The Neighbourhood Wizard
Cause and effect of changes in urban neighbourhoods

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Abstract: The Neighbourhood Wizard is a website that makes citizens aware of the consequences of the changes that they would like to realise in their neighbourhood. Users of the website can suggest changes to their neighbourhood. A Bayesian Belief Network is used to predict the effects of the changes on several indicators of liveability as experienced by the community. The Neighbourhood Wizard also shows what would be the optimal experience of liveability for different sections of the population.

1. INTRODUCTION

In the list of criteria that people use when buying or renting a house, the quality of the house itself plays a dominant role. However, the quality of the neighbourhood of the house, both physical and social, plays an increasingly important role as well when people are selecting their future home. It can often be noted that the inhabitants of neighbourhoods make an effort to keep up the quality of their surroundings and even try to improve it, as they realise that the 'liveability' of their environment is strongly determined by the social and physical quality of the neighbourhood. In many neighbourhoods in the Netherlands local initiatives for neighbourhood improvement are taken by groups of inhabitants or neighbourhood associations.

Municipalities generally have the policy to support and promote these initiatives. A good approach is to start by initiating dialogues on the issues involved and nurturing these dialogues until they mature, until they lead to new, shared, moral understandings (Etzioni 2004). Many municipalities

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therefore actively seek the participation of inhabitants in the development and (re-)design of neighbourhoods.

Two issues are commonly encountered in the process of citizen participation in urban development. Firstly, citizens are not generally educated to acknowledge the complexity and range of problems in their neighbourhood, but rather tend to focus on the problems they encounter in their daily activities. Citizens are not always able to acknowledge the viewpoints and needs of all members of society and their suggestions for improvement therefore tend to be too constricted.

Secondly, citizens tend to express themselves in terms of solutions when asked to describe the problems they encounter and the wishes they have for the improvement of their neighbourhoods.

Both issues are addressed in the research project that is reported in this paper. The paper first introduces the objective of the research project. Section 3 outlines the general approach and research method that was followed for the development of the project. Section 4 introduces the term liveability, which plays a key-role in this work. Section 5 discusses how people experience liveability and how this can be modelled. Sections 6 and 7 explain how we built a knowledge representation from data that was collected regarding the experienced liveability of neighbourhoods in the city of 's-Hertogenbosch. Sections 8 and 9 discuss the development and evaluation of the prototype system. Finally, in section 10 we draw conclusions regarding the work done and future work.

2. OBJECTIVE

The research project presented in this paper aims to support the process of participation by neighbourhood inhabitants in (re-)designing their neighbourhood. In this project we have focused on making citizens realise what the consequences are of their ideas for changes in the neighbourhood. These consequences are often more complex than citizens can oversee and have to do with many different aspects of the quality of the neighbourhood. Changes in the neighbourhood may have a positive influence on one aspect, but work out negatively for other aspects. Furthermore, proposed changes may have a positive effect for one group of inhabitants, but be assessed negatively by inhabitants who have different requirements.

The objective of the project was to develop a tool that allows citizens to propose changes to their neighbourhood and assess the quality of these changes. The assessment is done in the context of how the community will experience the various aspects that determine the liveability of the neighbourhood.

This tool can be used by citizens to gain a deeper insight in their own desires and in the multifaceted qualities of the changes they propose. In the process of participatory planning and design, this kind of tools can have an important educational and motivating function (Frissen 2003).

3. APPROACH

The main problem that needed to be addressed in this research project was how to assess the proposed changes in the context of multiple aspects of liveability, aspects that are appreciated differently by different sections of the population, e.g. teenagers or elderly people. Having to deal with uncertainty, we selected Bayesian statistics as the methodology to model the causal relationships between neighbourhood characteristics and inhabitants' experiences.

The development of the prototype was limited by narrowing its scope from 'any' neighbourhood to the plaza type of habitat. The prototype was tested in the Dutch city of 's-Hertogenbosch. Recent research by the so-called Bosch Architecture Initiative (BAI) has delivered a comprehensive set of data regarding how people experience a considerable number of physical and qualitative aspects of plazas in the city. This data collection played a central role in constructing the knowledge representation for the system.

