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Role of physical attributes of preferred building facades on perceived visual complexity: a discrete choice experiment

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Abstract

Complexity has been known as a crucial psychological factor influencing the evaluation of the building facades preferences. However, little is known about the role of physical attributes of preferred building facades on perceived visual complexity. The objective of this study is to assess perceived visual complexity of urban building facades in terms of physical attribute in different levels. Discrete choice experiments were used to study the perceived visual complexity of preferred building facades. A sample of 213 students from Golestan University evaluated preference and perceived visual complexity of 36 pairs of images based on ten physical attributes of building facades in different levels (material (brick, stone), the contrast of materials (absent, present), color (absent, present), ornament (high, low), curve (straight, curved), vegetation (plants, no plants), windows orientations (vertical, horizontal), fenestration (large, small), articulation (side recesses, flat) and architectural style (modern, classic, traditional). The results revealed that all physical attributes of preferred building facades were found significant on perceived visual complexity expect for three attributes: architectural style, color and window to wall size. Thus, participant preferred a high-ornament facade with curved lines, vegetation, classical style, articulation, contrast between materials, as well as vertical windows. The articulation and ornament attributes were the most significant on perceived visual complexity. The results of this study can help city planners, architects, and designers to design facades with more general preferences and reduce the visual pollution of the cities.

Keywords Information-processing theory · Multinomial logit model · Building facades · Visual complexity

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1 Introduction

Today, visual ugliness, heterogeneity, and pollution have become an integral part of the city face and urban façade. This may endanger the sustainability of cities and turn into a severe global issue as the urban experience has often been negative and the anxiety, depression, stress, and citizens' dissatisfaction that is usually associated with urban life today (Dzebic, 2018; El-Ghonaimy, 2019; Guo et al., 2022). When we talk about environmental problems, the first things that come to mind are land, water, air and noise pollution. However, one type of pollution that is gaining importance today and affecting people psychologically and spiritually is visual pollution (Shaban et al., 2018; Yilmaz & Sagsöz, 2011). One of the most significant visual pollution that has a psychological influence on people is urban building facades (Razzaghi-Asl et al., 2017; Yilmaz & Sagsöz, 2011). The building facades, as an interface between the interior and exterior, represent the urban landscape and are one of the effective factors in determining the quality the urban landscape. However, one of the most important factors affecting facade pollution is the high visual complexity of the facade that means chaos (Chmielewski, 2020; Oludare et al., 2021).

Complexity is expressed as the quantity of data that a person can perceive in his visibility angle of the landscape. Based on Kaplan's (1998) theory, individuals prefer landscapes that meet the two basic needs of immediate understanding and perception. Hence, given the presence of more information, the complexity of façade can encourage exploration and immediate engagement with the environment. With the increase of visual information, the space becomes more perceptible away from monotony. As complexity increases, the density of new information provided increases, but too much information confuses the individual (Akbarishahabi, 2021). Thus, it is recommended to avoid low and high levels of complexity in design of building facades.

Researchers showed that the perceived complexity of buildings is an important indicator of determining the attractiveness of the building. Therefore, visual complexity can improve the quality of a scene and complexity is as an important variable in appearance. Therefore, it is necessary to identify physical attributes that can provide an intermediate level of complexity or play a decisive role in enhancing the preference.

Studies have shown the building facades are designed based on people's visual preferences (Hussein, 2020; Zhen et al., 2020; Oludare et al., 2021) can help improve the sustainable development of cities. Thus, the research background in visual preferences of citizens toward building facades broadly supports the quantitative assessment of the constructions on the basis of physical attributes (Ghomeishi, 2021; Häfner et al., 2018; Ilbeigi & Ghomeishi, 2017; Jalali et al., 2013; Sadeghifar et al., 2019). Since visual complexity is the most important factor in design facade and as one of the most important psychological factors that influence the evaluation of the building facade preferences (Kawshalya et al., 2022; Lorenz & Kulcke, 2021) despite this, the role of physical attributes of the building facade, especially at different levels, has been neglected (Chmielewski, 2020; Oludare et al., 2021).

