Studies of preferences as an extra dimension in system studies

Stina Alriksson[1,*], Carl-Erik Grip[2]

[1] *Linnaeus University, School of natural science, Kalmar, Sweden*
[2] *LTU (luleå University of technology) Dept Energy technology, Luleå, Sweden*
** Corresponding author. Tel: +46 480 446773, Fax: +46 480 447305, E-mail: stina.alksson@lnu.se*

Abstract: Industrial energy systems are complicated networks where changes in one process influence its neighboring processes. The network complexity increases if production/use of bio fuel is introduced in an existing system. Process integration can be a useful tool to study such systems and thus avoid sub optimization.

However, changes in an industrial complex do not only influence the technical values of energy and material efficiency. The social impact is also important and sometimes is comparable to that of technical factors.
A process integration project has recently been carried out for a paper mill in northern Sweden with a side view on future expansion with a bio refinery. An activity to study the social impacts were included through a Conjoint analysis, a stated preference method that combines statistics and interviewing technique.

The results indicate that the participants are divided in four groups, the largest group focusing on a change in the process towards a bio refinery, the second largest focusing on the local environment. The third and fourth group both look at the local forestry, one group wanting to increase local forest production, and one rejecting an increase.

Keywords: *process integration, bio refinery, conjoint analysis, social values.*

1. Introduction

1.1. Pulp and paper – development of energy efficiency and biofuel production

The Swedish wood industry is an important part of the Swedish economy and is responsible for 12 % of the Swedish export. Totally, it is the world's second largest exporter of total paper, pulp and sawn timber. The forest industry is Sweden's largest user of bio-energy and also the largest producer of bio energy. Presently this energy is used mainly internally [1]. A lot of effort is put on work to improve energy efficiency and sustainability. Also several large projects have been started on conversion of by-product into bio fuel e.g. green motor fuel [2].
A partly conversion of a paper producer into a bio refinery involves a lot of changes which will influence the rest of the mill, the employees, the surrounding society and the interaction with the actors involved in supply of wood raw material. It is important, in order to get a successful practical implementation, to consider also non-technical factors, like ete attitudes and reactions of these actors.

It was decided to test these ideas in a process integration project that was carried 2009-2010 in an existing pulp and paper mill. The project studied changes to improve energy efficiency as well as a hypothetical transformation to also include a bio refinery [3]. The project included several different methods and models. A process integration model of the paper mill was developed using the mathematical programming tool reMIND [4]. The results from this model was compared to a Pinch-analysis. The work also included a study on the effect on the wood suppliers and market prices of raw material, using the tool ReCOM, a regional economic market model. A study using the conjoint method [5] was included to study the effect of a plant conversion on attitudes and popular acceptance. Only plant employees were included as test group to limit the size of the first study.

1.2. What is conjoint

The choices people make are based on many things as previous experiences, training, attitude, habits, ethics etc. A person will choose the product or alternative that is most useful for this person (utility theory). The decision is formed by simultaneously considering multiple factors, a unique quality of the human brain. On a daily basis a person makes hundreds or possibly thousands of choices in this way, and this is what the method of conjoint analysis takes advantage of.

Conjoint analysis is a stated preference method, which can be used to assess people's preferences for a specific product, service or situation. It is used to evaluate the attributes of the product/service/situation and thereby makes it possible to determine which attribute is the most important in the evaluated situation. Individual or group level preferences can be estimated by decomposing the responses into part-worth's, thus the results come in quantitative measures which means that they can potentially be incorporated into other models such as process integration models and/or economic models. Studies have previously been made in which conjoint analysis results has been integrated in a Life Cycle Assessment (LCA) as weights in the environmental valuation phase [6]. There has been some attempts to integrate process integration with economic modeling [7] but to the best of out knowledge studies of social values has never been integrated in a process integration project. Further information on conjoint analysis can be found in [8-11].

The purpose of the study was to study the preferences of the employees when asked to compare local environment, global environment, increased local forest outtake and change of process from paper/pulp to paper/pulp and bio refinery. Another aim of the study was to find methods to integrate the result with the process integration result.

1.3. Scope of paper

The paper describes the conjoint method as such, the possibility to integrate the result with process integration models and economic models, as well as the possible use of the results as a basis for decision-making in the paper mill as well as for community decisions.

