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Impact Assessment of Lean Practices on Social Sustainability Indicators: An Approach Using ISM Method

Aline F. Marcon, Eduardo F. da Silva, Marina Bouzon

Abstract**—**The impact of lean management on environmental sustainability is the research line that receives the most attention from academicians. Therefore, the social dimension of sustainable development has so far received less attention. This paper aims to evaluate the impact of intra-plant lean manufacturing practices on social sustainability indicators extracted from the Global Reporting Initiative (GRI) parameters. The method is two-phased, including MCDM approach to uncover the most relevant practices regarding social performance and Interpretive Structural Modeling (ISM) method to reveal the structural relationship among lean practices. Professionals from the academic and industrial fields answered the questionnaires. From the results of this paper, it is possible to verify that practices such as “Safety Improvement Programs”, “Total Quality Management” and “Cross-functional Workforce” are the ones which have the most positive influence on the set of GRI social indicators.

Keywords**—**Indicators, ISM, lean, social, sustainability.

I. Introduction

It is relevant to know which are the fragilities of the social aspects in manufacturing industries, once that is the first step to accomplish a better work experience to the laborers. Since the announcement of Our Common Future report, in 1987, in which the concept of sustainability was defined, concerns on economic and environmental dimensions have emerged, while social dimension is still normally set aside, particularly in industrial environment. Sustainability is usually expressed in terms of Triple Bottom Line (TBL): people, profit and planet [1]. As people began to worry about the impacts of industrial activities on the environmental pillar by the 20th century, the myth that protecting the environment was against industry profitability emerged [2]. However, stakeholders are constantly pressuring manufacturers to incorporate the social and environmental aspects within their production process in order to protect the environment and society from adverse repercussion of the manufacturing process [3].

Lean management is a business approach that hands over greater value for customers by removing non-value-adding activities [4]. The impact of lean on environmental sustainability is the research line that receives the most attention from researchers since 2001. Furthermore, the interest on this topic has increased in recent years and is presently the only line in lean management and sustainability that is widely studied [5]. Therefore, the social dimension of sustainable development has so far received less attention than the environmental dimension [6] and economic dimensions. Thereupon, the main objective of this research is to uncover the main lean intra-plant practices, which should be implemented in order to improve social sustainability indicators.

Aline F. Marcon is with Production and Systems Engineering Department, Federal University of Santa Catarina, 88040-900 Brazil (corresponding author, phone +5548988280047; e-mail: alinefmarcon@gmail.com).

E. F. da Silva and M. Bouzon are with Production and Systems Engineering Department, Federal University of Santa Catarina, 88040-900 Brazil (e-mail: efsilvaa@gmail.com, marinabouzon@gmail.com).

II. Theoretical Background

In order to measure sustainability, many sets of indicators were developed. Among them, the GRI is considered to be the leading framework for sustainability reporting [7]-[11]. For this work, in order to measure the sustainable aspects, a group of sustainability indicators named G4 from GRI was selected. Only indicators which express the characteristics of the social dimension of sustainability in a firm’s scope were used; that is, external links were not considered due to the delimitation of this study.

Considering the rising consciousness on environmental and social matters, lean approaches have lately incorporated concepts of social, economic and environmental sustainability [12]. Reference [13] bring a list of lean practices, from which we have extracted only the internal ones (door-to-door): Cross-functional Workforce (P_1), Continuous Flow Production/Just-in-time (P_2), Total Quality Management (P_3), Cellular Manufacturing (P_4), Preventive Maintenance (P_5), Process Capability Measurements (P_6), Safety Improvement Programs (P_7), Continuous Improvement Programs/Kaizen (P_8), Pull System/Kanban (P_9), Cycle Time Reduction (P_{10}), Lot size reduction (P_{11}), Lot size reduction (P_{12}), Bottleneck removal (P_{13}) and Quick changeover techniques (P_{14}). Reference [14] has proposed a new lean principle: sustainability; and endorses that organizations should consider the savings, environmental impact and so potential earnings of sustainable lean initiatives. Reference [15] stated that most research associating lean operations to sustainability issues have concentrated exclusively on environmental impacts and [12] verified that the social dimension is the one which drew the least attention from researches when compared to the environmental and economic pillars.