4. LIVEABILITY

The term *liveability of the built environment* is often seen in policy reports on both national and local levels. However, the usage of the term is rarely univocal; no clear and commonly accepted definition is available (Michalos 1997). In these documents, many other terms are used to differentiate the term liveability, such as 'welfare in the habitat' and 'quality of living'. Although most of these terms have a certain overlap in their meaning, we must conclude that liveability is not univocally defined, let alone in a measurable way. What is commonly understood, however, is that liveability is influenced by the personal appreciation of inhabitants and the relative importance of a range of aspects. The experience of liveability is personal, differs for every inhabitant, and is expressed using a varying number of other terms (Jirón and Fadda 2000).

5. EXPERIENCING LIVEABILITY

To be able to predict the liveability of a (changed) neighbourhood, we need to model the way inhabitants experience the liveability of their neighbourhood. *Figure 1* shows the model by Leidelmeijer and Marsman (1999) that we use for this purpose.

The model in *Figure 1* shows that an inhabitant experiences the liveability of an environment by evaluating his satisfaction of a number of characteristics of the environment. The satisfaction of each characteristic is determined by his appreciation of the state of that characteristic and is weighed by the importance that this characteristic has to the inhabitant.

Each inhabitant has a personal interpretation of the state of characteristics (e.g. the state of the characteristic ‘busyness’ might be ‘I think it is quite busy here’), a personal appreciation of that state (e.g. ‘I like it busy!’), and the importance of that characteristic for the experienced liveability (e.g. ‘busy or not, it does not matter to me’ or ‘the busyness here matters a lot to me’). Every inhabitant of a neighbourhood will have a different, personal experience of how liveable the environment is.

The values that inhabitants give to the characteristics in the model are influenced by their personal preferences in the context of the habitat of the environment. The characteristics also influence each other, which is indicated in the model by the dotted lines (see section 5.1 and *Figure 1*).

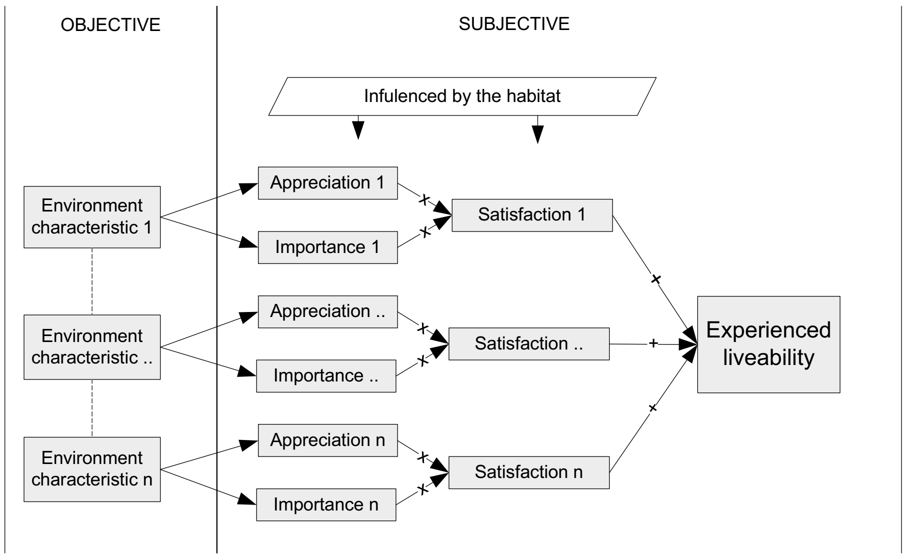

Figure 1. Experiencing liveability (Leidelmeijer and Marsman 1999).

Figure 2 shows an example of how a particular individual experiences the liveability of a particular habitat with respect to three of its characteristics.

The person in this example finds the composition of the environment 'simple'; its status is perceived as 'popular'; and the security of the environment is perceived as 'safe'. The person's appraisal of these characteristics is found in the second column. This appraisal leads to a satisfaction per characteristic and the aggregation into the overall experienced liveability.