1.1 Visual complexity

Based on the two theories proposed by Kaplan and Kaplan (1989) and Berlyne (1974) theories complexity as one of the most important psychological factors influences the evaluation of the building facades preferences and should be taken into account (Akalin et al., 2009; Ghomeishi, 2021; Herzog & Shier, 2000; Hussein, 2020; Imamoglu, 2000; L. Ma et al., 2021a, 2021b; Memari & Pazhouhanfar, 2017; Nasar, 1994; Stamps III, 1999a; Sun et al., 2017).

Berlyne (1974) stated that the most important and preferred component for an image is visual complexity. Berlyne's arousal theory suggests that environments provide specific stimuli for humans, and environments that provide an optimal level of preferred complexity. Visual complexity is the presumed attributes of a unique organism and its environment, which relates to individual differences and the distinctions of complex stimuli. In this definition, complexity stimuli are a stable attribute of the physical environment, which are used as an estimated method for visual complexity (Wahdattalab et al., 2020).

Similar to Berlyne (1974), by presenting Information-processing theory, Kaplan (1987) demonstrated that information content is a determinant of preferences as a result of visual complexity. Unlike Berlyne (1974), Kaplan does not argue for an arousal mechanism. Kaplan and Kaplan (1989) suggests that visual preferences of the landscape originate from two primary human responses to the environment: the need for understanding and the desire to discover. In other words, in their analysis of environmental preferences, they suggested that people have an intrinsic need to be in the environment, which means they collect information which can then create feelings and integrate mental representations to support efficient performance (Kaplan et al., 1989). In this framework, the visual complexity of a scene is an essential determinant of preferences as it encourages exploration and offers immediate engagement with the environment.

1.2 Visual complexity and preference of building facade

Many studies have emphasized to the role of the visual complexity of environment on people's preference (Kawshalya et al., 2022; Ma et al., 2021a, 2021b; Pan et al., 2022). Nasar (1989) listed complexity as an important variable which influences human preference for the outdoor environment. In a study on urban facades, complexity was found as the most important factor influencing preference toward building facades (Memari & Pazhouhanfar, 2017) that is compatible with subsequent studies (Hussein, 2020; Lorenz & Kulcke, 2021). Kawshalya et al. (2022) evaluated the street's visual complexity through perceptual and objective measures of visual complexity. They found a positive relationship between the satisfaction level of individuals and the visual complexity on the street. Whang (2011) also attempted to examine the role of complexity and order on the aesthetic experiences of architectural forms to measure the complexity and order in the facades. He argued that the degree of complexity in an architectural facade could be increased or decreased by changing some attributes, including number, shape, relationship, and surface materials of building elements. Furthermore, complexity as one of subcategories of facade's shape was known as a predictor of visual preference. Generally, studies showed complexity as influencing design factors on the preference of building facades.

1.3 Physical attribute and preference of building facade

Literature review on this area has pointed to various physical attributes of urban facades. In a study, Ghomeishi (2021) examined 36 physical attributes of residential landscapes in six categories of wall appearance, wall material, wall form, wall texture, window size and form, balcony size, and extra decorations from the viewpoints of architects and non-architects. The results showed that the wall form, the size and form of the window were more important physical variables in explaining preference. The amount of open space and the size of window area also affected on judgments of preference (Pan et al., 2022; Prieto & Oldenhave, 2021).

Stamps III (1999a) noted that decoration and details are essential components of building preferences and examined the relative effects of subjective observations on details for three design elements: door and window trim, ornament, and texture. He reported that the facade of the building decorated with cornice, ornament, shingles, as well as door and window trim were preferred to the facade without those elements. Furthermore, Herzog and Shier (2000) confirmed the effect of these features on students' preference of building facades using a composite measure of complexity. Another study by Ghomeshi and Jusan (2013) stated that articulation in building facades led to high score preference by designers. Furthermore, Baper and Hassan (2012) recognized articulation as the most influential feature in interpreting the continuity of architectural Identity.

