REDESIGN OF AFFORDABLE HOUSING FACADES.
PREPARATION OF A VISUAL EXPERIMENT

ERES Conference, Milano 2010
(unpublished material)

Arch. Dr. Francesca RICCARDO
Dr. Clarine van Oel
Ing. Peter de Jong
Department of Real Estate & Housing
Faculty of Architecture | Delft University of Technology | the Netherlands

Key words: housing, renovation, energy efficiency, aesthetics, façade design

Abstract

Housing in Europe counts for 27% of the European energy consumptions which makes sustainable transformation of existing housing a relevant topic, especially in the view of the energy targets set for 2020. The energy efficiency as well as the architectural value of the post-war residential buildings is particularly poor, but since in the coming years this part of the stock will be renovated, there is a chance to improve the present performances of such blocks. To deal with energy efficiency, decay and livability problems improvements of building facades seem to be indicated. However, in order to deal with especially livability problems, it is not only relevant to consider technical aspects of façades but also involve residents' preferences for architectural aesthetics.

Important questions addressed in this study are to what extent are tenants willing to pay higher rent, and whether their willingness to pay higher rent depends on selected characteristics of facades that have a combined effect on the energy efficiency and the aesthetics value of buildings.

In this paper it is reported the preparation of a visual experiment on the described issue and in particular the development of a questionnaire to asses preferences of tenants. For the development of the questionnaire it is adopted the Discrete Choice Method which is applied with the purpose of evaluating tenants' preferences in innovative façade directed renovation approaches.

**REDESIGN OF AFFORDABLE HOUSING FACADES.
PREPARATION OF A VISUAL EXPERIMENT**

Introduction

In the view of the ambitious European energy targets set for 2020 sustainable transformation is of growing importance (EC, 2007). The European residential sector, for instance, accounts for 27% of the total European energy consumption (www.cecodhas.org, visited in 2007). The energy-efficiency of the housing stock developed between the '40s and the '70s is poor and, since there was a large demand of housing after the WWII, a rather large share of the housing stock dates back to this period. As in other European countries, this part of the housing stock will be renewed over the coming years, and this will offer a chance to improve the energy efficiency of these dwellings. It is estimated that measures like roof and wall insulation alone can cut energy consumption of buildings by half, reducing the overall energy consumption across Europe by 20% (Esteves, 2007).

After the conflict, new building technologies were introduced to meet the high demand for housing and this stimulated a rapid production of residential buildings. This led, however, to scarce emphasis on qualitative aspects and contributed to early decay of these dwellings. According to a survey of the Federal Government of Germany, 80% of all European building decay is found in the building envelopes which is responsible for maintenance costs and which quality does not often meet the present demands and standards (Koopman, 2007). Many Dutch and other European early post-war large neighbourhoods lack identity (Andeweg and Koopman, 2007) and attention for aesthetics. Buildings are characterized by plane and grey facades and lacking architectural identity contributing in a general dissatisfaction of tenants with their housing. This is often associated with vandalism (Melgaard, 2007) and typically neighborhoods suffer nowadays from liveability problems.

To deal with the decay, and to improve liveability in these neighborhoods, improvement of the facades seems to be indicated (van Beckhoven et al., 2005). So far, architectural neighbourhood improvements are often limited to mural paintings, coloured plastering on existing facades, enlargement and glazing of small balconies and redesign of central hall (Brunoro and Andeweg, 2007). However, the urge to improve the energy efficiency of this part of the housing stock may create new chances to deal with the decay of these neighborhoods as well. Since energy efficiency measures often involve insulation of facades (van Oel et al., 2010) increasing the aesthetical value of the dwellings in the neighbourhood may be part of a solution to deal also with liveability issues. To properly treat liveability problems, it is important not only to consider the technical aspects of the façade (or more broadly, the building envelope), but to involve residents' preferences as well. There is ample evidence that individual preferences of architectural aesthetics share common patterns and are neither arbitrary nor idiosyncratic (Ulrich, 1983; Kaplan 1979; Oostendorp and Berlynn, 1978 in (Groat, 1988)).

In addressing aesthetics, it is important to distinguish subjective from objective descriptions. In evaluating architectural aesthetics, feelings are the subjective component, while objects constitute the objective elements. Subjective aesthetics judgments reflect one's personal preferences and are based on feelings of pleasure or displeasure elicited by the form of an object in a representation (e.g. by the massiveness of a building facade). Feelings do not describe the object in itself, but represents the observer's feeling when looking at that object. Indeed, Stamps pleas for an architectural design practice that adopts more objective description like 'new buildings eight times higher than older buildings will make the block look bad' rather than adopting confusing-subjective design principles like 'the new building should harmonize with the existing buildings', to prevent misunderstandings (Stamps, 2000).

Based on this subjective versus objective component, Stamps argues that most of the architectural facades can be geometrically described, which is the theoretical base of the present study. Research indicates that individuals prefer exteriors that express a sense of the past, and have detailed, curved, decorated, grooved or three-dimensional surface (van den Berkhof, 2008) (Herzog and Shier, 2000). Older buildings are generally preferred but as long as they are well-maintained (Herzog and Shier, 2000). Most observers prefer ornate buildings and in fact, residences with more complex facades are more appreciated (Stamps, 1999; Herzog 1996; Frewald, 1990; Pederson 1986; Nasar 1983 in (Gifford, 2002)). Many studies found out that the public generally dislike modern or atypical styles and that, independent of the location, architectural style has a great effect on their judgment (Purcell & Nasar, 1992; Devlin & Nasar, 1989; Groat, 1982 in (Stamps and Nasar, 1997)). There is demographic and temporal stability of preferences over countries and time (Stamps, 1999c), but there might be cultural differences in preferences. In the Netherlands, the bricks pattern, for instance, is widely appreciated, whereas building components that are intrusive or otherwise affect the visual landscape are generally unwanted. Also, most of the Dutch home buyers appear to prefer traditional exteriors, whereas only a small minority would opt for experimental or modern architecture (e.g. Poppe 2006; Faiers & Neame, 2006; Boelhouwer, 1996 in (Thissen, 2007)).