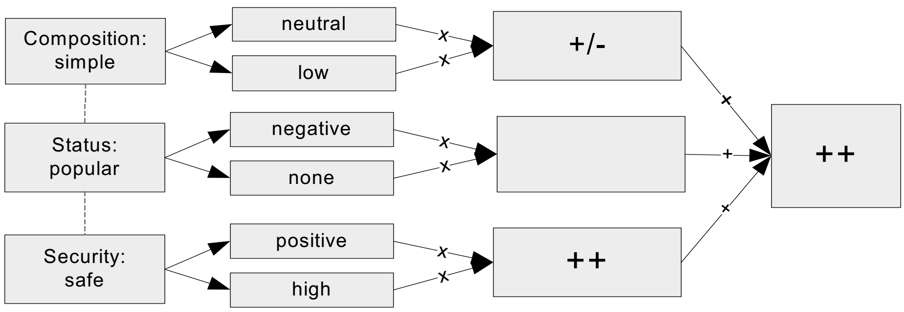

Figure 2. Example of the liveability of a habitat as experienced by an individual.

5.1 Mutual Influence of Characteristics

In the given example only three characteristics of the environment were taken into consideration. Actually, the number of characteristics of the environment is theoretically unlimited. In the example, the characteristic 'Status' is not given any importance in this context. There are many such characteristics that appear not to have a significant contribution to the overall experience of liveability. These characteristics we have termed *elements*. The characteristics that do have a significant influence on the overall experience of liveability are called *aspects*.

Although the elements do not have a direct influence on the experience of liveability, they do influence the state and appraisal of other characteristics. Therefore we cannot prune them from the network. The state of the aspects also influences the perception of other characteristics (both elements and aspects). Changing the state of a characteristic will influence the perception of other characteristics: if we reduce the number of cars, the plaza may appear more green.

These interrelationships are modelled in the network, which forms the basis for the Neighbourhood Wizard application. Changing the state of elements will influence the state of aspects, or even trigger a chain of changes in other aspects or elements, and will eventually lead to a differently perceived liveability.

5.2 Habitat and Wish-Profiles

The term *habitat* can be defined as the physical/functional and social environment in which people live (de Leeuw-Hartog 1988). *Lifestyle* is the behavioural pattern that can be identified for people with similar demographic, social-structural, and cultural characteristics (Stoppelenburg 1982). Research has shown that the lifestyle of people and their habitat are related, albeit not one to one (Anderiesen and Reijndorp 1990). In our research, we define the habitat as the present physical and social environment that influences the way people experience the liveability and characteristics of their neighbourhood. The lifestyle of people is categorised, in our research, in so-called wish-profiles. A *wish-profile* is a collection of desired characteristics of the neighbourhood that is common for a particular section of the population, e.g. teenagers.

While there are significant differences in the type of characteristics that are considered important in these various wish-profiles, there are a number of characteristics that can be regarded as significant to all (Keers et al. 2004). These prove to be important indicators for the liveability of neighbourhoods, as perceived by the majority of a population. However, the choice of indicators to be involved in the evaluation of a particular neighbourhood can be made dependent of the objectives of the evaluation. In the Neighbourhood Wizard, this means that for each application of the system, the moderator (normally the municipality) can decide which elements and aspects of the neighbourhood should be included in the user-sessions.

6. DATA COLLECTION

At the start of the research project, data was made available from a recent survey of people's experiences of liveability regarding the city of 's-Hertogenbosch in The Netherlands. In this survey, people were invited to participate in several walks through the city and were asked to fill out a questionnaire. The questionnaire consisted of differentials that helped people to indicate their experiences of characteristics such as 'public furnishing', 'available facilities', 'public accessibility', 'status', 'appearance', 'ambiance', etc.

For plazas, over 40 characteristics were included. For each of these characteristics, the subjects were asked how they experienced the characteristic on the plaza they were visiting and to indicate this on a differential with a scale of seven possible values ranging from deficient, through moderate and neutral, to ample and excessive. Per characteristic, specific terms were used to indicate these values. The classification and categorisation of the terms was helping people to really understand the meaning of the elements.