2. Methodology

The study was carried out through a web-based questionnaire where employees at a paper mill were asked to rank eight different alternatives where local and global environmental impact, local forestry and change in the process were altered in different ways. From the responses, individual as well ass average preferences have been estimated.

2.1. Conjoint analysis

In a conjoint study, the respondent is asked to evaluate a set of alternatives where the factors are varied in a fractional factorial design (reduced design), with two or three levels of each factor (attribute). The factors must be carefully chosen, and can be identified through group discussions, in depth interviews or expert elicitation. Each factor must be provided with two or more levels (high/low). The number of factors must be limited since respondents will not be able to maintain the same level of concentration if the number of evaluations is too large. Four to six attributes are often considered functional [11].

The alternatives that the respondents are asked to evaluate are created through an experimental plan. In order to keep the workload manageable for the respondents the number of alternatives to evaluate needs to be kept at a reasonable level.

The factors were chosen through discussions with Billerud Karlsborg AB in order to make the study relevant for the paper/pulp mill. Relatively early in the process it was decided that the study should be held internally at Karlsborg in order to avoid rumours and speculations in the surrounding society since a bio refinery is not planned in Karlsborg as of today. In the final design of the study, a fractional factorial design with four factors in two levels (2^4) were used, see table 1. The resolution of the design was IV, and only main effects were studied.

Table 1, The design of the study.

Alternative	Local forestry	Process	Emission of carbon dioxide	Local environmental impact
A	Same as now	Pulp/paper + bio refinery	Same as now	20% increase
B	Same as now	Pulp/paper	Same as now	Same as now
C	Same as now	Pulp/paper + bio refinery	Decrease	Same as now
D	Increased outtake	Pulp/paper + bio refinery	Decrease	20% increase
E	Increased outtake	Pulp/paper	Same as now	20% increase
F	Increased outtake	Pulp/paper + bio refinery	Same as now	Same as now
G	Same as now	Pulp/paper	Decrease	20% increase
H	Increased outtake	Pulp/paper	Decrease	Same as now

The study was distributed as a web questionnaire. A message was posted on the intranet to encourage employees to participate. The questionnaire consisted of three parts, first an introductory letter with information on the study and the factors, then the conjoint analysis where the respondents were asked to rank the alternatives in Table 1 from 1-8, and finally the participants were asked questions on residency, age, gender, educational level, work situation and any training in energy efficiency, environment, work environment and forestry.

All employees hand the opportunity to fill out the questionnaire, it was open for two weeks in order to cover all shifts. In all 61 persons answered the questionnaire and from these six responses had to be removed due to inconsistent answers, leaving 55 responses. There are 425 employees at the mill leaving us with a response rate of 13%.

2.2. Analysis of data

In this study two ways of analysing the data are used, first by calculating the main effects from the experimental plan, and then using partial least squares regression, PLSR.

Partial Least Squares Regression (PLSR) is a bilinear multivariate regression method that can simultaneously handle several response variables. PLSR is based on a linear transformation of the original variables to a limited set of latent variables (orthogonal factors), PLSR also attempts to maximize the covariance between the independent and dependent variables. The main advantage of PLSR is that the results can be presented graphically with all individual responses visible. Further information on this method can be found in [12]. The Unscrambler software was used to perform the PLS regressions in this survey [13].

Cluster analysis has proven useful to find segments among respondents in conjoint analysis studies [14-15]. The cluster analysis forms clusters of the respondents by putting respondents (samples) that are similar to each other into groups, at the same time as respondents that differ in response are kept apart. In this project, a hierarchical cluster analysis was applied to the individual main effects from the experimental plan (cluster method: between-groups linkage and interval measure: squared euclidean distance). The analysis was performed with the classification unit from the SPSS v. 17.0 software package [16].

3. Results

3.1. Respondents

Age and gender of the respondents can be seen in table 2. 22 respondents (40%) worked with operation of the mill, 12 respondents (22%) worked with maintenance, 9 respondents (16%) worked with process- and product development and 11 respondents (20%) worked with administration. 41 of the respondents (75%) worked daytime while 14 (25%) worked shifts.

Table 2, age and gender of the respondents in numbers.