In a similar study, Loodin and Thufvesson (2022) also explained that style, details, decorations and paned windows are the most critical visual elements in the preferences of building facades. Study on Gorgon's building facades showed that color was the most influential positive predictor accounting for people's preferences (Sadeghifar et al., 2019). Architectural style and color are also evaluated as the most important elements in building façade (Hussein, 2020; Zhen et al., 2020). Material also reported as one of the architectural variables may express symbolic meaning and is related to positive external aesthetics assessment building facades (Ghomeishi, 2021). Furthermore, the contrast between elements created by a building facade have significant impacts on the visual richness of a building façade (Prieto & Oldenhave, 2021).

Vegetation has been indicated as another physical attributes in explaining preference in studies (Herzog & Shier, 2000; Ilbeigi & Ghomeishi, 2017; Kawshalya et al., 2022). Previous studies on urban landscapes confirmed the role of nature in enhancing people's preference that led to enhanced mental health. Collectively, studies suggested that physical attributes in different levels can affect the aesthetic assessment and preference of individuals from urban building facades. However, little is known about role of physical attributes of the preferred building facades on the perceived visual complexity.

To date, several studies have analyzed how measuring visual complexity the built environment that among computer vision and image processing methods (such as Shannon's entropy, RMS contrast and fractal dimension). The results show among the other methods, fractal dimension offers the most accurate perceived visual complexity (Hussein, 2020). However, compatibility is generally not high with actual perceived level of visual complexity (Akbarishahabi, 2021; Ma et al., 2021a, 2021b). An alternative method to assess perceived complexity is discrete choice experiments (DCE). A DCE is a sequence of multinomial choice questions that respondent is asked to make a discrete choice between two or more discrete alternatives in a choice set. Evidence shows that this method obtains a better understanding of the choices made by the respondents (Dimal & Jetten, 2020; Häfner et al., 2018). In addition, it does not have the concerns related to response bias in open-ended questions and the incremental numerical rating scale (Van Dongen & Timmermans, 2019). Thus, DCE was suggested for this study.

1.4 Objectives, hypotheses of the present experiment

The main objective of this study is to explore the relationship between physical attributes of the preferred building facades in different levels and perceived visual complexity. To access to this objective, first, this study investigated relationship between physical attributes in different levels and preference and then perceived visual complexity. The theoretical model is presented in Fig. 1. The following hypotheses have been formulated with the purpose of enriching the understanding of the impact of physical attributes on perceived visual complexity.

H1 There is a significant relationship between physical attribute in different levels and preference of building façade.

H2 There is a significant relationship between physical attribute in different levels and perceived visual complexity.

2 Research method

Visual discrete choice experiments were conducted to measure respondents' preferences and perceived visual complexity of designed physical attributes of building facades in different level. In the DCE, individuals choose an alternative from various alternatives, and