Over 250 subjects have participated in this enquiry, 15 plazas were visited. Within the scope and constraints of the project, the data was an adequate starting point for the development of the knowledge representation and the first phases of prototyping.

7. KNOWLEDGE REPRESENTATION

The causal relationships between the elements and aspects of a plaza can be modelled on the basis of the data retrieved from the BAI enquiry. This data can be used as input for the construction of a Bayesian Belief Network (or Bayesian Network, BN in short). In short, a BN can be described as a directed graph where the nodes represent variables (here, characteristics of the environment) and the connections between the nodes represent the causal relationships between them. The variable represented in a node has a state that is determined by a conditional probability table in which the possible states of related nodes are the attributes.

Determining the structure of a BN is the first important step in modelling the knowledge domain. This can be done by the knowledge expert who constructs a network from the knowledge that is acquired through, e.g., communication with domain experts. Another way to construct the network is by examining significant amounts of data from the particular domain. In this project, the latter approach is used to come to a base network which was refined by domain experts.

7.1 Structural Learning

There are several methods to learn the structure of a Bayesian-network model from data. To learn the structure for the prototype system the NPC algorithm (necessary Path Condition) was used. This algorithm is a constraint-based learning algorithm that derives conditional independence and dependence statements (CIDs) by performing statistical tests on pairs of variables in the data set.

7.2 Structure of the Bayesian Network

The first network that was found is shown in *Figure 3*. In this first structure, the significance level of the dependency test was set to 0.05. We see that there are some characteristics that do not have a significant relation with any other characteristic (see *Figure 3*). Even when the dependency test significance level is set to 0.3, these relations still do not appear in the learned structure. This means that the data does not show sufficient evidence for the existence of these relations. For some relations this intuitively seems strange. For example, the missing influence of the playground elements seems incorrect. The municipality of ’s-Hertogenbosch noted that the placement of playground elements on a plaza always leads to a lot of criticisms from inhabitants.

There are several possible explanations why we did not find such relations:

- The collected data is incorrect;
- The influence of the playground elements is processed by one or more other characteristics. This means that the effects of changing playground elements will be the same as changing other elements;
- The criticism from inhabitants is not founded.

It is very difficult to point out the most likely of these possibilities. Probably all three reasons play a role. However, the second possibility can be checked with corresponding statistical tests, such as a Chi-Square test. The Chi-Square test did not find any relation between the playground elements and any other characteristic in the collection of data.

Therefore we must conclude that, given the situation and data, the state of playground elements does not have a significant influence on other characteristics of the built environment, in the context of how inhabitants

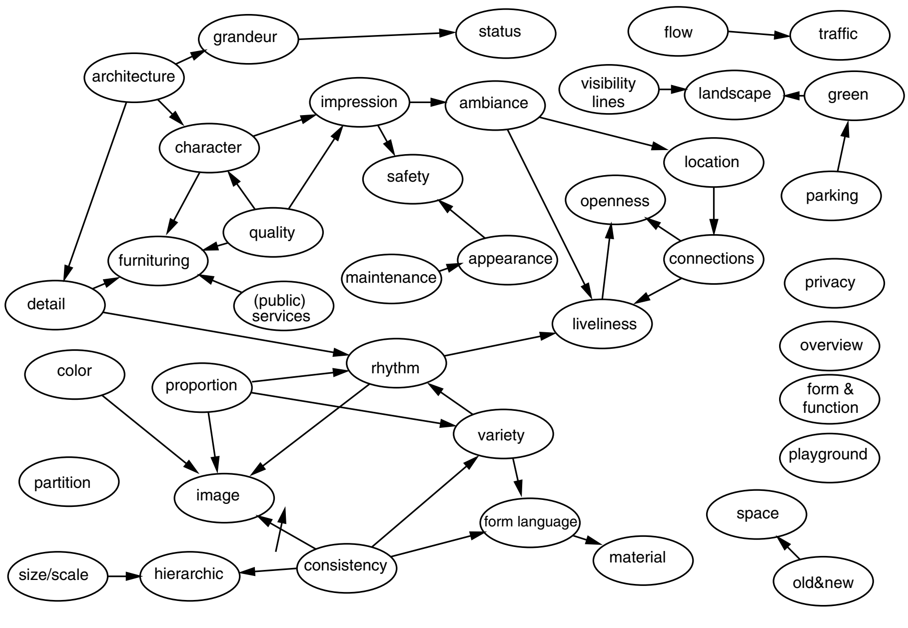

Figure 3. Structure of the BN learned with the Hugin NPC algorithm (significance level of dependency test = 0.05).

