TOWARDS A CLOSED STEEL ECO-CYCLE – CONJOINT ANALYSIS AS A DECISION TOOL

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ABSTRACT

The Swedish steel industry has over the past 20 years made substantial efforts to promote energy efficiency and environment protection. However, the dominant part of these investments has been directed to the individual production sites, most of which today have 'solved' their own acute environmental problems. The focus has therefore switched to the properties and performance of the steel products where the evaluation of environmental performance is a complex task that often requires simultaneous consideration of many different attributes.

Conjoint analysis is commonly used in marketing research, to evaluate how consumers appreciate specific attributes in products. It has also been widely used in health care, traffic planning and quality management. Conjoint analysis has also been applied to environmental issues such as energy, recreation, environmental valuation, ecosystem management, consumer preferences to products, public preferences to industrial projects, waste management, and environmental policy development. This previous research has shown that the method is well suited for evaluating environmental issues.

Here we briefly present the methodology and review some papers on environmental applications. It is our intention to use this approach as a tool to integrate environmental considerations into both process and product development within the steel industry.

KEYWORDS

Steel ecocycle; Conjoint analysis; Experimental design; Environment values

1. INTRODUCTION

Mining of iron ore and the production of steel has been one of the most important trades in Sweden during history. Today its contribution to the total Swedish export value is 6.6 % (iron and steel), or 54 % if all goods and products made out of steel are included in the sum (cars, industrial machinery, manufactures of metals, instruments, parts etc.) [1].

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directed to the individual production sites, most of which today have 'solved' their own acute environmental problems. The focus has therefore switched to the properties and performance of the steel products. A new challenge for the steel industry is to find out to what extent it can actively contribute to an evolution towards a low-energy, low specific CO_2, low-waste and resource-efficient society. Thus a research programme concerning the sustainability of the steel industry as a whole has been commenced – "Towards a Closed Steel Ecocycle".

This interdisciplinary programme aim to increase the technical level of competence and improve the production methods to accomplish a more sustainable and eco-efficient steel industry. The research programme is funded jointly by the Foundation for Strategic Environmental Research (MISTRA) and the industry. The programme consists of six projects, all contributing to a closed steel ecocycle, Figure 1.
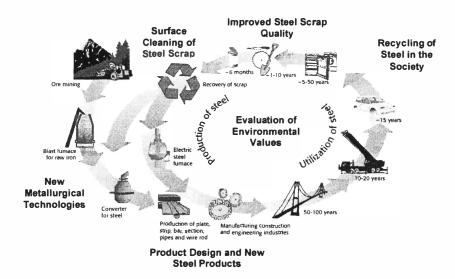

Figure 1. The programme "Towards a closed steel ecocycle" and its six projects [2].

The six projects that can be divided into three subprograms (project clusters):

Recycling
Improved steel scrap quality is a project that will investigate and develop analytical methods and sorting technology in the shredder plants to improve the quality control of steel scrap.

Surface cleaning of steel scrap. In this project methods for simultaneous preheating and surface cleaning of scrap will be developed for further use in the steel foundry sector.

New metallurgical technologies is a project aiming to investigate new slag systems and the potential for increased retention of metal valuables in the steel cycle. This will involve novel processes for slag treatment and metallurgical refining during steel-making.

Economising

Product design and new steel products. This project will develop design methods and systematics to minimise the environmental impact from steel products, together with an improvement of production and properties of the steel products.

Relevance studies

Recycling of steel in the society. The project will analyse the influence of economical and technical variables on the degree and appearance of the recycling of steel. Historical figures will be used to create a model that will be used for forecasting and analysis of possible future developments.

Evaluation of environmental values will provide LCC/LCA support for selected projects, assessment methodology and models as well as decision support tools. One part of the project will develop methodology and models for life-cycle environmental and cost assessments. Another part will develop methodology for evaluating and integrating preferences from various groups of stakeholders into the environmental decision-making process.

The scope of our paper is the second part of the project *Evaluation of environmental values*. We will briefly describe the research methodology for the subproject *Conjoint analysis as a decision tool for evaluation of environmental performance* and review some papers on environmental applications of this method.

2. METHODS

The evaluation of environmental performance and the choices between alternative solutions is a complex process. Different indexes and scaling systems have been developed to assist the decision-maker, but such approaches often suffer from the fact that the respondents have substantial difficulty in correctly separating and describing/scaling their preferences towards isolated attributes, e.g. toxicity, energy consumption and cost.

