Lebanese Industrial Center for Assessment and Development

A Collaboration Platform

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***Abstract*— Lebanese manufacturing industries face both severe external and internal competitions. External competition from low wage production countries and adoption of free market strategies force SMEs (Small and Medium Enterprises) to tap into productivity enhancement strategies. Internal competition comes from the lack of collaboration tools and infrastructure. This research aims at establishing a positive collaboration platform between industries and enabling them to share knowledge to reduce external fierce competition. A first step towards this effort would be to establish a relevant framework that would assess the current situation of an industry through the sustainability diamond matrix. Next stages would include grouping industries according to common deficiencies and establishing a cooperation framework.**

Keywords-Collaboration; Sustainability; Diamond Index; Center

I. Introduction

This paper presents the first step of establishing a center of industrial collaboration (LICAD)[1]: assessing the current industrial situation through a balanced quantitative sustainability approach. A drastic reshaping of how modern manufacturing is expanding its capabilities is needed for it to become sustainable in the long term. Reduction of emissions, control of waste generation and disposal, monitored energy consumption and responsible material selection (renewable ones) are the main pillars supporting every company wishing to be labeled as an environmentally-conscious manufacturing firm. However, for manufacturing-environmental sustainability to gain momentum of its own it has to be socially-economically viable. So, a sustainability framework index with 4 main pillars (Manufacturing, Environmental, Economical and Societal) will be presented later on, built specifically after an extensive literature review for the Lebanese manufacturing industry with an initial collection of multi-disciplinary indicators. This will serve to classify industries based on their primary needs as a first step towards the establishment of the collaboration platform.

Following, we will give a brief topic overview that will eventually lead to the identification of sustainability scales. In section three, we justify using casual loop diagrams, in systems dynamics, to represent the various components of our variables. In section four, we will detail the application of analytic hierarchy process to aggregate the indicators and group deficiencies together. The paper ends with a conclusion on the importance of assessing further industries to refine the diamond index.

II. Topic Overview

Sustainability is an elusive concept hard to delimit. We will adopt a mixed quantitative/qualitative estimation of sustainability. The approach will attempt to integrate unrelated indicators. For example, the comparison of water consumption [2] with Brand management [3] is tricky, to say the least, and to valorize mostly intangible notions is prone to subjectivity which might compromise the validity of the assessment [4]. However, using the Analytic Hierarchy Process introduced in the next section, the need for sustainability performance measurement is crucial, and by capturing the main indices and inducing the learning process, a leap towards local industrial sustainability is the ultimate goal. It goes without saying that the sustainability indices collected and aggregated are by no means absolute nor completely reliable, and they serve as the first step in the LICAD initiative to holistically enhance Lebanese industry. As it is called Lebanese sustainability diamond index, it is natural to deduce that it is an iterative process and it needs to be monitored for several years to set the baseline expectations and form a clearer picture of trend-indicators to periodically update indices.

Four main scales can be identified into which sustainability can be applied [5]:

1-Global systems: global warming, ozone depletion, biodiversity, etc. Treaties and joint ventures are most effective on this scale.

2-Bounded systems: urban planning, transportation, etc. Economics, law, ecology among others are most effective on this scale.

3-Business systems: through energy efficiency, cleaner technology, recycling policies, leaner supply chains, etc. business sustainability is possible.

4-Technological systems: in providing clear economic value while operating in a cleaner manner can technology sustainability be achieved.

This section enabled us to situate the complexity behind our work: integrating quantitative and qualitative data to generate a compilation of indexes. The following sections will explore factors influence on one another and the normalization of this influence.

III. SYSTEM DYNAMICS

Many of the factors involved in sustainable manufacturing interact, influencing and depending on each other. This is why we propose using system dynamics and, in particular, causal loop diagramming in this paper to model the different direct depending relationships and, through these, the many chains of cascading interactions between often very odd groups of variables. In order to integrate a multitude of variables and indicators, we will need to distribute them into pillars, categories and sub-categories. Their representation through a casual loop diagram will allow for a better more holistic view of the various components of sustainable manufacturing and enable decision makers to better assess companies. Their chain reaction (domino) effect will thus be best represented: a variable under a certain pillar might as well affect a variable theoretically not related. We identify four separate domains for analysis, i.e., manufacturing, environmental, financial, and social domains. The manufacturing occupies the central part of the diagram, and thus it evaluates policies intended to promote sustainable manufacturing practices [6].