Renewal of the façade or building envelope might thus improve energy-efficiency of housing and stops decay of neighborhoods, thus improving livability, but at the expense of rather high costs. Since part of these costs may be compensated for by societal savings due to lower emissions of greenhouse gasses, lower costs for maintenance, tenants will be facing higher rents as well. A previous study (van Eck et al., 2008) showed that residents are willing to pay more for measures that improve the energy efficiency of their homes. Since this study only involves occupant-owners, important questions are to what extent tenants are willing to pay a higher rent, and whether their willingness to pay a higher rent depends on selected characteristics of the building envelope that have a combined effect on the energy efficiency and aesthetic value of buildings?

This research focuses on post-war multifamily blocks which include buildings produced between 1945 and 1960, more particularly the middle-rise multifamily blocks which belongs to the most diffused housing type (the Netherlands 30% and in Europe 47% of the total housing stock)(National Board of Housing Sweden, 2005). We here report the development of a questionnaire to assess tenants' preferences. In the development of this questionnaire the Discrete Choice Method was used to evaluate the tenants' preferences in innovative facade directed renovation approaches. The respondents will be asked to choose between two hypothetical renovation design for middle-rise multifamily blocks differing in several facade characteristics. These characteristics included the ones that affect the energy efficiency and the aesthetical quality of the multi-family blocks, as well as the willingness to pay for a higher rent. High quality 3D imaging techniques were used to construct the images of the blocks. To allow for a better evaluation of the hypothetical situation, 3D-images were constructed using both normal and perspective view.

Research methodology

Discrete Choice Model

There are several methods to investigate consumers` utility (preferences) for a product or, as in this case, tenants' preferences for the facades of middle-rise multifamily blocks. In measuring tenants' preferences, or utility, for these multifamily blocks, one can distinguish between revealed preference methods, stated preference methods and non-preference methods.

The revealed preference method is based on the observation of actual made choices of tenants and it assumes that people show their preferences by their actions. The stated preference method is based on information extracted from interviews or choice experiments. Because this study aims to investigate tenants' preferences to recommend housing associations and/or municipalities as of how to manage the decay and livability issues of postwar neighborhoods that will be renewed over the coming years, stated preference techniques are the single one method that are of use to this study. A mere advantage is that these techniques also allow for the measurement of peoples opinion to non-economic goods, e.g. aesthetics and willingness to pay for a higher rent.

Within the stated preference methods, there is a direct and an indirect method to investigate tenants` utility. The direct method is known as the Contingent Valuation Method (CVM). The most important problems of CVM are related to cognitive stress and strategic responses (Bogerd et al., 2009). People experience difficulties in assigning a value to a product or service. There is also the risk of strategic bias as people might think they can influence the situation like the rent of a house. Because of these problems, we employed the indirect or the Conjoint Analysis Method (CAM), more specifically the discrete choice method (DCM). The tenant will be asked to assess two hypothetical housing blocks that differ on several façade characteristics (called attributes) and express his/her preference for either the two of these.

The DCM is based on efficiency in choice designs using the multinomial logit model. This model assumes that consumers make choices among alternatives that maximize their perceived utility. This is expressed in the formula below:

$$u = x_i\beta + e$$

u= utility
x_i= is a row vector of attributes characterizing alternative i
β = is a column vector of K weights associated with these attributes
e= is an error term that captures unobserved variations in utility (Kuhfeld, 2005, p122)

The multinomial logit model assumes that the probability that an individual will choose one of a number of alternatives from the choice set.

$$p(c_i|C) = \frac{\exp(U(c_i))}{\sum_{j=1}^{m}\exp(U(c_j))} = \frac{\exp(x_i\beta)}{\sum_{j=1}^{m}\exp(x_j\beta)}$$

m	number of alternatives
c_i	alternative
C	choice set
x_i	vector of alternative attributes
β	vector of unknown parameters
$x_i\beta$	utility of alternative c_i (Kuhfeld, 2005, p144)

In the present experiment, six attributes will be used. Development of an efficient design was conducted in SAS 9.2 (Discrete Choice Modeling).

Simulation of the multi-family block

The recommendations based on the visual experiment will increase their reliance and validity if the experiment itself is replicated in different geographical contexts (e.g. more than one country). To allow comparable replications, however, the model adopted for the 3D simulations of the building should be abstract enough to avoid recalling for local architectural characteristics (e.g. size and shape) which led to the decision to visualize the most common social housing, i.e. middle-rise multifamily blocks, in Europe. Since the *hallway-access* flat is among the most diffused housing typology in the Netherlands, a typical Dutch hallway multifamily block (Roeloffzen, 2004) is used as a basis model for the 3D simulations. Typically, hallway flats are located in middle-rise blocks, generally 4 storey high, with no elevator and with entrance via closed hallway. Each flat has normally 3 rooms. Usually there are 10 flats per floor and separated storerooms at the ground floor (Fig.1). The simulation concerns the front side of the building, as this is the first part to be perceived by someone approaching the entrance.