7.3 Resulting Network

Besides expected relations that were not found, there were also unexpected relations that were found. The reliability of these relations could also be confirmed with a Chi-Square test. This does not mean that these relations really exist in reality; it only means that they are present in the given data set. In reality, the apparent dependency between variables may in fact be a coincidence. The network structure was verified and refined with the aid of a number of professional city designers. Some additional relations were found using the NPC algorithm with a different dependency test significance level (0.2 and 0.3). The structure of the BN that was used for testing the prototype is shown in *Figure 4*.

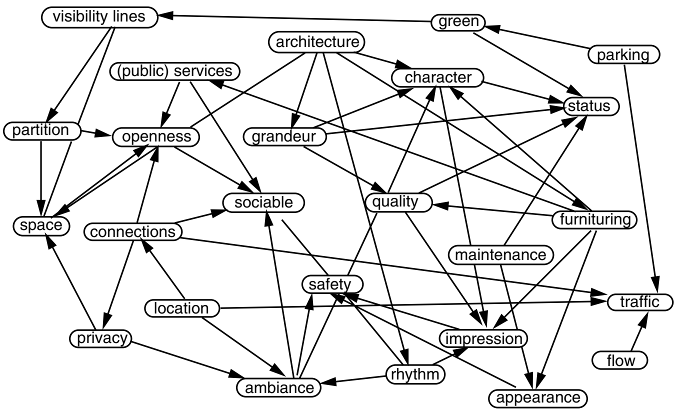

Figure 4. The Bayesian Network that was used for testing the prototype.

8. PROTOTYPE DEVELOPMENT

A prototype web application was developed to utilise the Bayesian Network. The development of the prototype was based on the following principles:

- User-interaction focused on a task assigned to the user. Users can experience this like a game;
- Representing the effects of changes to elements of the neighbourhood that users propose on the various aspects, or indicators of liveability;
- Representing the desired states of the aspects for different sections of the population. This way users can evaluate how changes will be appreciated differently by the different types of people;

- Availability of the system on Internet with no unnecessary threshold for usage by a large public;
- Easy to use interface and obvious navigation.

8.1 Changing Elements of the Neighbourhood

Changing the state of an element can be done in three different ways:

- Drawing;
- Picking a new state from a list of possible states;
- Getting help from the 'Wizard'.

The 'drawing' option gives the users the ability to draw modifications on a photograph of the plaza. In the current prototype, this is only a dummy function and the prototype does not recognize the drawn modifications. However, the drawing does have a function because users will learn to acknowledge the context and constraints of the changes they propose. The design interaction and common understanding of the difficulties involved in the urban planning of a plaza are very clear when using this interface. Future work should be carried out on evolving this interface.

In the second option – picking a new state from a list – the user first selects the element to be changed. After a selection was made, a list of possible states for that element is shown. The user picks a new state and the system updates the evidence for that element in the network. After this, the Bayesian Network is recompiled and the user is given the newly expected situation.

The third option – getting help from the 'Wizard' – is for users who do not want specific changes of elements but who wish to achieve a certain state of an aspect. The Wizard will help these users to create a situation that suits their vision. First, the user indicates the state of the aspect that the user wants to achieve (for example: the aspect 'Status' should be experienced as 'rich') the system gives a list of elements which influence this aspect directly. These elements are in fact the parent-nodes of the aspect in the Bayesian Network. The system responds with a number of suggested states of elements, one suggestion for every element that affects the aspect. The suggested state of an element is that state that contributes most to achieving the desired state of the aspect. The user can choose to apply a suggested change, so that the desired state of the aspect will become effective. The result of each change is shown as the percentage of the population that will actually experience this new state of the aspect.

