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User-based definition of higher-order decision constructs to model preferences for P&R transfer points

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Abstract

To achieve a reduction in the number of cars entering the city centre, transfer points (P&Rs) at the city edge should be realised where car users can switch to public transport. However, recently realised P&Rs in the Netherlands do not attract many car users. The planning of more frequently used P&Rs obviously requires a better understanding of the car users' preferences. For this purpose, the hierarchical information integration (HII) method will be used.

HII requires relevant attributes to be clustered into decision constructs. To the best of our knowledge, the researcher has so far always performed this. This might result in decision constructs that do not reflect the grouping process of travellers. Hence, to attain potentially more valid results the grouping of attributes should be based on empirical data. In this paper, we develop and apply such an empirically based grouping procedure and present the results of an Internet-based survey completed by potential users of P&Rs.

1 Introduction

Cities in industrialised countries are increasingly confronted with the negative consequences of car use growth, resulting in traffic jams and parking problems in and around the cities. City authorities therefore pursue a reduction of the number of cars entering the city centre. One way to achieve this is to realise high-quality public transport to the city centres. P&Rs could combine the advantages of public

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transport with those of the car. However, recently realised P&Rs in the Netherlands do not attract many car users. The planning of more frequently used P&Rs obviously requires a better understanding of the car users' preferences.

When describing P&Rs many aspects need to be taken into account. The traveller is confronted with those aspects from entering the P&R from the motorway until the departure from the P&R with public transport. First, the traveller may be informed about the attractiveness of the P&R, its location and the number of parking places. Of course, the P&R should be accessible. Arrived at the P&R, the traveller will consider the quality of the P&R. This involves the chance of finding a free parking place, parking costs, the liveliness at the car park, the distance between the parking place and public transport, and the fact whether this route is roofed over. Arrived at the platform the traveller has to wait a certain time. Travellers can fill in this waiting time by using additional facilities, such as heated waiting rooms, kiosks or supermarkets. Finally, characteristics of the public transport are relevant, for example the type of transport, frequency, costs, reliability and comfort. These aspects are announced attributes for the rest of this paper.

To trace the preferences of the car user, often the stated preference (SP) approach is applied (e.g. Davidson [1]). Following this approach, an individual evaluates a number of hypothetical choice situations by giving a rate or making a choice. From these evaluations, the contribution of the part utility of each attribute level to the total utility of an alternative can be derived.

However, a traditionally stated preference experiment can only handle a limited number of attributes. One of the methods, which takes a large variety of attributes into consideration, is the hierarchical information integration (HII), proposed by Louviere [2]. The advantage of HII is that this method is theoretically well funded (Oppewal [3]). The assumption of the HII-method is that individuals firstly cluster the attributes in higher order decision constructs, then evaluate each decision construct separately and finally integrate these evaluations into an overall preference or choice (Louviere and Timmermans [4]). Consistent with these assumptions an experiment will be conducted for each decision construct separately, within only the attributes that define the construct. Parallel to this, a so-called bridge experiment will be carried out, in which all the decision constructs will be compared to obtain an overall evaluation or choice.

The grouping of attributes into decision constructs has so far always been performed by the researcher. This may result in decision constructs that do not reflect the grouping process of travellers. Hence, to attain potentially more valid results the grouping of attributes should be based on empirical data.

The goal of this paper is to make a contribution to the development and application of a method that clusters pre-selected attributes into decision constructs needed to apply the HII method. Therefore, an Internet-based questionnaire was developed. In this questionnaire thirty pre-selected attributes are shown separately to the respondent in a randomised order. The respondents are asked to group these attributes into clusters, which contain similar attributes. An available method to analyse these clusters of attributes is Multidimensional

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Scaling (MDS) (Louviere [2]). MDS allows transforming these forthcoming similarity judgements to distances represented in a multidimensional space (Kruskal and Wish [5]).

This paper is organised as follows. Section 2 explains the theory behind the MDS method. Section 3 discusses the research design. In section 4 the results are presented and finally in section 5 some conclusions are drawn.