III. Methods

All the selected indicators from G4/GRI were slightly adapted to compose a questionnaire in order to show the direction of interest of them and, thus, to be equally interpreted by the decision makers. These indicators are: I_1: Increase in the "total number and rates of new employee hires (…) by age group, gender and region"; I_2: Increase in the "percentage of total workforce represented in formal joint management-worker health and safety committees that help monitor and advise on occupational health and safety programs"; I_3: Reduction in "type of injury and rates of injury, occupational diseases, lost days, absenteeism and total number of work-related fatalities, by region and gender"; I_4: Increase in the "average hours of training per year per employee, by gender and by employee category"; I_5: Greater equality in salary and remuneration for women and men; I_6: Increase in "total hours of employee training on human rights policies"; I_7: Reduction in the "total number of incidents of discrimination" and the need for corrective measures; I_8: Increase of the "total number and percentage of operations that have been subject to human rights reviews"; I_9: Increase in "percentage of operations with implemented local community engagement, impact assessments and development programs"; I_{10}: Increase in "communication and training on anti-corruption policies and procedures" and I_{11}: Increase in the "number of grievances about impacts on society field, addressed, and resolved through formal grievance mechanisms". All the information about the indicators aforementioned was extracted from the GRI Implementation Manual [16].

A. Data Collection

Data collection was performed by means of a questionnaire (Questionnaire A) including the selected lean practices mentioned in Section 2. This questionnaire was designed to evaluate the influence of a certain lean intra-plant practice on social sustainability indicators. Thus, the experts responded to questions such as "what is the influence of Practice i on Indicator j?" The questionnaire was applied to six experts (three from academia and three from industry), which have their judgments weighted according to the time in years of each respondent's experience in lean and social areas, as following: Expert 1 - 1 year; Expert 2 - 5 years; Expert 3 - 13 years; Expert 4 - 14 years; Expert 5 - 15 years; and Expert 6 - 20 years.

B. Finding Lean Practices Dependence Chain – ISM

Investing all available resources on a certain subset of lean practices may still not be the optimal approach to increase social sustainability, since one must consider the interrelationship among lean practices. That is, although one practice receives a stimulus to develop, it may not improve beyond a limit due to inefficiency of the practices in its dependence chain. The dependence tree is built using an ISM. ISM is a tool used to extract the mutual effects among variables with the aim to identify the driving variables; that is, it identifies variables that influence other variables in the system [17]. In this research, variables are the lean practices and procedures from [17] were implemented.

IV. Results and Discussion

A. Part I: Questionnaire A

In order to uncover the most important lean practices related to social indicators, experts were consulted using Questionnaire *A*. The answers for each question had to be a whole number contained in the interval [-3; +3], in which "-3" represents a strongly negative impact, while "+3" represents a strongly positive impact. Based on this data, a ranking was built, as shown in Table I.

TABLE I
RANKING

Practice	Position
P_1	3th
P_2	9th
P_3	2nd
P_4	8th
P_5	5th
P_6	7th
P_7	1st
P_8	4th
P_9	7th
P_{10}	13th
P_{11}	11th
P_{12}	6th
P_{13}	12th
P_{14}	10th

B. Part II: Questionnaire B – ISM Approach

A second questionnaire (named Questionnaire *B*) was sent to three lean experts. In this one, the experts had to analyze the relationship among the selected lean practices. According to [18], ISM Approach works by the following steps:

Step 1: All the previously selected lean intra-plant practices were listed as the variables. It means the variables are P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8, P_9, P_{10}, P_{11}, P_{12}, P_{13}, P_{14}.