Born	80's	70's	60's	50's	40's	No information	Sum
Men	3	6	9	18	6	2	44
Women	3	3	2	3	0	0	11

37 respondents (67%) lived 6-30 km from Karlsborg, 10 respondents (18%) lived in the vicinity, i.e. closer than 5 km and 8 respondents (15%) had more than 31 km to Karlsborg from their homes. 29 of the respondents (53%) were forest owners (or had someone in their closest family that owned forest), 25 respondents (45%) were not and 1 respondent (2 %) did not give any information on this question. 5 of the respondents (9%) had finished primary school, 27 respondents (49%) had finished secondary school and 23 respondents (42%) had a university degree.

3.2. Preferences

The average results are presented in Figure 1. It must be remembered that the number of respondents is small, only 55 complete responses, which means that the result could probably look different with more respondents.

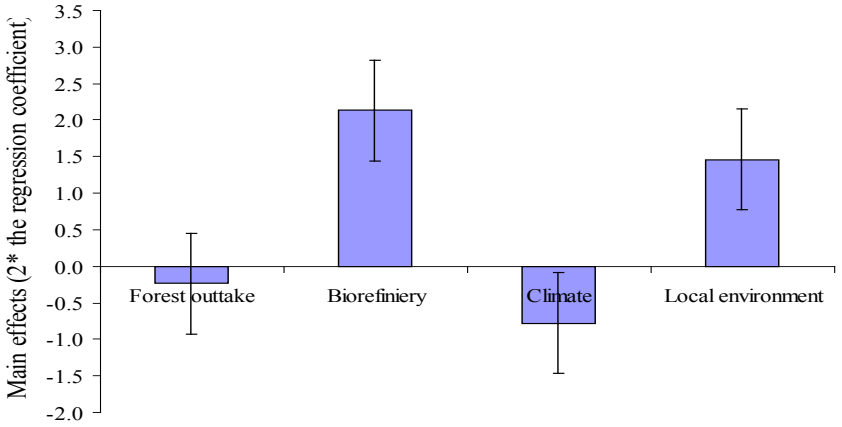

Figure 1. Averaged main effects with standard error for all respondents.

By using a PLSR-plot, individual results can be illustrated, see Figure 2. In the plot, the numbered marks represent individual respondents while the factors are marked with text. The PLSR plot is multi-dimensional, but here, only the first two latent variables are shown,

making the graph two-dimensional. The plot can be interpreted like a map, the closer a respondent lies to a factor, the more important the respondent regard the factor. The plot also reveals negative correlations when a respondent lies on the other end of the latent variable (axis) from a factor, she or he has a negative preference for the specific factor.