2 Theory Multidimensional Scaling

The goal of Multidimensional Scaling (MDS) is to transform respondents' judgements of similarity or preference of objects into distances represented in a multidimensional space. If two arbitrary objects are judged to be most similar compared with all other possible pairs of objects, the MDS-method positions these objects so that the distance between them in multidimensional space is smaller than the distances between any other two pairs of objects. The most often-used measure of dissimilarity is the Euclidean Distance (Chatfield and Collins [6]). The resulting perceptual map shows the relative positioning of all objects. Statistically, it is not only possible to find an MDS solution in a two or three-dimensional space, but also in a more-dimensional space. Hence, the interpretation of this solution is more difficult by increasing the dimensionality.

The number of dimensions refers to the number of coordinate axes, that is, the number of coordinate values used to locate a point in the space (Kruskal and Wish [5]). The determination of the number of dimensions represented in the data is generally reached by using the stress measure, which indicates the proportion of the variance of the disparities (differences in the computer-generated distances representing similarity and the distances provided by the respondent) not accounted for by the MDS model. The stress is minimised when the objects are placed in a configuration so that the distances between the objects best match the original distances. Stress always improves by increasing the dimensionality. A scree plot of the R^2 measures supports making a trade-off between improving the fit of the solution and reducing the number of dimensions.

3 Research design

Several choices are made to derive the clustering of attributes. To start, attributes which can influence the choice behaviour of the traveller are selected. This selection procedure was as follows. First, a list of attributes was obtained by analysing the successes and failures of already existing P&Rs from the literature (e.g. Ministry of Transport [7]). This list contained 60 attributes, which were tested in a pre-questionnaire test that consisted of two rounds. In the first round ten respondents were asked to evaluate the importance of 60 attributes on a scale from one (the attribute does not influence the choice behaviour at all) to seven (the attribute certainly influences the choice behaviour). The respondents were also asked to add some additional attributes, if any, which influenced their choice

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behaviour. In the second round, ten other respondents tested these additional attributes. In both rounds the respondents were also asked to sort cards with the attributes into stacks so that all the cards in a stack represented similar attributes according to the respondent.

After testing it was obvious that the respondents could not handle the clustering of 60 attributes. Therefore, the number of attributes was reduced to 30, based on two criteria. Attributes with too much overlap were combined to form a new attribute. Attributes which received very low importance scores and are not really prominent in the literature were also excluded from further analyses. Finally, a list of 30 attributes was obtained, which is described in Table 2.

In spite of the reduction of the number of attributes, it was obvious that the clustering of attributes with cards would be too time and costs consuming as it required interviewers to explain and supervise the task. Therefore, interactive software was used to carry out this task. This also provided the possibility to use the Internet for deriving respondents and collecting data easily. Making use of the computer, the task was simplified by showing the attributes separately to the respondent, thus making it possible that the respondent could place these attributes into one of six boxes with a click of the mouse. Accordingly, respondents could define a maximum of six groups, because these could clearly be arranged on the computer screen and from preliminary research it was observed that respondents hardly ever formed more clusters. After placing the attribute shown in one of the six boxes, the next attribute appeared. The order of showing the attributes was randomised for each respondent. By doing this, the chance of inaccurately classifying attributes because of fatigue effects is equal for each attribute. This means a minimalisation of the aggregated error. This process was repeated until all attributes were grouped into clusters. It was also possible to introduce some changes by dragging the attribute in question to another box.

The questionnaire consisted of three parts. The first part included questions about personal aspects and a filter question to reach the target group. The respondents who never used the car were thanked for their contribution and their questionnaires were excluded from the analysis. In the second part the respondents were asked to indicate the importance of all the thirty attributes given. The value attached to the attribute indicates the measure of influence of the attribute regarding the choice behaviour of the respondent concerning the decision whether to use the P&R or not. The order of the attributes presented was also randomised for each respondent. Placing this task before the clustering task has the advantage that the respondents have seen the attributes already before they have to group them into clusters. The third part of the questionnaire was the clustering task.

To reach the target group, a link to the Internet page with the questionnaire was included in the electronic newspaper of *snelheidscontrole.com* e-mailed on 9 June and 16 June. This newspaper contains the expected speed checks in the Netherlands. The Dutch car users among the subscribers to this newspaper belong to the target group. Furthermore, a link was established in the daily electronic newspaper of *kranten.com*, e-mailed from 25 June until 28 June (from

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Monday to Thursday); the link was also advertised on the site of *kranten.com* from 25 June until 1 July. On this site the most prominent news is presented from national leading newspapers.