8.2 Implementation Techniques

The Bayesian Network was implemented using the Netica software-library (www.norsys.com). Netica provides an API for using a BN in a Java environment. Java is also a suitable environment for web application development. The user interface was created using Java Server Pages (JSP). The use of JSP allows the complete separation of interface and technical functionality. Schematically the system interaction looked like this:

JSP Pages ←→ JAVA classes ← API → Netica Bayesian Network.

To ensure uniformity of the web application, it was made XHTML 1.0 compliant, uses an XML configuration file to configure the starting situation of each plaza, and has a separate language file for altering it easily for use in other languages. The dynamic composition of the graphs for the representation of predicted effects (see next section) is done with the help of the open source Java class library JfreeChart (www.jfree.org/jfreechart).

8.3 Presentation of Predicted Effects

The presentation of the predicted effects and other interactions with the user are the most difficult issues of this project. Charts are potentially a very effective and flexible way of presenting the predictions. A potential disadvantage of using charts is the fact that they are not always easy to read and understand. It cannot be assumed that the intended user-group, i.e. neighbourhood inhabitants, is accustomed to reading charts. Therefore, much caution is necessary with the visual ergonomics of the presentation using charts.

Two different types of charts are used in the prototype. One is called 'Level 3', using lines, and the other 'Level 2', using bars. These are the most useful views of the tool. In these two charts, the presently experienced liveability is shown in black. The experienced liveability that is expected after the situation is changed, is shown in red. A third view is called 'Level 1', showing a simplified presentation using stars.

In Level 3, for each aspect a chart like the ones in *Figure 5* is shown. Every chart represents one aspect (indicator of liveability). The possible states of the aspect are on the horizontal axis. The percentage of people that experiences the aspect in each of these states is shown on the vertical axis.

The green, vertical line represents the state that is preferred most by the section of the population that is currently selected by the user. In other words, it shows the preferred state for this aspect for the selected wish-profile. In the example of *Figure 5*, the teenagers want the 'Space' as 'stringent' as possible. The task that is assigned to the user, is to achieve a situation in which the chart shows a summit at this vertical line. However, in other wish-profiles the preference may be different and the green line will be in another place. Users of the system have to try to deal with all the desires from the different sections of the population. In the example of *Figure 5*, the teenagers will experience the proposed changes positively (left chart). But the elderly people will experience a negative effect for the aspect ‘Space’, since their optimal experience of ‘Space’ is ‘natural’ as shown on the right in *Figure 5*.

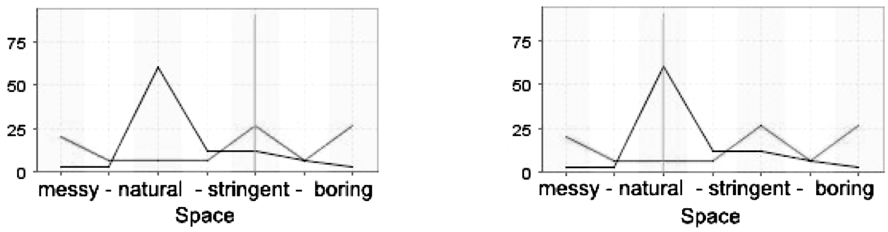

Figure 5. The aspect ‘Space’ in Level 3 with a green, vertical line indicating the state that is desired most in the selected wish-profile: teenagers on the left; elderly on the right.

The charts in Level 3 are always given for all the aspects at once. This way the users can see the mutual effects between the aspects. Users can select different wish-profiles to inspect the effects in relation with the desires of the different sections of the population. That way the green lines in the graphs will change according to the optimal state for the selected wish-profile.

Level 2 is a somewhat easier-to-read presentation of the effects. In this view, each chart also presents the effects for one aspect, but shows these effects in bars and for all wish-profiles at once.