2.1 Conjoint analysis

Conjoint analysis is a commonly used technique in marketing research, to evaluate how consumers appreciate specific attributes in various products. It has also been widely used in health care, traffic planning and quality management. Green and Srinivasan defined conjoint analysis in 1990 as: "… any decompositional method that estimates the structure of a consumers preferences (i.e. estimates preference parameters such as part-worths, importance weights, ideal points) given his or her overall evaluations of a set of alternatives that are prespecified in terms of levels of different attributes" [3]. Since conjoint analysis can be used to reveal the preference structure towards a product or situation, the method is especially suitable for valuing environmental issues [4].

In a conjoint analysis study a respondent is asked to value different alternatives or attributes in a hypothetical situation. The researcher is thereby allowed to evaluate the relative importance of

these alternatives or attributes. Due to the fact that the researcher constructs the hypothetical situation, on the basis of the attributes she or he wants the respondent to evaluate, the method differs from so called revealed preference methods where the actual behaviour of a person is studied. In the conjoint analysis situation, only the hypothetically constructed situation is studied, i.e. what the respondent *states* that she or he prefers. Thus, conjoint analysis is called a stated preference method.

Luce and Tukey first described conjoint measurement in 1964 [5]. Since then several related methods have evolved, for example choice modelling, conjoint analysis, contingent valuation etc. Many of these methods are similar in their design although several of them differ in the data they generate [6]. They also differ in response mode (rate/rank/choose), method of analysis and conclusions that can be drawn from the results [7]. Although no international standard exists, there are some basic steps that are present in most methods [3,8,9]:

1. Selection of attributes and attribute levels to be tested
2. Selection of data collection method (interview, questionnaire)
3. Selection of data collection design (rank/rate/choose)
4. Construction of the stimuli for presentation to the respondents (two-factor evaluation or full profile)
5. Data analysis

Conjoint analysis can be used for a variety of purposes, the most common are: prices sensitivity, product development, product evaluation, developing marketing campaigns, advertising, distribution, controlling, repositioning, competitive analysis and in later years, also environmental evaluation [3,8-11].

2.2 Experimental planning

Using statistical experimental design as a basis for the investigation enables the researcher to separate and estimate the main effects of the attributes to the respondent's rating/ranking/choice, without risking confounding with interactions.

There are a number of different experimental designs to choose from. The *full factorial design* uses all combinations of attributes and levels. When using this design the researcher can detect all main effects of each attribute as well as the mean effect and the interactions between the attributes [12-13].

However, if the attributes and levels are extensive, then the all-combination factorial designs will result in a very large number of combinations. Therefore it is common in conjoint analysis to use *fractional factorial designs* which bring down the number of tested combinations to a manageable number [6, 14-17].

Plackett-Burman designs are yet another type of screening designs used in conjoint analysis. The Plackett-Burman designs are especially suitable for surveys with a large number of attributes, where the fractional factorial design fails to cover all the data [18].

2.3 Data analysis

There are several ways of analyse the collected data, but the choice of method is dependent on the selected model and other decisions made earlier in the conjoint process [9].

Some of the methods used in the reviewed papers are listed below:
- Cluster analysis
- Multinomial logit model [19-20]
- Multiple linear regression [21]
- Binary logistic regression analysis [15]
- Analysis of variance (ANOVA) [15,17]

There is one interesting method that has not yet been evaluated to its full extent; namely bilinear regression methods. Gustafsson proposed the use of partial least squares regression (PLSR) [22]. PLSR is based on a linear transformation of the original data to a limited number of orthogonal factors, attempting to maximize the covariance between the attributes and the stated preferences. Multivariate calibration using PLSR is reviewed by Martens and Næs [23]. Results from a PLSR2-analysis can be efficiently communicated with different graphs and here we see an opportunity for further method development. Another advantage is that it is possible to evaluate the preferences, not only as an aggregate measure for the whole group of participants, but also individually for each participating respondent.

2.4 Literature review

An introductory literature review has been conducted through bibliographic database searches of Science Citation Index Expanded (SCI Expanded) and citation lists in identified articles.

3. RESULTS

Conjoint analysis (together with related methods) is a relatively new approach for evaluating environmental values. It was not until the mid 90's that the method was first used in a wider concept. Since then conjoint analysis has been applied to several environmental issues such as energy, recreation, environmental valuation, ecosystem management, consumer preferences to environmentally certified products, public preferences to industrial projects and environmental policy development. In Table 1 we have collected some of the conjoint analyses made over the last decade.