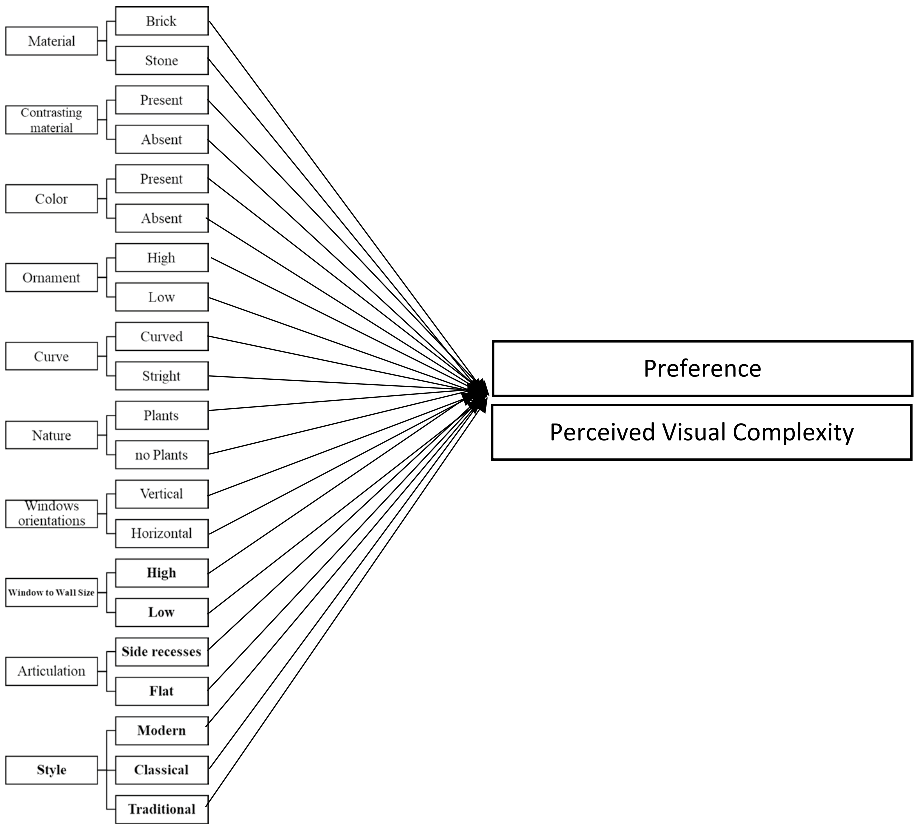

Fig. 1 Theoretical model

choosing one alternative over other alternatives. Results indicate that the chosen alternative has the highest utility (Dimal & Jetten, 2020; Häfner et al., 2018; Kuper, 2017). In this study, utility refers to the scene inside the image, not the image itself, and participants are asked to choose the environment inside the image. The utility derived from the environment is the only difference between the two alternatives (Van Dongen & Timmermans, 2019).

2.1 Participants

Participants according to other DCE studies (de Bekker-Grob et al., 2015; Van Oel & van den Berkhof, 2013) included 213 students (145 males, 68 females; an average of 19–26 years of age) of Golestan University. They were asked to fill the consent form to participate in the study.

2.2 Physical attributes and levels

Literature review on this area has pointed increasing the number of features leads to larger number of alternatives for each individual, making the process of comparison and selection difficult (Kemperman, 2021). Although many physical attributes of facade were mentioned in the literature, 10 design attributes with significance effects in literature review were used (including materials, material contrast, color, architectural style, ornament, curves, vegetation, window to wall size ratio (fenestration), windows orientations, and articulation). Table 1 shows an overview of the selected attributes and their levels.

As two fundamental *materials*, stones and bricks were most commonly used in the facades. Furthermore, due to the importance of multiplicity and contrast between the elements of a building facade on visual richness, the material contrast factor was also added to the experiment. The two levels of this attribute were the presence or absence of a *material contrast* expressing being a single material or two materials of the facade. The presence or absence of *color*, expressed as color attribute, was studied to measure the importance of color along with other attributes. The common *style* of the facade's architecture can be divided into modern, Classic and traditional categories. These three commonly used styles were presented as levels of architectural style attributes in this study. The *ornament* attribute was considered on two levels of low and high ornament. The difference between these two levels was achieved with regard to the detail and decor in the components. The ornament attribute was chosen regardless of which level it was used in, adjusted to the architecture style of the building. The presence or absence of *curve and vegetation* as curve and vegetation attribute levels are represented by other measured attributes. In this way, the curve attribute was adopted by adding the curve lines to the Cornice and the Vegetation via the flavor box in the facade. The *window to wall size* (fenestration) was considered in large (more than 30%) and small (less than 30%) levels. The window orientation variable was also measured on a nominal scale on both horizontal and vertical levels. To describe horizontal and vertical levels, a height was used to length (h / l) ratio of 1.5. Therefore, if the window is vertical, it means that its height is 1.5 times its length, and if it is horizontal, it its length is 1.5 times its height. In this way, two sizes of the window 1.8*1.2 and 2.7*1.8 were utilized in both vertical and horizontal directions in the design of facades. The *articulation* attribute was also examined on two levels according to the structure of the facade: flat and side recesses (balconies).

