CHEMICAL ENGINEERING TRANSACTIONS Volume 25, 2011
Editors Jiří Jaromír Klemeš, Petar Sabev Varbanov, Hon Loong Lam
Copyright © 2011, AIDIC Servizi S.r.l., ISBN 978-88-95608-16-7 ISSN 1974-9791
DOI: 10.3303/CET1125049

Environmental Performance Assessment in Transportation and Warehousing Operations by Means of Categorical Indicators and Multicriteria Preference

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This paper presents and tests a method to assess environmental performance in two logistic operations: transportation and warehousing. The research method employed was the case study method. The environmental performance of a logistic operation was treated as an intangible term, formed by five latent constructs: atmospheric emissions, liquid effluents, solid waste, usage of natural and energetic resources, and management and law accomplishments. The first four constructs have a direct impact on the environment. The fifth construct is a prior and necessary condition. Six experts in environmental management, with the aid of the AHP multicriteria method, distributed 100 percentage points among the constructs. The most important construct was management and law-requisites; the second most important was usage of resources. Constructs were appraised by indicators and assessed by questionnaires answered by managers of the two operations. Global results were 74.73 % and 77.61 % out of the maximum score in transportation and warehousing, respectively. Gaps give clues to reformulations in the environmental management strategy.

1. Introduction

The formal concern with the environment is recent in the history of mankind. Since 1960, many world-famous meetings have taken place, such as ECO-92, in Rio de Janeiro, and the Kyoto summits. One consequence was the increment of public and legal pressures on industrial activity, encouraging the debate on how to make it more environmentally friendly. EMS (environmental management systems), among other requirements, adds to the company commitment a high environmental performance, which demands measurement models, usually based on indicators (Chee Tahir and Darton, 2010; Sellitto et al., 2010). Kuhre (1998) argues that, even without a formal system, indicator-based measurement allows environmental performance to improve, including the LCA approach (Zobel et al., 2002, De Benedetto and Klemeš, 2010).
Environmental indicators can capture and integrate data from different sources and transform them into a unified communicable variate, such as a global index at the top of the information pyramid. In the middle, latent constructs integrate data collected from

Please cite this article as: Sellitto M., Borchardt M., Pereira G. and Gomes L., 2011, Environmental performance assessment in transportation and warehousing operations by means of categorial indicators and multicriterial preference, Chemical Engineering Transactions, 25, 291-296
DOI: 10.3303/CET1125049

the field, the base of the pyramid (Hammond et al., 1995). Melo and Pegado (2002) quote some advantages of a formal indicator-based measurement model: (i) synthesis and communication of complex information required for the management; and (ii) quantification of gaps (performance minus expectation) for prioritization. Pegado et al. (2001) observed a flaw in some measurement systems: they place more importance on internal management efficiency than on environmental field effects.

Environmental performance measurement models can be applied in operations in many ways. Some were synthesized in Sellitto et al. (2010). Others are: Ecoblock (Pegado et al., 2001; Melo and Pegado, 2002), a multidimensional measurement methodology for environmental performance that uses ecological footprint; Process Analysis Method (Chee Tahir and Darton, 2010); EMINENT (Klemeš et al., 2009), an information system-supported approach for energy saving; and the integration between waste and renewable energy in order to reduce carbon footprint (Perry et al., 2008).

The objective of this article is to present a method to assess environmental performance in logistic operations. We calculated a global index ranging between 0 and 100% which is specific for two operations and comparable to other indexes in productive chains, and in cumulative fashion. To exemplify the method, we applied it in transportation and warehousing operations in parts of an industrial supply chain. Limitations are related to the research method: (i) only two logistic operations; and (ii) judgment, not physical measurement. The research was entirely supported by funds from CNPq Brazil.

2. Research

The research question was: (i) how can environmental performance of logistic operations be assessed? The main objective was to test a method to assess the environmental performance of a logistic operation. Secondary objectives were: (i) to identify and prioritize latent constructs and indicators that explain the environmental performance of a logistic operation; and (ii) to assess performance and analyze gaps. The main contribution is the specific result of the case, which is not generalizable yet. Repeated cases may expose regularities and should be helpful to formulate a grounded theory about the object (Eisenhardt, 1989). The method resembles the design research rationale (Hevner et al., 2004; Manson, 2006): a method can be conceived as a result of a design process, such as producing software or an artifact. After a mental phase, an idea arises that must be verified in field cases (March and Smith, 2005).