558 Respondents filled in the questionnaire completely; 424 (76.0%) males and 134 (24.0%) females. The fact that men use the car more frequently than women (Lucassen [8]) is an explanation of the overrepresentation of men.

Looking at the age groups, 45.9% of the respondents are younger than 30, 47.3% of the respondents are between 30 and 50 years of age and 6.8% of the respondents are older than 50. The small number of respondents older than 50 can be explained by the fact the Internet is less widely available to this group,

Finally, the level of education was examined. A majority (74.6%) of the respondents had a bachelor's or master's degree; 25.4% had received lower or intermediate education. The number of highly educated respondents is explainable because of the fact that people with a bachelor's degree or higher have a higher availability of the Internet (Bosveld and Greven [9]). Looking at the percentages, the response group is not representative when taking into account the three aspects mentioned above. Therefore, the differences between the categories of these aspects need to be analysed.

4 Clustering of attributes in decision constructs

The input of the MDS calculations is a 30-30 data matrix with the dissimilarity data in the cells. These values are calculated as follows: the maximum possible number of times that attribute pairs can be grouped in the same cluster (i.e. 558 times) minus the real number of times that the attribute pair in question has been grouped in the same cluster. The dissimilarity data obtained are of ratio level. Indeed, the lowest value in the matrix is zero, which is reached when all respondents group the attribute pair in question in the same cluster; the highest level is 558, which is reached when none of the respondents group the attribute pair in question in the same cluster. The calculations are made with the help of the ALSCAL procedure in SPSS [10].

SPSS allows determining a solution containing one to six dimensions. The more dimensions, the better the distances of the observed similarities can be presented. However, the more dimensions, the more difficult it is to understand the solution as well. Therefore, a well-balanced solution has to be found which is interpretable.

To determine the dimensionality of the solution, it is not only possible to study Kruskal's stress measure for each dimensionality; it is also possible to apply the R^2 (explanatory variance) as well. Table 1 gives both values for each dimensionality. The solution obviously improves when including one to two dimensions as is indicated by the decrease of the stress and the increase of the R^2 value. The change from two to three dimensions also leads to a better solution, but to a lesser degree, although the increase of the R^2 value is still present. The improvement of the solution is substantially smaller when a change is made from three to four dimensions. After studying the two and the three-dimensional

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solution, the three-dimensional solution was chosen because this solution allows a more sophisticated interpretation.

Table 1: Stress and R^2 values for each dimensionality

Dim	Stress	Decrease stress	Dim	R^2	Increase R^2
1	0.49	0.51	1	0.60	0.60
2	0.31	0.18	2	0.80	0.20
3	0.23	0.08	3	0.89	0.09
4	0.17	0.06	4	0.92	0.03
5	0.13	0.04	5	0.94	0.02
6	0.10	0.03	6	0.95	0.01

To interpretate the three-dimensional solution three plots are made: the x-coordinates of the solution against the y-coordinates, the x-coordinates against the z-coordinates and finally the y-coordinates against the z-coordinates. This results in Figure 1, Figure 2 and Figure 3. In other words, these three figures are the two side-views and the view from above of a cube. Thus, the figures have to be interpretated as such. In these figures, the numbers of the attributes (see Table 2) have been chosen so that the numbers support the interpretation of the solution.

Attributes in the same cluster are more similar to each other than to those in other clusters. Therefore, these attributes belong to the same decision construct. Based on the solution, the attributes can be grouped in the following five main clusters, also represented in Table 2: public transport, time, parking, costs and staying at the P&R. From the plots it can be seen that the cluster *public transport* can be grouped again into two subclusters, *reliability* and *comfort of the public transport*. The attributes within the cluster *time* are positioned a little further away from each other, but nevertheless a clear cohesion can be seen. However, all attributes within the cluster *parking* are situated very closely to each other. Hence, a dichotomy can be distinguished: on the one hand the information aspects, on the other hand the facilities about parking. The three attributes within the cluster *costs* are positioned close to each other. Furthermore, it is noteworthy that the other attributes are positioned far away from this cluster. Finally, the attributes within the cluster *staying at the P&R* have been positioned remarkably close to each other, except for attribute 30, *the possibility to rent a bike*. This is explainable given the fact that the remaining ten attributes are truly about *staying at the P&R* whereas attribute 30 is seen as an additional provision which does not directly have anything to do with *staying at the P&R* itself. The remaining attributes can be grouped into subclusters that are about *safety*, *human contact* and *additional provisions*. The classification, which has been measured with data derived from a great number of possible transferring travellers, deviates from the respondents' original thoughts about clustering attributes concerning *information*, *costs* and *time*. While initially a separate cluster *information* was considered, the respondents appear to combine the aspects of information with the different parking aspects.