Table 1 Physical attributes' levels used in DCE on the building facade

Physical attribute	Level 1	Level 2	Level 3	Reference
1. Material	Brick	Stone		Askari and Dola (2009), Ghomeishi (2021), Oludare et al. (2021), Prieto and Oldenhave (2021), Utaberta et al. (2012)
2. Contrasting material	Absent	Present		Askari and Dola (2009), Baper and Hassan (2012), Hussein (2020), Oludare et al. (2021), Zhen et al. (2020)
3. Color	Absent	Present		Herzog and Gale (1996), Hui (2007), Hussein (2020), Oludare et al. (2021), Sadeghifar et al. (2019), Utaberta et al. (2012), Zhen et al. (2020)
4. Architectural style	Modern	Classic	Traditional	Askari and Dola (2009), El-Ghonaimy (2019), Ghomeishi (2021), Ghomeshi and Jusan (2013), Hui (2007), Imamoglu (2000),; Sadeghifar et al. (2019), Utaberta et al. (2012), Zhen et al. (2020)
5. Ornament	High	Low		Akalin et al. (2009), Askari and Dola (2009), Ghomeishi (2021), Ghomeshi and Jusan (2013), Herzog and Shier (2000), Ilbeigi and Ghomeishi (2017), Prieto and Oldenhave (2021), Sadeghifar et al. (2019), Stamps III (1999a), Utaberta et al. (2012), Zhen et al. (2020)
6. Curve	Straight	Curved		El-Ghonaimy (2019), Ghomeishi (2021), Herzog and Shier (2000), Lorenz and Kulcke (2021), Stamps Iii (1999a)
7. Vegetation	Plants	No plants		Ghomeshi and Jusan (2013), Herzog and Shier (2000), White and Gatersleben (2011)
8. Windows orientations	Vertical	Horizontal		Alkhresheh (2012), Baper and Hassan (2012), Ghomeishi (2021), Sadeghifar et al. (2019)
9. Window to Wall Size ratio	Large (30% $< X$)	Small (30% $> X$)		Alkhresheh (2012), El-Ghonaimy (2019), Ghomeishi (2021), Ghomeshi and Jusan (2013), Oludare et al. (2021), Sadeghifar et al. (2019), Van Oel and van den Berkhof (2013)
10. Articulation	Recesses Side	Flat		Baper and Hassan (2012), Ghomeishi (2021), Herzog and Shier (2000), Sadeghifar et al. (2019), Zhen et al. (2020)

2.3 Experimental design and data collection

In the facade design preferences, based on visual experiments, it is more credible if the experiment is repeated in different geographic conditions. Therefore, the simulated buildings were modeled abstractly to prevent local architectural characteristics from influencing the responses. This experiment was done in Gorgan context. Accordingly, as a basic model, a 5-storey residential apartment was used, as presented in the results of Memari and Pazhouhanfar (2017) in Gorgan as one of the facades with more preferences.

It was then decided to use Computer simulation instead of photos taken from constructed buildings to isolate the investigated variable away from any potential confounding variables such as lack of good construction, surrounding buildings that might affect the design, the quality of the photo, and poor maintenance(Ghomeishi, 2021). Computer simulation is considered as the most efficient way to manipulate and control the research variables and their levels (Alkhresheh, 2012).

In this study, 10 attributes with two levels and one attribute with 3 levels were used. A full factorial design is included all possible combinations and there would have been a need for 1536 (2 * 2 * 2 * 3 * 2 * 2 * 2 * 2 * 2 * 2) separate images, thus, *D*-optimal orthogonal design was employed and evaluated using the program SAS Version 9.2 to reduce the number of combinations to 72 (Kemperman, 2021; Kuhfeld, 2010). Therefore, a version was obtained which showed how and to what extent each attribute should be presented in each set from experimental design with SAS. Also, the pattern of images in each set and the overall structure of the sets were presented. In this way, these 72 images were randomly arranged in 6 blocks, each of which had 6 sets with paired images (Fig. 2). The participants responded randomly in two series (which included visual experiences related to preferences and complexity) of these six versions of questionnaires.