IV. GENERATING THE SUSTAINABILITY INDEX

Since a hybrid qualitative/quantitative approach will be adopted, a comprehensive index is preferred for the decision making purposes. Through numerical aggregation, a single index will emerge that will assess the company's sustainability performance across the several domains [7]. There has been numerous methods proposed to compare indicators of different nature in a systematic manner, while capturing and controlling the inherent judgment subjectivity. Among the most adopted methods are AHP (Analytic Hierarchy Process) introduced by Saaty [7] and the Multi-attribute Utility Theory proposed by Keeney [8].

In this paper, the AHP method will be adopted with a few proven modifications in literature [9]. By now, there are many proposed sustainability assessment frameworks with a great variety of indicators and units. It is better, yet challenging, to conduct comparisons among sectors and companies relying on many performance indicators. AHP makes it possible to prioritize alternatives based on different criteria, thus enabling judging and comparing companies based on multi-disciplinary indicators. Criteria are split between quantitative and qualitative scales. This makes direct integration into a single composite index not possible. For example, measuring the percentage of female managers is straight forward, while assessing deployed processes requires a certain expertise and human judgement. It is the prioritization derived by pair-wise comparison that solves the multi-scale judgments problem and enables calculation, through weighing and adding, of the overall priorities of alternatives which mark their impact on the primary goal of sustainability. AHP has several clear benefits; it can handle in a relatively easy manner data of qualitative and quantitative nature, and perhaps one of its most appealing feature it that it allows compensatory rules in multi-criteria decision making process. What this infers is that by adopting the AHP, poor performance of certain criteria can be offset by good performance of others, i.e., bad score in the social dimension can be offset by a good one in the environmental dimension leading to an overall passing performance with respect to company sustainability. We will present the procedure, based on AHP, of calculating a composite index aggregating indicators ranging over environmental, societal, economical and manufacturing levels which will permit quick and efficient ranking of companies within a sector with respect to sustainability performance.

A. *Selection of Indicators*

After extensive literature review [10][11], suitable performance indicators which fall under Societal, Economical, Environmental and Manufacturing dimensions are selected with the goal of preliminary assessment of a company sustainability performance and benchmarking industries within a given sector. Indicators, whenever possible, ought to be of a quantitative nature for the obvious reason of less risk of subjectivity. However, for some indicators, a qualitative judgment is more appropriate. An important requirement for the continued accuracy of this methodology is the periodical review of indicators to track any changes in status and possibly add a few if the need arises. An indicator needs to have clear unit of measurement if quantitative and clear judgment scale if qualitative.

Let us set the main sustainability dimensions (or group of indicators) as the j's (economic j =1, environmental j = 2, and societal j=3, manufacturing j=4). The manufacturing dimension has been separated as a standalone dimension since the field of application is restricted to primary and secondary industries. The respective indicators serve as an initial assessment enablers of how much a company is seeking to modernize and achieve the much sought over status of sustainable development.

- The economic group of indicators serves as an overview of the company's economic impact on its stakeholders as well as the local and national economic system. It uses basic economic interactions of expenses versus revenues.
- The environmental group of indicators serves as an overview of the company's impact on its

surroundings (water, atmosphere, land). It uses basic environmental indicators such as pollution and recycling.

- The societal group of indicators serves as an overview of the company's endeavors to properly treat its employees, suppliers, customers. It uses basic societal interactions such as employee turnover rate and safety.
- The manufacturing group of indicators serves as an overview of the company's technological advancement so as to minimize production related waste and emissions. It uses basic manufacturing indicators such as inventory tracking and machine scheduling.