Figure 1 Example of hallway access apartments in middle-rise multifamily blocks (the Netherlands). From Roeloffzen, 2004

Characteristics of interest

Envelope redesign implies dealing with numerous attributes having combined effect on aesthetical values of buildings and energy efficiency. Several studies showed evidence of an effect of physical characteristics of residential facades on aesthetic value including silhouette, materials, colors, patterning, visual character, height, shape, facade articulation, trim, ornament, visual area, partitioning, openings, architectural style, roof shape, and age. Regarding these characteristics, complexity and order, frequency of features, massing, visual bulk, homogeneity, whole to part impression, amount of detail, and visual commons were frequently investigated (Stamps, 2000, Herzog and Shier, 2000, Stamps, 1999b, Stamps, 1999a, Stamps, 1999d, Stamps A. E. and Nasar, 1997, Nasar, 1994).

Examples of facade characteristics with effects on energy efficiency include envelope geometry, thermal insulation of materials, fenestration, sun shading, transparency of materials, green and living walls, solar panels, and surface coloring. For these characteristics, features of interest might be maximizing compactness, absorbing solar radiation, transferring heat, gaining and maintaining heat, avoid overheating, generating energy, controlling daylight and provide ventilation (Hegger et al., 2008, Herzog, 2008, Knaack, 2007, Richarz, 2007, Schittich, 2006) .

From previous work, we learned that six characteristics, or attributes as they are called in Discrete Choice Modeling (DCM), would be an acceptable number to use in the questionnaire. The façade characteristics were either chosen because they related to current practice, at least in ambitious projects that were submitted to the Dutch National Renovation

Prize[1] (www.nationalerenovatieprijs.nl, visited in 2009), or other well-known renovation projects, or contrary, for their innovative character. The latter implies the selection of attributes which describe ambitious façade solutions not yet adopted in practice. This is the case, for example, of the choice of living walls, still considered an innovative solution.

Five of the attributes are façade characteristics combining an effect on aesthetic value with an effect on energy efficiency. The sixth attribute is the willingness to pay for a rented dwelling. These six attributes and their levels will be shortly discussed in the next paragraph. Table 1 provides an overview of these attributes and how these attributes were operationalized into three levels for each attribute.

FAÇADE DESIGN ASPECT	FAÇADE ATTRIBUTE
Building form	1. Facade articulation – Surface geometry
Façade materialization	2. Surface colouring – facade materials
Sustainable appearance	3. Visual character - thermal insulation
Window design	4. Fenestration – glazing proportion
Façade sun shading	5. Fenestration – solar protection
Reasonably affordable solutions	6. Rent levels

Table 1 Façade design aspect and the respective façade attributes

Facade articulation – Surface geometry

The form of a building affects both aesthetic judgment and energy requirements. The combination of façade articulation and surface geometry deals with the perceived aesthetic value of the building and its proprieties of maintaining heat (energy efficiency).

Stamps proposes to geometrically describe the complexity in the articulation of a facade surface by applying the concept of (volumetric) convexity. This is defined by the difference in volume between the convex hull of the building and the building itself. The convex hull is the smallest convex shape which would entirely surround a building of whatever shape (Stamps, 2000); the larger the number of projections from a façade (e.g. bay windows), the higher the volumetric convexity. Complexity levels in facade articulation can be obtained by adding and/or subtracting volumes which form may range from straight, inclined and curved to free forms.

From the perspective of energy efficiency the form of a building is a relevant attribute. Size differences in surface areas affect the heat losses of a building: the smaller the envelope area of a given volume, the lower is the heating requirements of the building itself. This relationship might be quantified using the concept of compactness in surface geometry. The compactness of a building is calculated by the ratio of the heated–transferring enclosing surface area (A) to the heated volume of the building (V) (=A/V ratio) (Herzog, 2008). For residential buildings to reach the primary energy requirement of 15KWh/m2a (so called passive houses), the compactness ratio should be at least 0.2. In terms of energy efficiency, low convexity levels of a building volume correspond to high compactness in surface geometry leading to lower energy requirements.

In this study, the three levels of convexity are considered:

- low convexity by curved volumes, high energy efficiency
- medium convexity by straight volumes, medium energy efficiency

[1] *The National Renovation Prize (NRP) is a biannual competition awarding good renovation practices in the Netherlands. In 2009, 49 residential projects entered the competition. The ex-ante renovation and ex-post renovation characteristics of the entries are collected in reports available on the site of the NRP (WESTRA, E., MAK, A. & VAN ETTEN, R. (2009) Inschrijvingen. Nationale Renovatie Prijs 2009.)*