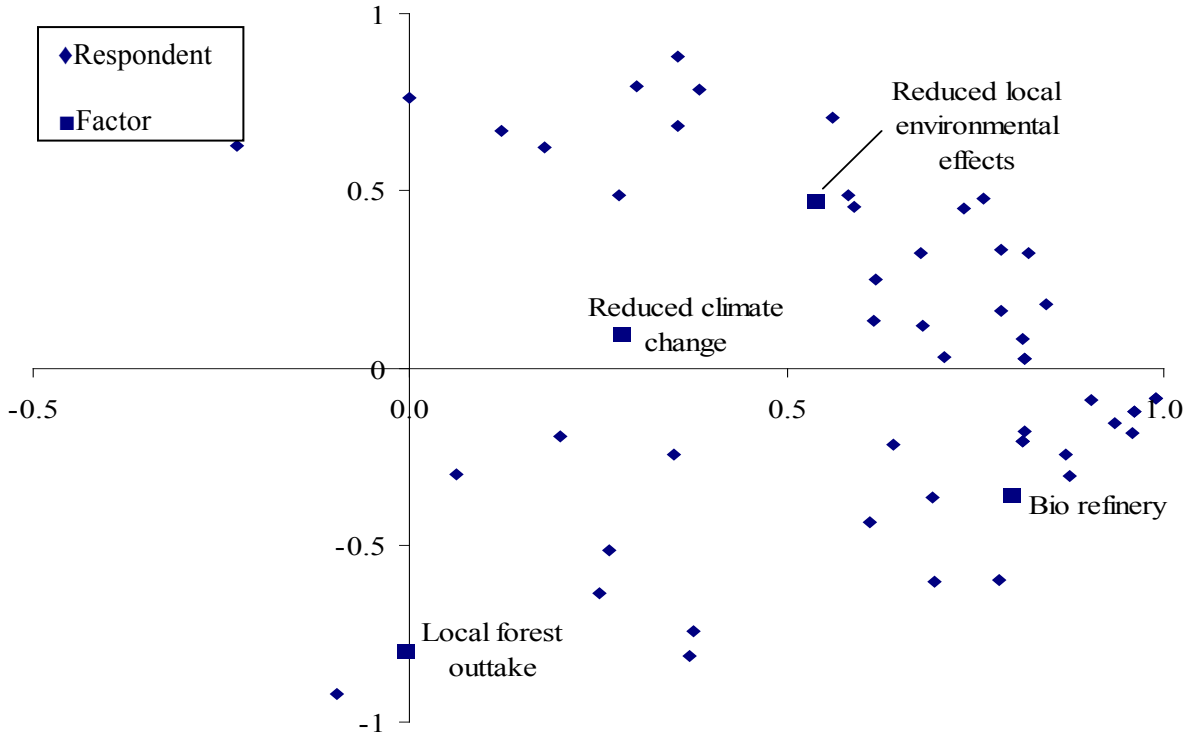

Fig 2. PLSR2. The first two latent variables explaining 65% of the total variance.

If the preferences are compared to the known facts on the respondents, from the information they left in the questionnaire, women are generally more concerned for the local environment than men (p=0.009). Age influence the view on local forestry (p=0.011). Preferences for the local environment are influenced by educational level (p=0.016) and whether or not the respondent or anyone in her/his close family own forest (p=0.010).

If respondents working with maintenance are compared to respondents working with process and product development, there is a significant difference in how they prioritize an increase in forest outtake (p=0.033), see Figure 3.

3.2.1. Training

Respondents with a university degree prioritise increased forest outtake more than respondents with primary and secondary school degrees (p=0.046). 10 respondents had taken part in three or four of the training subjects (forestry, energy, environment or work environment) and for these respondents preferences for forestry differed significantly from the others (p=0.010). The training subjects individually had no influence on the preferences at all. One more thing is interesting to notice, all educations correlate to each other, i.e. if a person has attended one education, she or he is more likely to attend educations in other areas as well.

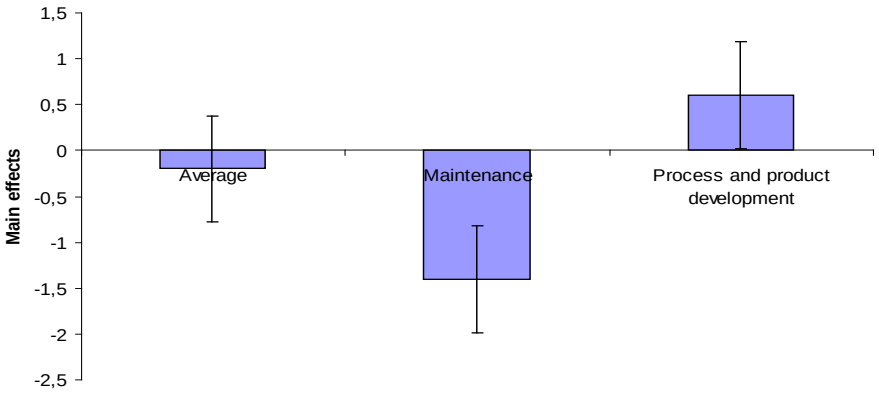

Fig 3. Averaged main effects for respondents working with maintenance (n=12) and process and product development (n=10).

3.2.2. Clusters

Through cluster analysis four clusters (groups) of respondents were formed, see Figure 5.