Some of these dimensions will be split into sub-categories for concentrated judgment (to be explained in the next section) and for easier calculation (also to be explained in later section, mainly to keep down the number of pair-wise comparison). The environmental indices are presented in table 1 with three different sub-categories (1= atmosphere, 2= policies, 3= standards) labeled between parentheses from 1→3.

B. Judging the Indicators

The indicators have to be sorted between those who positively and negatively influence the company's goal towards achieving sustainability. So, let us mark the indicators with I's so to have I_ji (Indicator i from group j) and with + or – signs like I_(ji+) or I_(ji-) so to indicate respectively whether or not if they increase in value they contribute towards enhancing overall sustainability score. For example increased energy consumption per unit of output has a negative effect on the overall score.

C. Weighing the Indicators

It is a very critical step the weighing of these indicators. As with most cases, lack of data hinders absolute certainty when judging and placing weights. However, the pair-wise comparison technique derives relative weights in a practical and highly accurate manner relying on a selected group of experts. Pair-wise comparison enables the estimation of weights for each indicator i relative to other indicators within the same group j and it is done by comparing each pair of indicators. By answering the question of which of the two indicators i and j is more influential in the overall sustainability of the company. By indicating a preference for one over the other on a 1-9 (this range was chosen because it offers limited yet sensitive judgment enabling distinction) scale, the intensity of relevance is detected. For example, if indicator i is given a score of 4 when compared to indicator j, this means that i is 4 times more important than j in determining the overall score of the company.

After comparing each pair of indicators, a NxN positive reciprocal matrix is formed (1) with the reciprocal property (if i is 5 times more important than j, then j is 1/5 times more important than i).

$$a_{ij} = \frac{1}{a_{ji}} \quad (1)$$

Equation 1: Reciprocal property of a reciprocal matrix

A 3 step approximation of the normalized weights of the indicators:

1- Sum entries each column of the reciprocal matrix (2)

$$\sum_{i=1}^{N} a_{lk} \quad (2)$$

Equation 2: Sum of each column in reciprocal matrix

2- Divide each entry by the sum of its column to obtain the normalized pair-wise comparison N x N matrix (3)

$$\bar{a}_{lk} = \frac{a_{lk}}{\sum a_{lk}} \quad (3)$$

Equation 3: Normalized pair-wise comparison

3- The criteria weight or priority vector w is obtained by averaging the sum of each row (4)

$$W_k = \frac{\sum \bar{a}_{lk}}{N} \quad (4)$$

Equation 4: Priority column vector W

D. Checking Consistency

For an N x N matrix, (N-1) comparisons are enough to derive weights for the N indicators. However in AHP, N(N-1)/2 comparisons are made, which is more computationally exhaustive for the purpose of rendering the weights less sensitive to our inherent inconsistency of judgments and its redundancy permits the calculation of a ratio to measure the data's degree of inconsistency and determine the validity of the results called the consistency ratio. The smaller the ratio the better, and, as a general rule of thumb it should be ideally less than 0.1, however acceptable up to the limit of 0.2. A perfectly consistent matrix has a CI=0 as per condition listed in the equation (5) below.

$$lambda_{max} = lambda = n \quad (5)$$

Equation 5: Principal Eigen value for a consistent matrix

Two people will most definitely differ in their belief, at least as for the intensity of the degree of difference between two indicators, the same person will most likely report inconsistent judgments (i.e., A much more important than B, B slightly more important than C and C is slightly less important than A), which is part of our nature. The transitive property of logic of preference is what determines the consistency of the judgments, however too much consistency is impossible even undesirable in this case since it makes the AHP looses one of its more desired features which is to systematically combine experts opinions in a structured manner without losing their subjectivity enabling the determination of real experience weighted indicators. The rank of the indicators has to be transitive; however, the degree of intensity preference does not.

$$I_{ij} \times I_{jk} \neq I_{ik} \quad (6)$$

Equation 6: Relaxed (non-transitive) intensity preference

Three steps are required to compute the consistency ratio:

1. Compute the principal eigen value which the summation of product of summation of each column in the reciprocal matrix and the priority vector.