Block	Set	Alt	Material	Contrast	Colour	Style	Ornament	Curve	Nature	Window	Fenestration	Articulation
2	1	1	Brick	Contrast Absent	colour Absent	Classic	Low	Curved	No plants	Window Vertical	Window large	side recesses
		2	Brick	Contrast Present	colour Present	Classic	High	Straigt	Plants	Window Horizontal	Window small	flat

Fig. 2 Example of a experimental design with SAS Version 9.2

For each choice option, the images were constructed using AutoCAD and Autodesk Revit software. All renderings are taken from the observer's point of view. Finally, the residential facades were moved to Adobe Photoshop and the trees were added to them. Figure 2 presents an example of a choice task in choice experiment.

2.4 Procedure

Since the purpose of this study was to investigate the people's visual preference and complexity of physical attributes of preferred buildings facades, the statistical population was selected from non-architecture and architecture students. Given that these two groups have different visual literacy and each has different criteria in expressing preferences and complexity, the statistical community can provide a framework for measuring the research variables. Data collected among students in the Golestan University. First, aim and a short description of the survey procedure were presented. Subsequently, participants completed the first part of the questionnaire, which includes demographic details. Next, participants were randomly selected a block. In this study, each participant was shown only two block including paired images of preferences or complexity. Each block contains 6 choice sets, and each set contains 2 alternatives. The participants were asked to choose from the paired images of the first group based on what they preferred, and for the second group, to choose from paired images based on visual complexity. This questionnaire was shown to the students using Java software on the laptop (Fig. 3). A total of 213 questionnaires were completed. The response time of each participant to the questionnaire was about 8 to 10 min. By selecting blocks from menu then 'start survey' binary images are shown. Each participant chooses one of the images. In the end, data will place in an excel file related to same block. Each respondent was randomly assigned 12 choice sets with two varying alternatives, leading to a total of 2556 observed choices (213 * 6 * 2 = 2376).

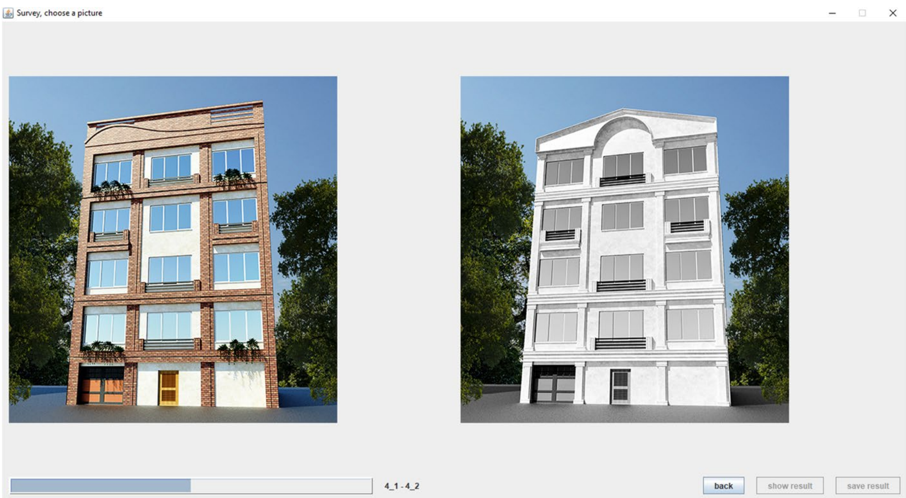

Fig. 3 Screen shots of software and a choice task in the questionnaire

3 Results

The results were analyzed in SAS 9.4. In SAS, regular Cox model (PROC PHREG) method estimator were used after initial data processing to obtain a multinomial logit model (MNL). This model was used to analyze understanding of attributes. The choice patterns of all participants were analyzed using the MNL (Kemperman, 2021; Kuhfeld, 2010).