- high convexity by straight and inclined volumes, low energy efficiency

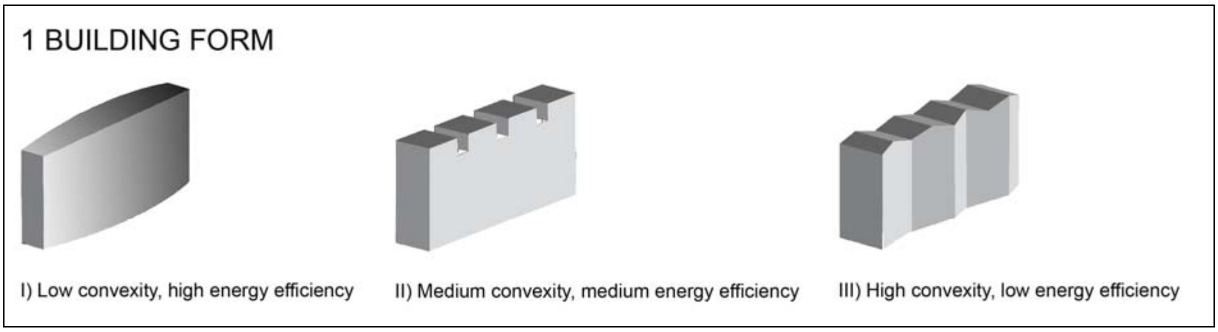

Figure 2 Visual scheme of the 3 levels in building form

Surface coloring – facade materials

The combination of surface colouring and façade materials attributes deals with the materialization of a facade. For aesthetics, it concerns the physiological proprieties of certain tins and their association with different dwellings types visible from the outside. Regarding energy efficiency, it deals with the propriety of materials to absorb solar radiation due to their color. Color is experienced as a fundamental quality in visual perception. It has been shown, for example, that intense colors (independent from hue) and high visual complexity (strong color contrast) are psychologically stimulating, while subdued colors (grey) have the opposite effect. In a comparison of different hues with same intensity saturation, red is more stimulating than blue (Daniels, 2007). Preferences for colors depend on the hue's saturation and brightness. Hue is primarily related to perceived warmth (reds warmer, blues and greens cooler), while brighter colors are considered fresher, lighter, and more cheerful than darker hues (Gifford, 2002).

In terms of energy efficiency, the color of a surface affects the amount of heat the building absorbs or rejects. Dark colors typically absorb a greater percentage of solar radiation than lighter colored objects. In countries where the cooling season is considerably longer than the heating season, in fact, the use of light-colored envelope materials is more cost effective and energy efficient (Meerow, 1993). Any material is characterized by an albedo value which measures the ability of that material to reflect away the sun's visible and invisible infrared energy. Light/reflective colored façade materials have higher albedo (close to 1), whereas dark/absorptive materials have low albedo (close to 0).

The albedo of a material not only depends on color but also on the geometrical characteristics of its surface (e.g. surface marking) and temporal variations (e.g. weathering and wear). In general, envelope materials with high-albedo contribute to high energy efficiency in summer by directly reducing the heat gain through a building's envelope, while low-albedo materials lead to high energy efficiency in winter (Taha, 1992). A surface can be optimized in terms of energy efficiency by its degree of absorption, i.e. by its coloring. Façade in countries with long heating seasons, like the Netherlands, are most energy efficient consisting of materials with low to medium albedo. In this study, the following colors were chosen for their albedo levels:

- very dark (green)
- dark (brown)
- medium dark/medium light color (beige)

Since albedo and thus the energy efficiency not only depends on color, but also on the geometrical characteristics of the building, these 3 colors are combined with three groups of dwelling types:

- simplex dwelling (as typically present in middle-rise multifamily blocks)
- simplex top floor and simplex extended dwelling
- simplex extended dwelling at the bottom

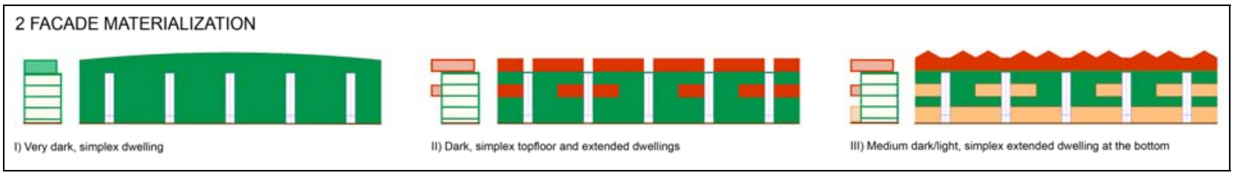

Figure 3 Visual scheme of the 3 levels in facade materialization

Table 2 summarizes darkness, material, color and albedo of materials associated to dwelling types and attribute levels.

DARKNESS	MATERIAL	COLOUR	ALBEDO	LEVELS
Very dark	Wood panels	Avocado green (RGB 116, 114, 92)	0.15	I) 1 very dark material (0.15 albedo) to simplex
Dark	Bricks	Brown (RGB 187, 107, 57)	0.28	II) 1 very dark material (0.15 albedo) to simplex, and 1 dark material (0.28 albedo) to simplex extended + simplex top floor
Medium dark	Painted concrete panels	Tan (RGB 238, 171, 121)	0.43	III) 1 very dark material (0.15 albedo) to simplex, 1 dark material (0.28 albedo) to simplex extended + simplex top floor, 1 medium dark material (0.43 albedo) to simplex at the bottom

Table 2 Darkness, material, color and albedo of materials associated to dwelling types and attribute levels.

Visual character – thermal insulation

The combination of visual character and thermal insulation deals with the apparent sustainable look of a building on the aesthetic side and the heat transfer proprieties of facade materials giving that appearance.

To address the impression of sustainable character in a building, this study will use the frequency of a sustainable looking material on façade partitions. Literally, character means ‘a distinctive significant mark of any kind’ (Simpson and Weiner, 2009). For univocal considerations on the impression of a building’s character, the concept of ‘frequency’ might be used. Usually this concerns a ‘block face’ which is a view comprising the facades of all the buildings on a block. In this research it is applied to the vertical partitions of a single building. The character of a building depends on the frequency of the facade features shared with the adjacent buildings, in this experiment with the adjacent vertical partitions of the same facade. The percentage of houses (partitions) on a block to create an impression of visual character of the blocks itself is clearly somewhere between 50 and 100% (Stamps, 2000). In his study testing the overall character of a block in terms of style, number of storey and type of roof, Stamps found out that a design feature on a block face would have to be present in 88% of the building before people would describe it the overall character of the blocks as having that feature (Stamps, 1999b).