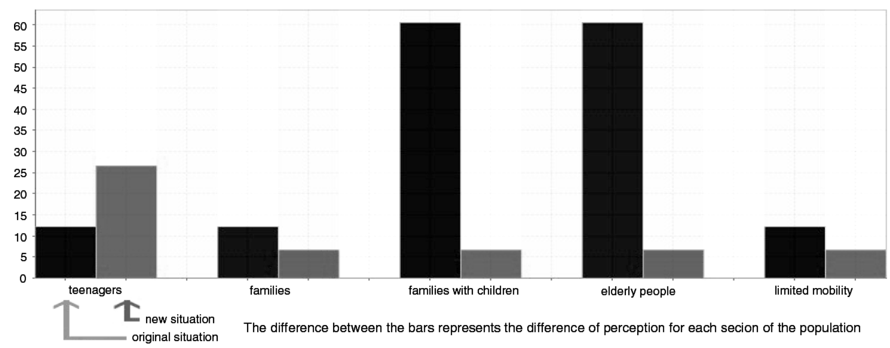

Figure 6. The aspect ‘Space’ in Level 2 with the effects for all wish-profiles.

The chart shows two bars for each wish-profile, the black bar indicating the original situation, the red bar showing the expected effects. This chart presents how the majority in each section of the population will appreciate the effects. Referring to the line-charts in Level 3, these bar-charts show the percentages found at the intersection of the lines with the green vertical line indicating the preference of each population group. This way the user can see directly whether the proposed changes are experienced positively or negatively in the different wish-profiles. In the example in *Figure 6*, teenagers will think that the changes are positive for the given aspect ‘Space’, but elderly and families with children will think negatively of the changes.

8.4 Navigation

The navigation of the prototype should be self-explanatory and easy to use for every user. Once a plaza is selected, the user is presented the current situation in photographs and in charts. This allows the user to interpret the liveability as currently experienced at this plaza. Through the navigation buttons, the user can start to make changes to elements of the plaza. After each change, the effects will be shown immediately in the charts. The user can select which level of complexity the charts should show (lines, bars, or stars). *Figure 7* shows two screenshots of the web application prototype.

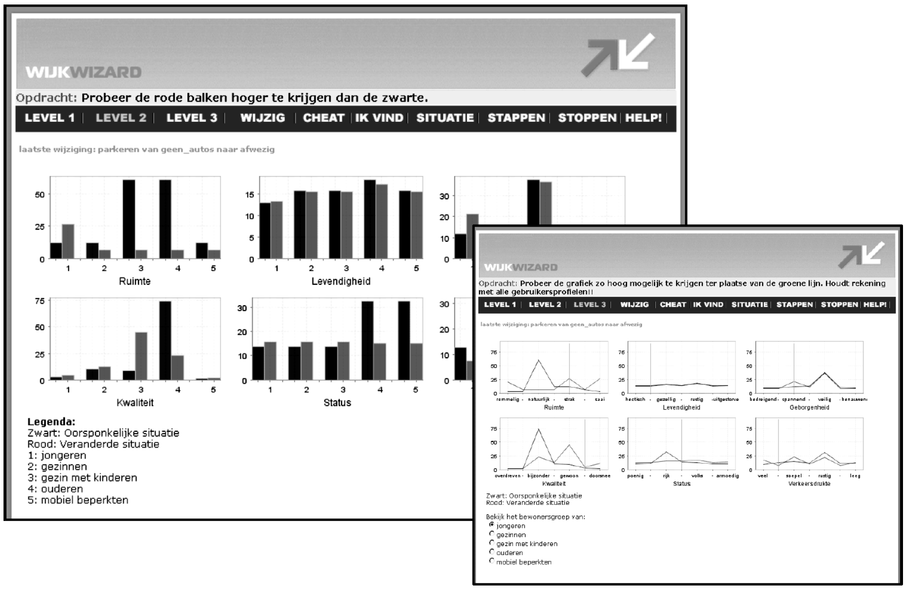

Figure 7. Screenshots of the Neighbourhood Wizard web application prototype. Background: Level 2 - Foreground: Level 3.