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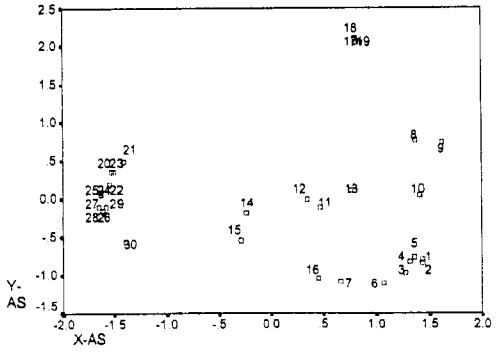


Figure 1: X-axe en Y-axe of the three-dimensional configuration

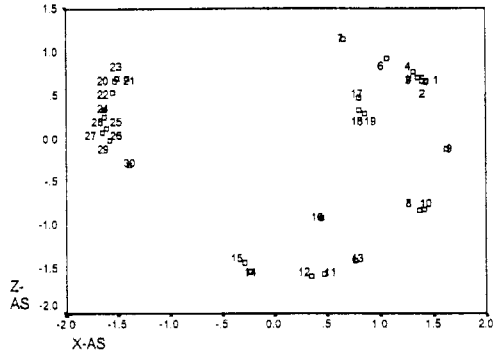


Figure 2: X-axe en Z-axe of the three-dimensional configuration

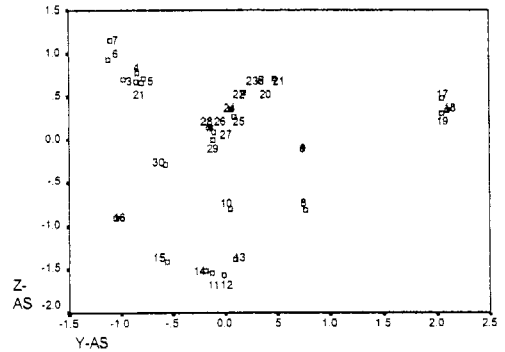


Figure 3: Y-axe en Z-axe of the three-dimensional configuration

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Table 2: Clusters of attributes with values of influence on choice behaviour

No	Attribute	Importance
	1 Public transport (PT)	***4.8***[1]
	Reliability	**5.0**[2]
1	Number of transfers until destination	5.3
2	Frequency (number of departures per hour) of PT to the city	5.5
3	Separate free (bus) lane for PT to the city	3.8
4	Punctuality of PT from P&R (deviating from the time table)	5.3
5	Number of destinations in the city to be reached without transferring	4.9
	Comfort	**4.2**
6	Transport to city also possible by rail	3.8
7	Certainty of seat in PT to the city	4.5
	2 Time	***4.7***
8	Time needed to look for a parking place at destination	4.9
9	Amount of traffic toward/in the city	4.8
10	Extra travel time from principal road to P&R	4.4
	3 Parking	***4.0***
	Information	**4.3**
11	Information on the way about travel time per P&R and per car	3.7
12	Information on the way about occupancy of the parking place of the TP	4.2
13	Chance to find a parking place at the P&R	5.1
	Facilities	**3.7**
14	Possibility to reserve a parking place at the P&R	3.2
15	Parking lane to bring and meet travellers at the P&R	3.3
16	Walking distance from parking place at the P&R to platform PT	4.5
	4 Costs	***4.3***
17	Total costs of transferring (costs parking + costs PT)	4.9
18	Costs road pricing (per car kilometre) after passing the P&R	3.5
19	Parking costs at destination	4.6
	5 Staying at the P&R	***3.1***
	Safety	**3.8**
20	Supervision at the P&R	4.1
21	Surveyable, lighted pedestrian route from parking place to PT	3.8
22	A good state of repair P&R (clean, no graffiti, paved parking place)	4.2
23	Liveliness at the P&R	3.1
	Human contact	**2.8**
24	Manned ticket service	2.8
25	Manned information desk at the P&R	2.8
	Provisions of P&R	**2.8**
26	Heated waiting room	3.2
27	Kiosk	2.4
28	Toilet	3.0
29	Additional provisions (eg. dry cleaner's, supermarket, filling station)	2.6
	Extra	**2.2**
30	Possibility to rent a bike at the P&R	2.2