Clearly, numerous materials add to a sustainable character of a building, but due to their innovative character and aesthetic potential, green wall materials (vegetated surfaces) are here considered. Aesthetic improvement, in fact, is one of the major design objectives for most green walls and in particular for buildings with repetitive facades. Enhancements are usually obtained by working with patterns, rhythms, shapes, plants textures and colors (some plants materials may change color and presence of foliage during the years) (Cities, 2008). Wall planted sections in building envelopes seem to be energy efficient. Actually, plant-covered walls contribute to the improvement of the thermal performance and sustainability of the built environment (Eumorfopoulou and Kontoleon, 2008). However, the potential energy savings by improving building insulation characteristics are difficult to assess and will be minimal for already well insulated walls (Design for London et al., 2008).

The R-value measures the thermal resistance of an insulating material (Oak Ridge National Laboratory, 2008). The higher R is, the better the building insulation's effectiveness (U.S. Department of energy, 2009). Materials with an excellent thermal resistance have a maximum value of R-50 (Ft2fh/btu equivalent to 8.80m2K/W) (e.g. vacuum insulated panels) while poor insulation have a R of about -0.2 (ft2fh/btu equivalent to 0.03m2K/W) (e.g. bricks). Moss tiles are an innovative cladding material reaching thermal resistance by R-35 (www.verticiel.ca, visited in 2009) . This makes them effective for improvement of thermal performances in buildings. Since they resemble grass in texture and color they may give the impression of green-sustainable appearance when applied to surfaces which makes them suitable in testing sustainable visual character of building.

In renovation, top end volumes may be added to existing blocks. Such additions are considered in this study as new constructed façade partitions to test for the combination of visual character and thermal insulation. The three levels addressed in visual character and thermal insulation are

- 0% façade partitions by moss tiles with R-35
- > 50% façade partitions by moss tiles R-35 (including addition of 'I' shaped towers)
- 100% façade partitions by moss tiles R-35 (including addition of 'L' shaped towers)

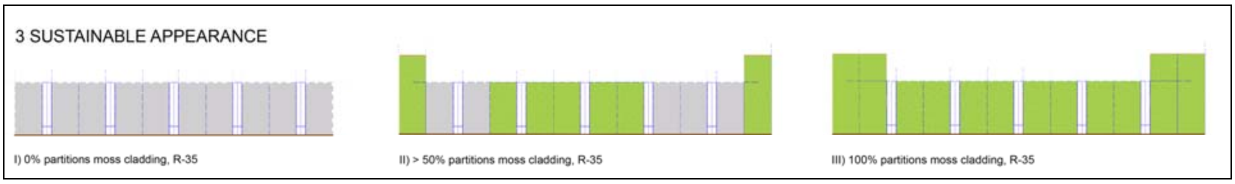

Figure 4 Visual scheme of the 3 levels in sustainable appearance

Fenestration – glazing proportion

Fenestration (design of windows) and the proportion of glazing affect the perceived aesthetic value of the façade and the building's ability to maintain the heat (energy efficiency).

In terms of architectural design, fenestration is influenced by factors like shape, size, density and location on a facade. The presence of windows in a façade affects the perception of the building massing; the more windows, the less apparent massing. For a resident's perception, building fenestration is very important and counts even more than visual area and facade articulation in subjective judgment of massing (Stamps, 2000). In this study, perceived massing is measured by height to length ratio of the windows in the front facades.

In addition to the height to length ratio, the proportion of glazed area in the total façade surface is important as this affects the energy efficiency of a building. Both the proportion of glazing of a facade and the quality of the glass (e.g. good thermal transmittance) influence the total primary energy consumption of a building (Herzog, 2008). If the transparent area of a residential facade is more than 30%, this is considered a high proportion of glazing. With a higher percentage, thermal performance in summertime has to be checked.

As with the height/length ratio of the windows, in this study the proportion of glazing refers to the front façade of each dwelling. The following levels were used in the design of the vignettes for the questionnaire:

- horizontal window (0.3); surface percentage glazing > 30%
- vertical window (2.4); surface percentage glazing <30%
- window covering the whole facade of a dwelling which is called here full size window (0.4); surface percentage glazing ≈100%

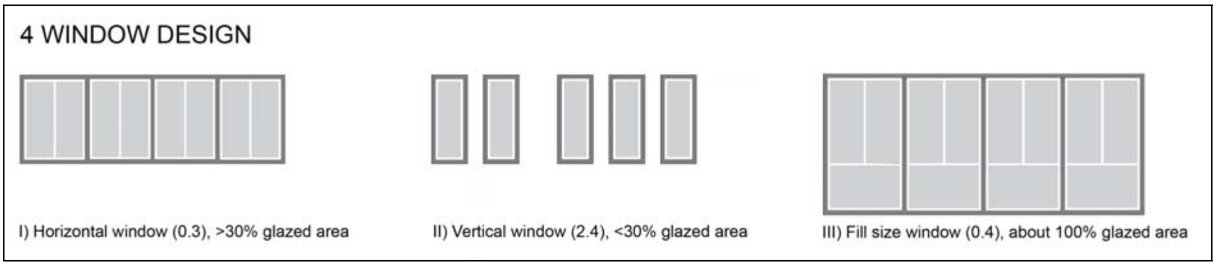

Figure 5 Visual scheme of the 3 levels in window design

Fenestration – solar protection

The combination of fenestration and solar protection refers to the shading of the building façade by solar shading devices. From an aesthetical point of view and in line with the presence of windows on a façade, such devices may affect the apparent massing, especially due to the formal features of the type of manipulator (e.g. color, external or internal location to the facade). Equivocally, solar shading devices affect the energy efficiency of the building by reducing incoming solar radiation.