$$lambda_{max} = sum\ product[\ \sum_{l=1}^{N} a_{lk}\ , W_k] = \ sum\ product[\ \sum_{l=1}^{N} a_{lk}, \frac{\sum_{k=1}^{N} \bar{a}lk}{N}\ ] \quad (7)$$

Equation 7: Principal Eigen value

2. Compute the consistency index

$$CI = \frac{lambda_{max} - n}{n-1} \quad (8)$$

Equation 8: Consistency index

3. Compute the consistency ration CR relying on prof Saaty's random consistency index RI

$$CR \ = \frac{CI}{RI} \quad (9)$$

Equation 9: Consistency ratio

- If CR<= 0.1, the judgments are said to be consistent enough
- If CR<=0.2, the judgments are said to be acceptable and need to be revisited if possible
- If CR>0.2, the judgments are said to be inconsistent and a re-evaluation of the alternatives is in order.

Random consistency index RI is given in the following table 1:

TABLE I. RI VALUES

	n values									
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

E. Normalizing Indicators

In order to aggregate different indicators of different natures and behaviors from every group j across several years t into a single index, normalization is necessary. The fitting time-dependent Min-Max normalization will be used, and the normalized indicators will range between 0 and 1. The following two equations are used for more is better and less is better indicators, respectively.

$$I_{N,ijt}^{+} = \frac{I_{ijt}^{+} - I_{min,jt}^{+}}{I_{max,jt}^{+} - I_{min,jt}^{+}} \quad (10)$$

Equation 10: Min-Max normalization for positive indicators

This normalization allows for different indicators to become compatible and therefore possible to aggregate. However, for this normalization to be possible and in order to benefit from the more holistic approach of mixed quantitative/qualitative assessment there remains the problem of assessing the qualitative indicators values in such a way to still be able to use the more accurate relevant model and not having to switch entirely to the rating model. The following proposed steps allow valorizing of qualitative indicators to fit alongside the quantitative ones in the relevant model scoring methodology:

1. Using the qualitative rating scales used in the rating model (for example High, Medium, Low), a pair wise comparison will derive values for each of the scale components (ex: High=0.5, Medium=0.3, Low=0.2).
2. Now, based on the expert's opinions, a company will be deemed to rank on each one of the rating components given a certain percentage of certitude (ex: 30% high, 60% medium, 10% low).
3. By multiplying the scale components value with their respective probability we get an approximate value of the indicator (ex: high=0.5*0.3=0.15, medium=0.18, low=0.02)
4. We idealize these number by dividing each one by the largest one (ex: high=0.833, medium=1, low=0.111)

F. Calculating Sub-Indices

Before calculating the global sustainability index, sub-indexes $I_{N,ijt}$ for the four domains need to be calculated.

$$I_{jt} = = \sum_{jit}^{n} W_{ji}\, I_{N,ijt}^{+} + \sum_{jit}^{n} W_{ji}\, I_{N,ijt}^{-} \quad (11)$$

Equation 11: Sub-index

$$\sum_{ji}^{n} W_{ji} = 1\ , W_{ji} \geq 0 \quad (12)$$

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Equation 12: Weight of indicator i in group j

I_{jt} is the sustainability sub-index for group j in time t and W_{ji} is the weight of indicator i in group j.

G. *Combining sub-indicesinto the global index*

The global sustainability index I_S is calculated using the weighted sum of the sub-indexes (13):

$$I_{St} = \sum_{jt}^{n} W_{jt} \times I_{jt} \quad (13)$$

Equation 13: Sustainability index

V. CONCLUSION AND FUTURE WORK

This paper presented the index that will be used to assess around 337 local industries. The results will serve to categorize companies based on common deficiencies and support the collaboration process. The deficiencies will be categorized according to the preliminary four categories as well as to the sub-categories. Currently, the 337 industries to be investigated were selected and a collaboration database is being established on [1] .

Future steps will include data gathering from the selected industries and surveys sent for technical managers. Following a thorough analysis of the gathered information, the selected indicators will be re-investigated and confirmed. An online tool will then be made available for industries to test their sustainability and to identify which norms they need to investigate to enhance their index.

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