Step 2: A set of symbols (VAXO scale) was used to answer Questionnaire *B* in the collecting data procedure, according to the following rules: **V**: means variable *i* influences variable *j*; **A**: means variable *i* is influenced by variable *j*; **X**: means variable *i* and *j* influence each other; **O**: means variable *i* and *j* are unrelated.

Step 3: This step consists in the construction of the Structural Self-Interaction Matrix (SSIM). This is a triangular matrix and brings the aggregated responses from the experts and it was built by a consensus.

Step 4: This step is about transforming SSIM into a binary matrix to make it possible to analyze data quantitatively. The following rules are adapted from [18] and were used to construct the binary matrix:

- In the SSIM, if (*i, j*) is evaluated as **V**, then in the Reachability Matrix (*i, j*) will value 1 and (*j, i*) will value 0;
- In the SSIM, if (*i, j*) is evaluated as **A**, then in the Reachability Matrix (*i, j*) will value 0 and (*j, i*) will value 1;
- In the SSIM, if (*i, j*) is evaluated as **X**, then in the Reachability Matrix (*i, j*) will value 1 and (*j, i*) will value

1;

- In the SSIM, if (*i, j*) is evaluated as **O**, then in the Reachability Matrix (*i,j*) will value 0 and (*j, i*) will value 0.

Based on this, Table II aggregates the two steps aforementioned and presents the binary matrix together with the values of *Driving Power – F* (represents the total number of variables, including itself, which it may have an effect on) and *Dependence – D* (denotes the total number of variables which may have an effect on it).

According to the total number of *F* and *D*, a graphic analysis was performed and presented in Fig. 1. The graphic presented in this figure is known as MICMAC (Impact Matrix Cross-Reference Multiplication Applied to a Classification) analysis and comes up with four definitions for variables according to the quadrant where they are inserted. Quadrant I aggregates autonomous variables that have weak driving power and weak dependence [18]. Quadrant II is where dependent variables are located [18]; that is, variables which have weak driving power and strong dependence. Quadrant III has the linkage variables, which have strong driver power and dependence. Quadrant IV compiles the independent variables, which are those with strong driver power and weak dependence.

TABLE II
FINAL REACHABILITY MATRIX

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	F
P_1	1	1	1	1	0	0	1	1	0	1	1	0	1	0	9
P_2	0	1	1	1	0	0	0	0	0	1	0	0	0	0	4
P_3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
P_4	1	1	0	1	1	0	0	0	1	1	1	0	0	0	7
P_5	0	1	1	0	1	0	0	0	1	1	0	0	1	1	7
P_6	0	1	1	0	0	1	0	0	0	1	0	1	1	1	7
P_7	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3
P_8	0	1	1	0	0	1	1	1	1	1	0	0	1	0	8
P_9	0	1	1	0	0	0	0	0	1	1	1	0	0	0	5
P_{10}	0	1	0	0	0	0	0	0	0	1	0	0	0	0	2
P_{11}	0	1	1	0	0	0	0	0	1	1	1	0	0	0	5
P_{12}	0	1	1	1	0	0	0	0	0	1	1	1	1	1	8
P_{13}	0	1	1	0	0	0	0	0	1	1	1	0	1	0	6
P_{14}	0	1	1	1	1	1	0	0	1	1	1	0	1	1	10
D	3	13	12	5	3	3	3	2	7	12	7	2	7	4	