Sunshade devices (e.g louvers, roller shutters, awnings, blinds, shading screens and plantings) can be classified according to material and color (Schittich, 2006, Herzog, 2008, Olgyay, 1963). The sun protection of a device depends on three major factors: the solar reflectivity of the material applied and its color, the inside or outside location of the shade device, and the arrangement of the applied shading. The effective reduction of solar radiation differs across devices. Reduction of solar radiation increases across venetian blinds, roller shades, insulating curtains, outside shading screen, outside metallic blind, coating on glazing surface, trees, outside awnings, outside fixed shading device and outside movable shading device (Dubois, 1997).

To study the propriety of apparent massing, three sun-shading devices are selected based on type and color. Both devices used in current practices and innovative devices will be included in the vignettes. Shading by plants, or bio-shading, is a relatively new strategy. The term bio-shading describes biological shading devices for building design and comprises a vertical layer of deciduous climbing plant canopies that trails on a metal framework. The device is externally mounted to the glazed facade of a building. In a study of office buildings, it turned out that the solar reduction of leafs (Virginia Creeper) is up to 37% by one layer and runs up to even 86% by five layers. In the same study, it was estimated that the pick temperature reduction of the interiors in hot summer afternoons was about 5.6C (Ip et al., 2008).

The shading coefficient is the ratio of the total solar heat gain from the transmitted, absorbed, and reradiated energy by the shade and glass combination compared to the total solar heat gain due to transmission, absorption, and re-radiation by a single un-shaded common window glass (it goes from 1 to 0, with 1 associated to common window with no shading) (Olgyay, 1963). In the present study, the reduction of solar radiation is measured by three levels of shading coefficient associated to the type of shading device:

- outside venetian blind white-cream colored, 0.15 shading coefficient
- outside aluminum shading screen, 0.28 shading coefficient
- dense tree performing heavy shade like bio-shading, 0.20 shading coefficient

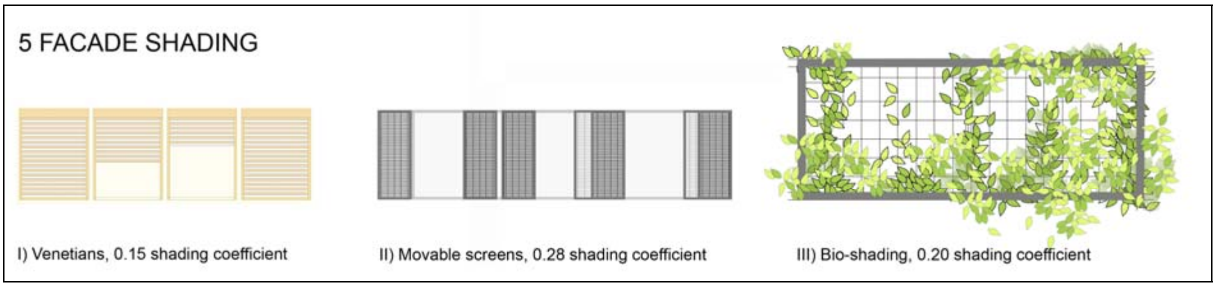

Figure 6 Visual scheme of the 3 levels in facade shading

Total rent

Social housing in the Netherlands is directed to low-income people with annual gross income below the modal income. In the period 2009/2010 the model income is by 32.500 euro (www.cpb.nl, visited in 2009). In the Netherlands, this part of the housing stock is owned and maintained by the housing associations. Rents in social housing are determined according to the national Housing Valuation System. According to this system, the rents are calculated in relation to the quality of housing by assigning credits for meeting a set criterion. The maximum number of credits is 150, currently associated with a rent of €669.09. Examples of points associated to quality of housing are size of dwelling (1 credit per m2), additional space (0.75 point per m2 of e.g. storage, garage), technical installations (5 point if technical private high performance heating) and façade isolation (7 to 8 points). All criterions have a pre-specified maximum of credits that might be assigned. In 2009/210, a credit corresponds to a maximum of €4.68. After renewal, rents might increase due to higher maintenance levels up to the maximum rent. For the current study, we decided to use rent levels to assess the willingness to pay of respondents by adding 5% and 10% to a baseline rent:

- € 550
- € 575
- € 600

Table 3 provides an overview of the attributes names and what concept was operationalized into the subsequent attribute levels..

ATTRIBUTE NAME (aesthetics / energy efficiency)	**OPERATIONALIZATION**		**LEVELS**
1) Facade articulation / surface geometry	Shape complexity / maintaining heat	Convexity by form of additions / compactness	I) low convexity by curved volumes, high energy efficiency II) medium convexity by straight volumes, medium energy efficiency III) high convexity by straight and inclined volumes, low energy efficiency