[1] Average importance score of the cluster *(in italics)*
[2] Average importance score of the subcluster **(in bold)**

Furthermore, initially the costs of for instance parking at the P&R and parking at the destination were expected to be grouped into a variety of quality aspects of the P&R and the destination. However, the empirical data clearly reveal that the clustering is based on the consideration between the different aspects of costs. This suggests that the aspects of costs have to be grouped into one cluster. The same argumentation applies to the aspects of time.

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As mentioned above, the response group is not completely representative of the population. Therefore, a comparison was made of choices of males and females, of younger and older respondents and of respondents with an intermediate and higher level of education. This comparison produced no significant differences. Therefore, the solution found is not susceptible for disfigurements of the representativity.

Before the clustering task the respondents were asked to evaluate the attributes concerning the influence of the choice behaviour on a scale from 1 to 7. In the last column of Table 2 the average importance scores are given not only for the single attributes but also for both each cluster and each subcluster.

Table 2 shows that the *reliability* within the cluster *public transport* is considered most relevant. The respondents especially consider the frequency of the public transport to be important. Furthermore, the cluster *time* is important to the respondents, especially the accessibility of the city, that is the time needed to find a parking place in the city itself and the traffic density of the city. Furthermore, the costs are important, primarily the comparison between the costs of the transfer and the costs of parking at the destination. Road pricing is less relevant in this cluster. The cluster parking is considered less relevant, but the information offered is more significant in this cluster than parking facilities. The chance of finding a parking place is very relevant as well as the information offered about free parking places. Finally, the whole cluster *staying at the P&R* is considered less important. Within this cluster the subjective safety is relatively the most important subcluster. In the other subclusters only a heated waiting room is somewhat appreciated.

5 Conclusion

The planning of more frequently used P&Rs obviously requires a better understanding of the car users' preferences. Often, the stated preference method (SP) is used for tracing those preferences. However, the number of attributes that influence the choice behaviour of the traveller is too large for using the traditional SP method. As a solution to this problem, the Hierarchical Information Integration (HII) method has been developed in the past. Accordingly, an experiment will be developed for each decision construct, which requires attributes to be grouped to define that construct. In this paper, a procedure was developed to define these constructs on the basis of the perceptions of potential users of P&Rs. This clustering of attributes was performed in an Internet-based questionnaire.

The grouping made on the basis of the empirical data is the clusters containing aspects about public transport, time, parking, costs and staying at the P&R. This deviates from the original thoughts about clustering attributes in terms of information, costs and time. Whereas initially separate cluster *information* was considered, the respondents appear to combine the aspects of information with the different parking aspects. Furthermore, initially the costs of for instance parking at the P&R and parking at the destination were expected to be grouped to

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a variety of quality aspects of the P&R and the destination. Nevertheless, the empirical data clearly reveal that the clustering is based on the consideration between the different aspects of costs. This suggests that the aspects of costs have to be grouped into one cluster. The same argumentation applies to the aspects of time. The evaluations of respondents how the thirty attributes influence their choice behaviour regarding the use of P&R show that the *reliability of the public transport* is quite important. Furthermore, *time* and to a lesser degree *costs* considerably influence a traveller's decision to use the P&R or not. The parking aspects are less important, except for the information aspects about parking. Finally, respondents evaluated the attributes about *staying at the P&R* as least important.

In this research the influences of each attribute were measured separately. However, it is not certain what influence these attributes have on travellers' real behaviour towards P&Rs. This will be examined in an additional study with the help of the HII method. The decision constructs will be defined based on the clusters found in this paper and attributes which were found to be of lesser importance will be excluded from further analyses. The results of this additional study will also be published.

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