Environmental performance is an intrinsically complex abstract object, which can be described as a complex system. We proposed a method to measure such complex abstract objects. We have structured components hierarchically in a triple-level structure in order to describe the object. The top term is explained by latent constructs, based on concepts apprehended by indicators: a tree-like structure of hierarchical levels. The top term is environmental performance. From previous research (Sellitto et al., 2010) we have obtained five latent constructs: atmospheric emissions; liquid effluents; solid waste; usage of resources; and management and law accomplishment. The authors considered the last construct a prior and necessary condition to the other conditions.

Benchmarking the constructs, Zhu et al. (2008) stated six constructs for environmental performance in GSCM (Green Supply Chain Management): (i) reduction of air

emission; (ii) reduction of waste water; (iii) reduction of solid waste; (iv) decrease in the consumption of hazardous/harmful/toxic materials; (v) decrease in the frequency of environmental accidents; and (vi) improvement of the environmental situation.

3. The case

The case included part of the logistics system of an industrial supply-chain, involving two operations: transportation and warehousing. The companies involved have consolidated tradition in environmental management, certified by ISO-14001. Six experts (scholar researchers and practitioners with scholar degrees) in environmental management visited and studied the operations of a logistic operator with ISO-14001 certification. They distributed relative importance (100 percentage points – pp) among constructs and defined a set of indicators for each construct. Table 1 shows application of AHP. Values above the diagonal represent judgments (values below are reciprocals).

Table 1: Judgment matrix

	Law	Resources	Solids	Liquids	Atmosphere	Prioritization	Order	CR
Law	1	1	2	2 1/2	4	31.57%	1	1.25%
Resources	1	1	1 1/2	2 1/2	3 1/2	28.91%	2	
Solids	1/2	2/3	1	2	3	19.98%	3	
Liquids	2/5	2/5	1/2	1	2 1/2	12.67%	4	
Atmosphere	1/4	2/7	1/3	2/5	1	6.87%	5	

Experts used the Saaty scale: [equal importance = 1; slightly more important = 3; more important = 5; much more important =7; dominant = 9]. Intermediate values were used in intermediate situations. According to calculations presented in Saaty (1980), researchers calculated the seventh row, the prioritization of the constructs, and the consistency ratio CR = 1.25 %, the probability that the matrix has not been obtained by rational judgment but by chance. Saaty (1980) states that CR < 10% is satisfactory. Experts stressed that in the operations, legal requirements and certifications are not only a prior condition, but important leverage for environmental actions.

For the assessment, managers answered a questionnaire about the field situation of each indicator, according to a Likert scale [very good = 1; good = 0.75; neutral = 0.5; bad = 0.25; very bad = 0]. By multiplying relative importance and evaluations and summing parcels, we reached a final index assessing the environmental performance of the operations.

Table 2 shows the tree-like structure for the assessment. The table shows primary results for indicators, intermediate results for constructs and, on the bottom line, the global performance for transportation and warehousing: 74.73 % and 77.61 % out of the maximum possible score, respectively.

Table 2: Tree-like structure for environmental performance in logistic operations