2) Surface colouring / facade materials	Colour complexity / absorbing solar radiation	Darkness of material associated to dwelling type / albedo of materials	I) 1 very dark material (0.15 albedo) to simplex II) 1 very dark material (0.15 albedo) to simplex, and 1 dark material (0.28 albedo) to simplex extended + simplex top floor III) 1 very dark material (0.15 albedo) to simplex, 1 dark material (0.28 albedo) to simplex extended + simplex top floor, 1 medium dark material (0.43 albedo) to simplex at the bottom
3) Visual character / thermal insulation	Impression of sustainability / transferring heat	Frequency of partitions by sustainable looking material (%) / thermal resistance (R-value)	I) 0% façade partitions by moss tiles with R-35 > 50% façade partitions by moss tiles R-35 (including addition of 'I' shaped towers) III) 100% façade partitions by moss tiles R-35 (including addition of 'L' shaped towers)
4) Fenestration / glazing proportion	Impression of massing / avoid overheating	Type of window design (height/length ratio) / glazed surface front façade of dwellings (%	I) horizontal window (0.3); surface percentage glazing > 30% vertical window (2.4); surface percentage glazing <30% III) window covering the whole facade of a dwelling which is called here full size window (0.4); surface percentage glazing ≈100%
5) Fenestration / solar protection	Impression of massing / reducing solar radiation	Types of sun shading / sunshade coefficient	I) outside venetian blind white-cream colored, 0.15 shading coefficient II) outside aluminum shading screen, 0.28 shading coefficient III) dense tree performing heavy shade like bio-shading, 0.20 shading coefficient
6) Total rent	Willingness to pay to rent a home in the building		I) 550 € II) 575 € III) 600 €

Table 3 Attribute, property measured, unit of measurement and levels.

Visualization of attributes and levels

For visual representations of buildings many techniques can be applied: 3D and 2D computer-aided design (CAD), photomontage, normal or perspective photographs, sketches, videos (of reality or miniaturized scenes) and virtual reality.

It could be argued that there is a difference in evaluations of scenes with different perspective and rendering color. Changing the perspective point, however, does not strongly affect the evaluation outcome (Stamps, 1999a). Photo images were found to perform better than verbal descriptions (Jansen et al., 2009). A disadvantage of photo images might be that respondents could recognize the buildings and have different associations with it. This problem might be overcome by using rendered images. In the present study we will use high realistic 3D color simulations of hypothetical buildings applying both a normal and a perspective view point.

The questionnaire

The six attributes with their respective category levels were all combined into 72 different combinations. A kind of receipt for the combinations were made with the statistical software program SAS and reflected a fractional factorial (statistical) design. This means that not all possible combinations of the attributes were used, but that optimal combinations were calculated. These 72 combinations were split in three blocks of 24 different combinations. Each respondent will get one block of 12 sets; each set has two different combinations (2x12). See figure 7 and 8 for examples of combinations.

Based upon this receipt, 3D visualizations were made with the software program 3D Studio Max, while MAYA was used to render the images. Since 72 combinations were needed to obtain a efficient (statistical) design, obtaining 3D images with both front and corner view required rendering of 144 images. Due to software limitations, each of the building objects needed for visualization was designed as an independent (external reference) file. The files were then mounted on master scenes according to the required combination of attributes. Afterwards, all the master scenes are exported in Maya for the elaboration of the renders. To compose the master scenes the external reference files are produced in three groups: façade type (smooth, plain and inclined), façade extensions (surface, bottom, top floor, tower I and tower L extension) and bio-shading (for smooth, plain and inclined façade).

Figure 3 Two combinations from set 1. Top picture: building form level 3, materialization level 3, sustainable appearance level 2, window design level 1, sun shading level 1, and rent level 2. Bottom picture: building form level 3, materialization level 3, sustainable appearance level 1, window design level 2, sun shading level 2, and rent level 3.

Figure 4 Two combinations from set 3. Top picture: building form level 2, materialization level 1, sustainable appearance level 1, window design level 3, sun shading level 1, and rent level 3. Bottom picture: building form level 1, materialization level 1, sustainable appearance level 1, window design level 3, sun shading level 2, and rent level 3.

The 144 renders were then used to develop an online questionnaire. The structure of the questionnaire is organized in three sections concerning respectively general questions on the major research topic, 12 paired choices and closing questions on the personal background of the respondent himself. Attention is given to the graphic layout of the questionnaire to keep the attention of the respondent high when answering the questions and possibly increasing the number of people completing the whole questionnaire.

Conclusions and next research steps

At this stage, one might tentatively conclude that it is possible to use 3D rendered images to investigate the preferences of tenants about the design of the façade / building envelope. The results of a pilot study of students of Architecture will be discussed at the conference.

References

ANDEWEG, M., T. & KOOPMAN, F., W., A., (2007) State of the Art: The Netherlands. *Improving the Quality of Existing Urban Building Envelopes – State of the Art.*

BOGERD, A., VAN OEL, C. & DE HAAS G. (2009) Occupant-owners preferences in deciding about innovative renovation concepts. *ENHR 2009.* Prague.

BRUNORO, S. & ANDEWEG, M., T. (2007) Conclusions. *Cost C16. Improving the quality of the existing urban building envelopes. State of the art.* Delft, Delft: Delft University Press.

CITIES, G. R. F. H. (2008) Introduction to green walls. Technology, benefist and desing. .

DANIELS (2007) Advanced building systems. A technical guide for architects and engineers

DESIGN FOR LONDON, GREATHER LONDON AUTHORITY'S LONDON PLAN, ENVIRONMENT TEAMS & PARTHENSHIP, L. C. (2008) Living roofs and walls. Technical report: supporting London Plan Polocy. London.

DUBOIS, M., C., (1997) *Solar Shading and Building Energy Use,* Lund.

EC (2007) Communication from the Commission to the Council, the European Parliament, the European economic and social Committee and the Committee of the Regions. A European strategic energy technology plan (set-plan). 'Towards a low carbon future'. Brussels.

ESTEVES, E. (2007) Europe's building requirements are falling behind the times *Press Release Eurima.*

EUMORFOPOULOU, E., A. & KONTOLEON, K., J. (2008) Experimental approach to the contribution of plant-covered walls to the thermal
behaviour of building envelopes. *Building and Environment,* 14.