Table 1, Environmental applications on conjoint analysis

Field	Application	Reference
Energy	Environmental impact of wind farms	[14]
	Environmental, health, and employment effects of energy programs	[24]
	Household preferences for energy-saving measures	[17]
	Willingness to pay for green electricity	[25]
Recreation	Indicators for recreation	[26]
Agriculture	Farmers' perception of unsprayed crop edges	[16]
	Agricultural environmental benefits and costs	[27]
Ecosystem management	Deer hunting and landscape change	[19]
	Value ecosystem change	[4]
	Forest management	[28]
	Tropical rainforest preservation.	[29]
	Ecosystem management	[30]
	Change in river quality on the tourism value of Kruger National Park:	[21]
Environmental evaluation	Environmental valuation	[6,i10-11, 31-32]
	Valuing wetland attributes	[33]
	Valuing watershed quality improvements	[34]
	Valuing the benefits of environmentally sensitive areas.	[35]
Waste management	Preferences within the composting industry	[36]
Products	The impact of environmental certification on preferences for wood furniture and wood products	[15] [37]
	Design for the environment	[38]
	Clean-fuel vehicles	[20]
	Integration of environmental management and product design	[39]

Traditionally, conjoint analysis has been used in marketing, and an important feature for a market researcher is how much money a consumer is willing to pay for a specific attribute of a product. This way of thinking has been applied also in ecological economics and used in a wide range of conjoint analysis on environmental issues. Farber and Griner estimated the value of improved water quality [34]. Rolfe et al. completed a survey where conservation of rainforest was studied. In this study environmental attributes were mixed with socio-economic attributes resulting in a survey which demanded the respondents to take ethical considerations along with environmental [29]. The authors showed that the conjoint method very well handles this mixture of socio-economic and environmental attributes to the alternatives.

Conjoint analysis can also be used to facilitate the planning of new projects. Carlsson et al. evaluated some attributes in a planned wetland [33]. The attributes investigated were surrounding

vegetation, biodiversity, fish, fenced waterline, crayfish and walking facilities. The authors found that meadow land, fenced waterline and crayfish were understood to decrease social welfare, while biodiversity and walking facilities were given the largest values for "Willingness To Pay".

Portinga et al. studied the preference for different types of energy saving measures in households [17]. Energy-saving strategies (technical improvement, different use of products and shifts in consumption), domain of saving (home or transport) and the amount of energy savings (small or large) were investigated. It was found that saving energy at home was more acceptable than transport measures, and technical improvements were more acceptable than behavioural measures. Interestingly, there was almost no difference in the household's preference to whether the energy-savings were small or large.

There have been several conjoint analyses made, where a specific attribute for a product was investigated. In 2004 Anderson and Hansen studied the impact of environmental certification on preferences for a wood CD rack [15]. Although the respondents were not representative for the general population, the results showed that a small part (approximately 20 %) of the respondents rated environmental certification as the most important feature of the CD rack. Within this group the respondents were willing to pay extra for the certificate. Among the other respondents however, price was the most important factor, followed by adjustability of the shelves. The results of the study indicate that the large majority of consumers are not willing to pay extra for environmental certified wood in furniture.

Chen made a similar conclusion when a model was constructed to consider the interactions between consumers, policy makers (government) and producers [28]. The author demonstrated that green product development is an expression with different meanings to different stakeholders. For example, producers, consumers and the government may have different views on the "greenness" of a product as well as on its actual benefit to the environment. In the model, conjoint analysis is used to model the consumers purchase behaviour. The author finds that "green product development and stricter environmental standards might not necessarily benefit the environment".

Another interesting application of conjoint analysis is due to Probert et al. analysing preferences within the composting industry in Wales [36]. Main groups of stakeholders were asked to evaluate some attributes of compost soil (pH, price, screen size and level of production specification). The authors conclude that the conjoint analysis works well in this situation and that price was the most important attribute of compost utility by the means of contractors and retailers.
For evaluating the quality of recreational areas, Gossen and Langers constructed a hierarchical conjoint analysis [26]. The method can be used when indicators that influence particular decisions are identified in advance. Twenty-seven hypothetical rural areas were constructed and evaluated by 1250 respondents for cycling, walking, swimming, sailing and fishing. The most important quality indicators were found to be tranquillity, accessibility, water quality and nuisance value.

4. CONCLUSIONS

Conjoint analysis is a method that is well suited for evaluating environmental issues, as shown in several research projects. The possibility for the researcher to model the hypothetical situation and choose what attributes and levels to be studied gives a unique opportunity to address the specific environmental issues that are of concern within each specific project.

There is a need for the steel industry to have methods and tools to integrate environmental considerations into both process and product development. These tools need to take into consideration the views from several different groups of stakeholders (experts, developers and users). Conjoint analysis seems to be a promising starting point.

We aim to develop such a tool by combining the conjoint analysis with statistical experimental design and multivariate data analysis, using bilinear projection methods and graphical presentation of results as preference maps.

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