helps us to improve environmental performance and where best practices might be found. The decision-makers of supply chain could easily interpret this index, then finding the correct sense which they should react. If enclosed in the periodic environmental report, the $I_{E,t}$could also be used to present the progress of the supply chain to the various parties interested in environmental performance of the supply chain. As $I_{E,t}$would be applied to different supply chains, it would be possible to compare and rank them in terms of environmental performance.

By this module, we provide the decision maker a tool which allows him:

- To analyze the current and potential value of activities implemented andto consider actions to strengthen this value as such the implementation of environmental best practices. This analysis allows him to define the scope of activities and to consider several options for this end, as part of differentiation strategy by CSR (Corporate Social Responsibility).
- To analyze the profile of the environmental performance related to supply chain decisions during the planning phase, choose the configuration of the chain and the way to exploit it in advanced and optimized manner in order to ensure target level of environmental performance. This level of environmental performance defines the strategy or CSR policy that the decision maker wishes to implement.
- To know precisely the additional investment in terms monetary, which he must engage to achieve the level of environmental performance desired.
- And finally, to have quantitative performance indicator which used to control the supply chain and for the purposes of communication.

V. CONCLUSION

Organizations have made tremendous progress in environmental protection abreast of recent years. Faced with popular and regulatory pressures, they have had no choice but to develop an environmental management increasingly rigorous. However, in most organizations, the environment remains on the margins of activity producing value. This is one reason why environmental protection is seen even today as an additional production cost.

Applying the principles of sustainable development in industrial management, in other words, CSR is still a difficult task. In this sense, companies have very little knowledge and tools and consulting firms are often helpless against the demands of companies that want to engage in CSR. Since the concept of CSR was first proposed by the Caux Roundtable (2010), it has remained a challenge to organizations that struggle to determine how it can be operationalized and measured [27].

In the origin of this paper, was the problem of taking into account the environmental impacts of supply chain practices. In this context, our goal has been to provide an assessment module of these impacts. It was also for us, to assist in the definition of judicious and targeted axis of the progress allowing to evolve evaluation systems of environmental performance in supply chain.

We proposed a module for environmental decision in the supply chain. We mobilized, among others, the value chain and AHP method. The primary objective of this study is to lay the foundations for a new generation of environmental indicators that will allow us to know our level in terms of environmental performance.

Finally, we considered the realistic case of a supply chain issue of the Moroccan automotive industry, which served us the application framework for our mathematical module.

To assure the reliability of this module, we considered core environmental indicators during its construction. The module presented in this paper promises advance in environmental performance assessment of the supply chains and makes environmental information more useful to the decision-makers. Any supply chain and based on this module, can know their achievements towards environment. Even though further development is called for, it is evident that this module has the potential to become very useful as one of the tools available.

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