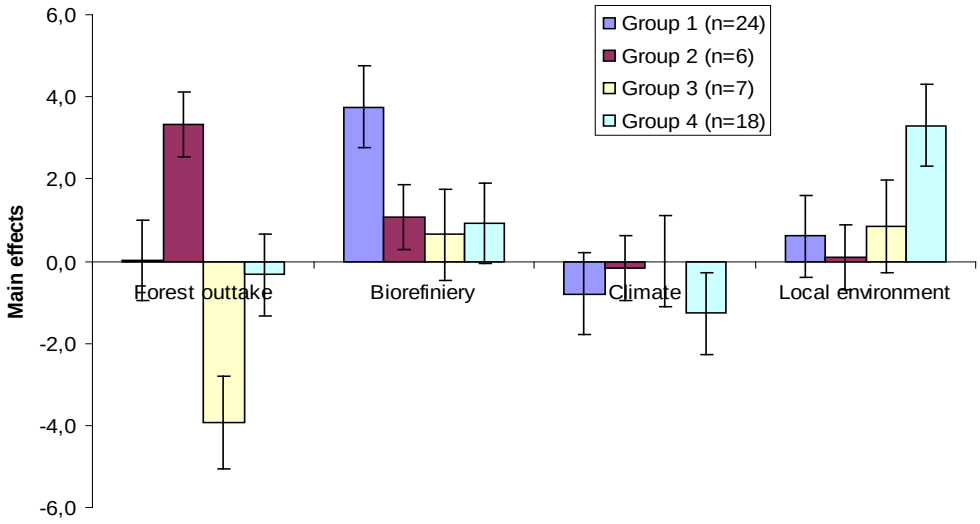

Fig 5. Groups created through cluster analysis.

The number of respondents in this study are to few to draw any further conclusions from the clusters, but in a large-scale study, the clusters could be analyzed for common characteristics such as educational level, occupation, gender etc.

4. Discussion and Conclusions

4.1. Discussion

The number of respondents were fewer than most favorable, probably due to many different reasons. The questionnaire was made available on the Billerud intranet for two weeks, in order to cover all shifts, but it would probably have needed further marketing for more employees to fill out the questionnaire. It would have been preferable to have at least 100 correct responses to the questionnaire.

The results from a conjoint analysis are quantitative. They can be averaged for the whole group or presented individually for each respondent. New groups can also be found through

cluster analysis (see Figure 5). Since the number of respondents are so small, it is not possible to draw any further conclusions on common features among the people in the same group (cluster), but with a larger set of samples (respondents) this would be possible. For the industry this means that it could be possible to pinpoint groups of employees that can be especially helpful in implementing new energy efficient processes, or groups that need extra information to be able to carry out new procedures in a correct way.

Conjoint analysis has been used to illustrate and discuss if the results from a conjoint analysis can be used together with a process integration tool such as a remind model and/or an economic model such as the ReCOM model.

The quantitative results can be used in process integration in several ways, see Figure 6.

A It can be used together with en economic model such as ReCOM as a means of choosing scenarios in the model. The factors in the conjoint analysis can be tailored to indicate how the market would respond in a hypothetical situation.

B Conjoint analysis can also be combined with economic theory and used to derive Willingness To Pay (WTP). This implicit pricing can also be used in economic models such as the ReCOM model. The economic model can be used to derive relevant levels to the factors of the conjoint analysis.

C Conjoint analysis can be used to weight different factors in the process integration model. The weighting can possibly also be used in the economic model. The factors will need to bee rather specific, for example emission of NOx from process XX.

D A process integration model can be used to derive relevant levels to the factors of the conjoint analysis.

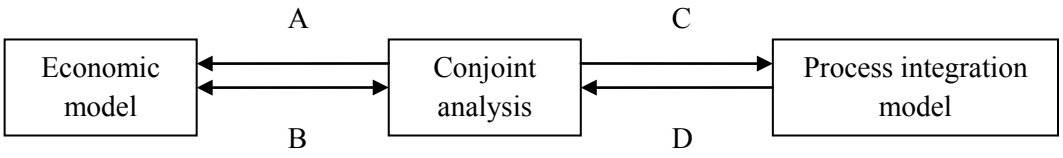

Figure 6. Possible exchanges between conjoint analysis, a process integration model such as a remind model and an economic model such as the ReMIND model.

4.2. Conclusions

Preference studies using Conjoint can be an important tool in studies and actions to improve energy efficiency and sustainability. It can be related in different ways to process integration models and economic models associated with them.

It is also interesting to notice that it is possible to find groups of respondents that were unknown previous to the study, as with the example with two groups of employees working with maintenance and process and product development. If an organisation wants to implement a change in the process conjoint analysis can be used to identify groups of participants with similar preferences and then tailor information to suit these specific groups.

The results of this study leave no clear information on the effect of training. If behaviour and attitudes of the employees are crucial for the full scale implementation of a process integration model, more research needs to be done on the effect of training. In this study, there were no significant connections at all between training and preferences.

Acknowledgements

The authors would like to thank the Swedish energy agency and the Billerud Karlsborg paper mill for financing the work. Also the people at Billerud Karlsborg are thanked for their cooperation in the work

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