Constructs	Indicators	Transportation	Warehousing
Atmosphere	External Noise	1.29 pp	1.29 pp
6.87%	Dust	0.86 pp	1.72 pp
	Industrial smell	1.72 pp	1.72 pp
	Black smoke from vehicles	1.72 pp	1.72 pp
	Sub-total/gap	5.58 pp/1.29 pp	6.44 pp/0.43 pp
Liquid Effluents	Oils and greases	1.58 pp	2.11 pp
12.67%	Sewerage effluents	2.11 pp	2.11 pp
	Industrial conservation effluents	2.11 pp	2.11 pp
	Building conservation effluents	1.58 pp	1.58 pp
	Kitchen oil	0.53 pp	0.53 pp
	Industrial sludge from old products	1.06 pp	1.06 pp
	Sub-total/gap	8.97 pp/3.70 pp	9.50pp/3.17pp
Solid Waste	Computer items	1.67 pp	1.67 pp
19.98%	Textile waste	1.67 pp	1.11 pp
	Electrical/electronic items	0.56 pp	2.22 pp
	Lamps	2.22 pp	2.22 pp
	Metallic scrap	2.22 pp	2.22 pp
	Papers, cardboards, plastic stuff	2.22 pp	2.22 pp
	Sanitary waste	1.11 pp	2.22 pp
	Food waste	1.11 pp	1.67 pp
	Electric cells and batteries	2.22 pp	2.22 pp
	Sub-total/gap	14.98 pp/5.00 pp	17.76pp/2.22pp
Natural and	Water consumption	3.21 pp	2.41 pp
Resources	Electric energy consumption	2.41 pp	2.41 pp
29%	Lubricant oil consumption	3.21 pp	1.61 pp
	Plastic oil consumption	3.21 pp	3.21 pp
	Fuel consumption	3.21 pp	1.61 pp
	Paper consumption	1.61 pp	2.41 pp
	Wood consumption	3.21 pp	3.21 pp
	Spare parts consumption	3.21 pp	3.21 pp
	Office supplies consumption	1.61 pp	2.41 pp
	Sub-total/gap	24.89 pp/4.02 pp	22.49pp/6.42pp
Management	Well water license	2.26 pp	4.51 pp
and Law	Federal license	3.38 pp	3.38 pp
31.57%	State license	3.38 pp	3.38 pp
	City or county license	3.38 pp	2.26 pp
	ISO-14001 certification	3.38 pp	3.38 pp
	Qualification of suppliers	0.00 pp	0.00 pp
	Security normalizations attendance	4.51 pp	4.51 pp
	Sub-total/gap	20.30 pp/11.58 pp	21.42 pp/10.15pp
	Total	74.73%	77.61%

Table 3 compares gaps. Management and law, solid waste (in transportation) and usage of resources (in warehousing) have the most important gaps. Eventually, they must be focused on in a reformulated operation strategy. Due to internal correlations, actions should influence more than one indicator in the construct.

Table 2: Compared gaps in constructs among operations

Construct	Transportation	Warehousing
Atmosphere	1.29%	0.43%
Liquid Effluents	3.70%	3.17%
Solid Waste	5.00%	2.22%
Resources	4.02%	6.42%
Law and Regulations	11.58%	10.15%

We showed those findings to the body of managers. They said that the result is coherent with their observations. Regulations are quite important in the activity, mainly due to external activities related to the operation of transportation and the concerns associated with safety in the warehousing operation. As regards official regulations, managers stressed that, although the company fulfills all the requirements, it could go beyond the mere compliance with legal requisites as far as many items are concerned.

With regard to transportation, managers said that a great amount of operations occurs outside the facilities of the company. As a result, some solid or liquid refuse does not pass by the company management system. Operators may be forced to make choices or decisions along the routes, requiring public facilities to discard tires, batteries or lubricant oil, with a probability of an incorrect destination. As to warehousing, managers admitted that usage of materials and energetic resources has received little attention, mainly with paper and plastic for packages. The company makes low usage of returnable packages. Furthermore, it lacks an action which focuses on the rationalization of fuel for forklifts and load vehicles and takes account of alternatives such as natural gas, instead of diesel oil. Such actions should be considered in a reformulated strategy.

4. Conclusions

The main purpose of this paper was to present a method to assess the environmental performance of logistic operations. The method offers a normalized performance index, ranging from 0 to 100 %. It reflects the irreversible path of a complex phenomenon, such as the environmental performance of operations. The research method was a case study in transportation and warehousing operations. The method combined qualitative research techniques, such as focus groups sessions, and mathematical calculations.

As further development of this work, we suggest using multicriteria methods other than AHP for the prioritization, and testing the method in another kind of service operations, such as urban sewerage, as well as comparisons with manufacture operations. Preliminary applications have already been developed, and the tree-like structure for measurement differs to a great extent. The method can also be applied in productive chains, such as the automotive chain. The application along the chain can identify flaws in environmental performance. Finally, it can be proposed the integration of the method to the well-known cleaner production and reversal logistic technologies.

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