9. EVALUATION OF THE PROTOTYPE

The prototype was tested and evaluated by inhabitants of the city of ’s-Hertogenbosch. After the test they were asked to complete an online evaluation form. The prototype offered sessions for seven different plazas in the centre of ’s-Hertogenbosch. Over one hundred subjects participated in the test. A small number of them also filled in the evaluation form.

The evaluation form contained nine different propositions. The subjects were asked to indicate how much they agreed with these propositions, on a scale from 1 to 10, where 1 represented a total disagreement with the proposition and 10 a total agreement.

A score of 7.4 was given to the proposition “Thanks to the Neighbourhood Wizard, I now see that certain ideas are positive for me, but negative for other members of our community.” A score of 7.0 was given to “The Neighbourhood Wizard shows me that changes can have positive effects on one aspect, but negative effects on other aspects.”

The evaluation of the test confirmed the educational function of the prototype, but the number of returned evaluation forms is too small, at the time of writing, this paper to make a definite statement about this. However, the observation of such a clear positive result in a small number of evaluations can be interpreted as an indication for a small deviation in larger evaluation, hinting to a strong conclusion.

10. CONCLUSIONS AND FUTURE WORK

The most important conclusions of this project concern the functioning of the prototype:

- The Neighbourhood Wizard helps users to see that certain ideas are positive for them, but negative for other sections of the population;
- The Neighbourhood Wizard shows users that changes can have positive effects on one aspect, but negative effects on other aspects;
- The Neighbourhood Wizard helps users to realize the complexity of a design task and as a result users will have a better informed view on plan proposals and probably a higher appreciation of plans.

10.1 Limitations of the Data Collection

Besides the positive conclusions there are also a few points of attention, mainly regarding the aspect of data collection.

The given data collection is retrieved from an enquiry in one particular city and may not be representative for other cities. The BAI has chosen rather abstract terms to collect the data, which make an unambiguous interpretation difficult. Some people may have misunderstood the used terms and therefore given a derogatory opinion on one ore more characteristics.

Additionally, the inclusion of more concrete elements, such as the number of parking lots or lanterns, can help take away long-living irritations that inhabitants may have. When users cannot express these small irritations, the tool itself will provoke a new irritation. Another shortcoming is that the data collection does not discriminate between the various sections of the population nor were all sections represented.

The data collection is restricted to physical characteristics. However, the liveability of the built environment is also influenced by non-physical characteristics, such as sources of deterioration and social characteristics of the community.

10.2 System Improvements

During the development of the prototype much effort was needed for the design of the user interface. In an early stage of this project the importance of the interface was recognized. Yet, the evaluation of the prototype still pointed out some issues.

The use of charts for the presentation of the predictions was expected to give the most problems. The evaluation revealed that this was not the case. The main issue appeared to be the navigation structure. Users had to click too many times before they came to make a functional action.

A new interface was developed on a short notice. This new interface had one main screen in which all actions could be performed, requiring fewer clicks. Users were also given a specific task to perform. For example “try to raise the red bars above the black bars”. This new interface is shown in *Figure 6*. It is not yet evaluated on a large scale.

10.3 Future Work

The causal relations between characteristics are constructed from the analysis of a data collection. It is possible that some relations are found that do not exist in reality. Future work is needed to investigate the relations between characteristics in depth.

Another future research task would be the search for a different technique for the prediction of effects.

Although the predictions achieved through the Bayesian Network are valid and plausible, this technique does not offer an explanation of the expected effects. In many cases the reason for these effects are obvious and users will understand the prediction, but in some cases the predictions are not so obvious and require further explanation. For example: The creation of a quiet plaza has negative effects on the safety of the plaza. This is not a logical, though correct, prediction because the quietness of a plaza will attract criminal behaviour. Future work should be conducted that either adds knowledge to the system that can be used in constructing explanations, or focuses on finding a different approach to model the causal relations that includes explanations.

11. ACKNOWLEDGEMENTS

The project members are indebted to the Bosch Architecture Initiative, in particular its president Aart Wijnen, for their cooperation and making the data collection available. The municipality of ’s-Hertogenbosch, in particular Constant Botter, has contributed through discussions and giving insight in their policy for participatory design and planning.

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