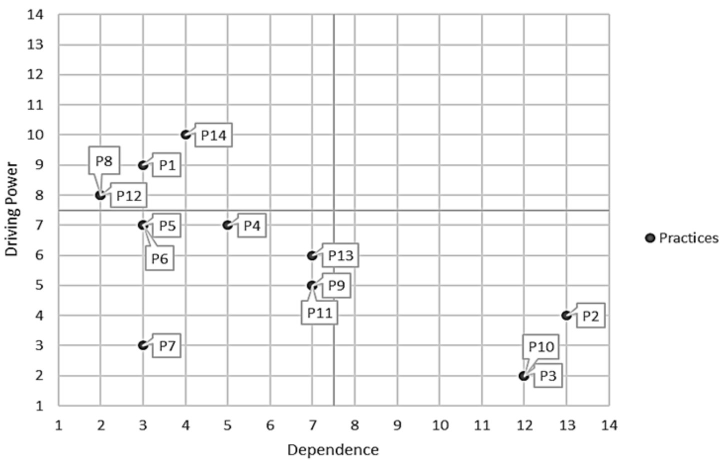

Fig. 1 MICMAC analysis

Step 5: From Table II, a level partition was made. This is accomplished by an iterative method and determines the practices hierarchy in the ISM diagram.

Step 6: Once the level partitioning is done, a diagram is built and presented in Fig. 2. The relationship between the practices *i* and *j* is shown by an arrow pointing from *i* to *j*.

P1 (Cross-functional Workforce), in the base of the diagram, is the one which has the major Driving Power. Hence, the practices located on the top of the diagram are those which have the major Dependence, or the minor Driving Power. It is noteworthy, the case of practices P9 (Pull System/Kanban) and P11 (Lot Size Reduction), with a mutual correspondence arrow meaning that there is an interdependence between both practices. This bilateral relationship is understandable since the Pull System, based on Kanban, has an intrinsic link to the Lot Size Reduction initiatives. It can be inferred that lot size reduction allows the pull system; the same way pull system makes feasible the progressive lot size reductions.

C. Part III: Combined Analysis and Discussion

The ISM analysis finished in the MICMAC and ISM digraph, however, in this section, the analysis has evolved in order to build a ranking considering data obtained from Questionnaire A and the ISM analysis. Thus, the impact of lean practices on social indicators was considered combined with the interrelationship of lean practices. From Fig. 1, a new inclined axis was drawn equals to 45 degrees (see Fig. 3).

The use of this feature served to design all points in a single line, through which concerning the positioning of each practice, attributing numerical values to the variables. The drawn axis represents the scale of driving power; the lower right end represents the least power of influence of a variable; once at this point, the variable has total dependence and has no influence on any other variable. In the upper left corner is the point of major driving power, and less dependence.

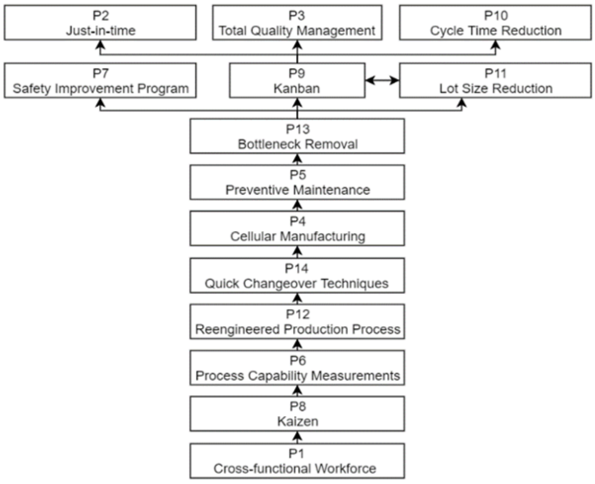

Fig. 2 ISM diagram

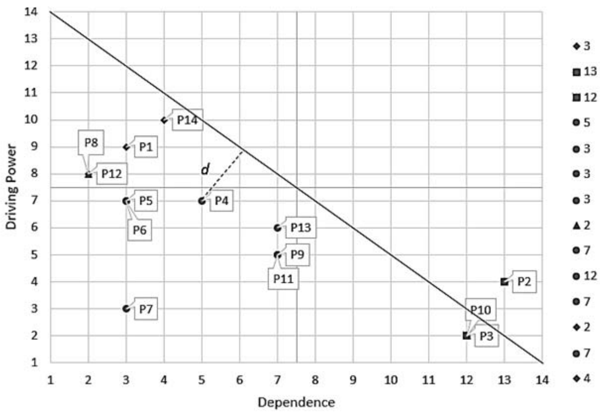

Fig. 3 Designed axis

By this point of analysis, it is also important to highlight that even the points included in the same quadrant have a different level of driving power and dependence. To consider this difference and compensate it after the points have been projected on the axis, a Correction Coefficient (CC) was developed.