GIFFORD, R. (2002) *Environmental psychology: principles and practice*, Colville, WA : Optimal books, 2002.

GROAT, L., N., (1988) Contextual compatibility in architecture: an issue of personal taste? *Environmental aesthetics; theory, research, and applications* Cambridge, UK : Cambridge University Press.

HEGGER, M., FUCHS, M., STARK, T. & ZEUMER, M. (2008) *Energy manual. Sustainable architecture,* Munich.

HERZOG (2008) Facade construction manual.

HERZOG, T., R. & SHIER, R., I. (2000) Complexity, age and building preference. *Environment and behaviour,* 18.

IP, K., LAM, M. & MILLER, A. (2008) Shading performance of a vertical deciduous climbing plant canopy. *Building and Environment,* 8.

JANSEN, S., BOUMEESTER, H., COOLEN, H., GOETGELUK, R. & MOLIN, E. (2009) The impact of including images in a conjoint measurement task: evidence from two small-scale studies. *Journal of Housing and the Built Environment,* 26.

KNAACK (2007) Facades. Principles of construction

KOOPMAN, F. W. A. (2007) General Overview of the Problems, Needs and Solutions in the
Dutch Urban Building Envelopes. *COST C16 Improving the Quality of Existing Urban Building Envelopes - Needs.*

MEEROW, A., W., BLACK, R., J. (1993) Enviroscaping to Conserve Energy: A Guide to Microclimate Modification. *Circular EES-43, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.*, University of Florida.

MELGAARD, E. (2007) General Conclusions. *COST C16 Improving the Quality of Existing Urban Building Envelopes - Needs.*

NASAR, J. L. (1994) Urban Design Aesthetics: The Evaluative Qualities of Building Exteriors. *Environment and Behavior,* 26, 24.

NATIONAL BOARD OF HOUSING SWEDEN (2005) Housing statistics in the European Union 2004. Falun.

OAK RIDGE NATIONAL LABORATORY (2008) The DOE Insulation Fact Sheet. .

OLGYAY, V. (1963) *Design with climate; bioclimatic approach to architectural regionalism*, Princeton : Princeton University Press, 1963

RICHARZ (2007) Energy efficiency upgrades

ROELOFFZEN, J., F., T., LANTING, R., SCHOLTEN, N., P., M., DEN BREEJEN, F., DE WILDT, R., VAN ROSSUM, H., BLASS, J., DE VRIES, K., W., WILLEMSE-TER

BRAAKE, M., O., M. (2004) High-Rise Housing In The Netherlands: Past, Present And Sustainability Outlook.
SCHITTICH, C. (2006) *Building skins. New enlarged edition.*
SIMPSON, J., A., & WEINER, E., S., C. (2009) The Oxford English dictionary. Online resource. .
STAMPS A. E. & NASAR, J. L. (1997) Design review and public preferences: effects of geographical location, public consensus, sensation seeking, and architectural styles. *Journal of Environmental Psychology,* 17**,** 21.
STAMPS, A. E. (1999a) Architectural detail, Van der Laan septaves and pixel counts. *Design Studies,* 20**,** 14.
STAMPS, A. E. (1999b) Defining block character. *Environmental and Planning B: Planning and Desing,* 26**,** 25.
STAMPS, E., A. (1999c) Physical Determines of preferences for residential facades *Environment and behavior,* 31**,** 28.
STAMPS, E., A. (1999d) Physical Determines of preferences for residential facades
STAMPS, E., A. (2000) *Psychology And The Aesthetics Of The Built Environment.*
STAMPS, E., A. & NASAR, J. L. (1997) Design review and public preferences: effects of geographical location, public consensus, sensation seeking, and architectural styles. *Journal of Environmental Psychology***,** 21.
TAHA, H., SAILOR, D., AKBARI, H. (1992) High-albedo materials for reducing building cooling energy use. *Energy and Environment Division, Lawrence Berkeley Laboratory.* Berkeley, University of California.
THISSEN, C. (2007) Strategies for housing renovation in the Netherlands: promising technologies and cluster innovativeness. Utrecth, Utrecht University.
U.S. DEPARTMENT OF ENERGY (2009) The R-Value of Insulation.
VAN BECKHOVEN, E., BOLT, G. & VAN KEMPEN, R. (2005) Theories of neighbourhood change and neighbourhood decline: their significance for post-WWII large housing estates. *ENHR-conference "Housing in Europe: New Challenges and Innovations*
in Tomorrow's Cities". Reykjavik.
VAN DEN BERKHOF, D. (2008) Beleving van lounges op Amsterdam Airport Schiphol. Vormgevingsvoorkeuren van reizigers.
VAN ECK, A., J., L., , VAN OEL, C., J., & KOPPELS, P., W., (2008) The 'willingness to pay' for newly built energy efficient houses. *ENHR International Research Conference. Shrinking Cities, Sprawling Suburbs, Changing Country sides.* Dublin, Ireland.
VAN OEL, C., DE HAAS, G., J., , VAN HAL, J., D., M., & THOMSEN, A., F., (2010) Rigoureus WP2.
WESTRA, E., MAK, A. & VAN ETTEN, R. (2009) Inschrijvingen. Nationale Renovatie Prijs 2009.
WWW.CECODHAS.ORG (visited in 2007) the European Liaison Committee for Social Housing.
WWW.CPB.NL (visited in 2009) Bureau voor Economische Beleidsanalyse.
WWW.NATIONALERENOVATIEPRIJS.NL (visited in 2009) the Nationale Renovatie Prijs
WWW.VERTICIEL.CA (visited in 2009) Verticiel Inc.