$$CC = di / \Sigma d \quad (1)$$

where d represents the perpendicular distance among the point Pi and the designed axis.

Then, the result obtained from (1) is added, or subtracted, from the value obtained from the projection of the practice (point) on the inclined axis, as presented in (2).

$$CV = \text{position of the projection of the point in the axis} \pm CC \quad (2)$$

This equation gives the Corrected Value (CV) of each practice. To the point located above the inclined axis, CC was added to the value of the position of the point in the inclined axis, while to those which were located under the axis, CC was subtracted. It is justified because of the driving power variation - when above the inclined axis, the further from it, the greater the driving power; the opposite happens to practices located below this axis, which the farther they are, the less driving power they have in the system.

Having CV, then it is viable to calculate the Level of Influence (LI). Considering r as the total length of inclined axis, then:

$$LI = CV \times r \quad (3)$$

LI works as a correction factor to the initial ranking of the practices. The new ranking is presented in Table III.

TABLE III
THE INFLUENCE OF PI ON LI

	Ranking 1	ΣP	LI	ΣP x LI	Final Ranking
P_1	3th	9.2	0.85	7.76	3th
P_2	9th	2.6	0.11	0.29	12th
P_3	2nd	12.3	0.17	2.09	7th
P_4	8th	2.9	0.69	2.04	8th
P_5	5th	4.4	0.84	3.72	4th
P_6	7th	3.0	0.84	2.50	6th
P_7	1st	14.2	0.84	11.89	1st
P_8	4th	8.5	0.92	7.84	2nd
P_9	7th	3.0	0.54	1.62	9th
P_{10}	13th	-1.4	0.17	-0.23	13th
P_{11}	11th	1.4	0.54	0.77	11th
P_{12}	6th	3.9	0.92	3.62	5th
P_{13}	12th	0.5	0.54	0.29	12th
P_{14}	10th	2.0	0.77	1.54	10th

From the ranking presented in Table I, it is possible to verify practices P7 (Safety Improvement Programs), P3 (Total Quality Management) and P1 (Cross-functional Workforce) as the ones which have the most positive influence on the set of indicators. While practice P10 (Cycle Time Reduction) is evaluated as having the greatest negative impact. After aggregating part I and part II, the new ranking (Table III) has changed the second position from P3 (Total Quality Management) to P8 (Kaizen). This is justified once P8 presents a higher Driving Power, according to MICMAC analysis, than P3.

V. Final Remarks

The objective of this research was to identify the lean intra-plant practices which have the most positive and negative influence on the selected social sustainability indicators. This research aimed to create possibilities of improvement of this character and open lines of studies for this subject. It is very common to think the social care aspects as a synonymous of cost increase in a non-technical attribute; however, it is possible to notice that it is feasible to work on social aspects through lean practices, most of times already implanted.

Professionals from academic and industrial fields answered the questionnaires. The number of respondents was not very large because of the depth of subject and the time required to answer. As a suggestion for further studies, it is interesting to have access to the organizations to personally measure the indicators and expand the number of respondents.

ISM method evaluates the existence of a relationship among variables, measures this relationship and the direction of influence of a variable on another, but the method does not provide data on the intensity of that influence, for example. In this sense, for future works, it is suggested using Decision Trial and Evaluation Laboratory (DEMATEL) method, once it is capable to measure the level of influence among variables.

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