3.1 Relationship between physical attribute and preference of building façade (H1)

As the first step, this study investigated the preference for physical attribute of building facade. As stated, the results of selection patterns of all respondents were analyzed using an MNL. This model assumes that participants choose the options that have the most utility. Table 2 illustrates the importance of selected attributes in choosing facades that are preferred by participants. The higher value of utility indicates more importance of that variable in choosing the preferred facade.

Results of Table 2 show that all the physical attribute significantly affects the selection of facades except for materials and architectural style (traditional). This can be seen from the value of p, which indicates the level of significance of an attribute in the selection for the desired facade. The respondents must always choose one image which is preferred more from among two images, hence respondents prefer a level of attribute to another. In the analysis, the preference of one level is more than that of the reference level, and as a result, the value of the reference level is set to zero.

The utility estimates are relative estimates, and if the 95% confidence intervals of the HR do not include the utility estimate of one of the other attributes, this can be used to cluster the attributes according to their influence on people's choices. Figure 4 shows the attributes ordered from most influential to not influential.

According to utility estimates both ornament and curve attributes were most preferred as the most influential attribute in the preferences of building facades. Higher ornament preference was nearly double than lower ornament preferences (HR = 1.898, $\chi^2 = 56.35$, $df = 1$, $p < 0.0001$). The curve attribute versus non-curved (straight lines) attributes claimed the second rank of attributes in this study, indicating the importance of this attribute in the preferences of building facades (HR = 1.859, $\chi^2 = 49.84$, $df = 1$, $p < 0.0001$). Vegetation appeared to be the third most significant attribute. The participants favored the facades with vegetation (HR = 1.470, $\chi^2 = 20.71$, $df = 1$, $p < 0.0001$). The next attributes were classic style and articulation. In the style of architecture, respondents preferred the classic style to modern style (HR = 1.371, $\chi^2 = 9.62$, $df = 1$, $p < 0.0019$). However, the results were not significantly difference in the peoples' preferences with regard to the preference between modern style and traditional style (HR = 1.060, $\chi^2 = 0.32$, $df = 1$, $p < 1.060$). Regarding the articulation attributes, the facades with balconies were preferred to flat facades (HR = 1.358, $\chi^2 = 12.41$, $df = 1$, $p < 0.001$). Color, material contrast, Windows orientations and Window to Wall Size ratio were next attributes respectively. Therefore, regarding the material contrast, the presence of contrast is more preferred to its absence (HR = 1.258, $\chi^2 = 7.57$, $df = 1$, $p < 0.006$). In the case of color, the results showed the preference for color versus lack of color (HR = 1.229, $\chi^2 = 5.96$, $df = 1$, $p < 0.01$). The reference level of window orientations is horizontal, which means that a vertical window is more preferred than the horizontal windows (HR = 1.193, $\chi^2 = 4.35$, $df = 1$, $p < 0.05$). Large windows (opening with a

Table 2 Peoples' preferences (utility estimates) of the physical attribute

Design characteristic	Reference level	*df*	Utility	SE	x^2	*p*	HR	95% Ci HR
1. Material (Brick)	Stone	1	0.04	0.08	0.2	0.65	1.039	0.88–1.23
2. Contrasting material (Present)	Absent	1	0.23	0.08	7.57	0.006	1.258	1.07–1.48
3. Color (Present)	Absent	1	0.21	0.08	5.96	<0.01	1.229	1.04–1.45
4. Architectural style (classic style)	Modern	1	0.32	0.1	9.62	0.0019	1.371	1.12–1.67
Architectural style (traditional)	Modern	1	0.06	0.1	0.32	0.57	1.060	0.87–1.3
5. Ornament (High)	Low	1	0.64	0.08	56.35	$<.0001$	1.898	1.61–2.25
6. Curve (Curved)	Straight	1	0.62	0.09	49.84	$<.0001$	1.859	1.57–2.21
7. Vegetation (plants)	No Plants	1	0.38	0.08	20.71	$<.0001$	1.470	1.25–1.74
8. Windows orientations (Vertical)	Horizontal	1	0.18	0.08	4.35	<0.05	1.193	1.01–1.40
9. Window to Wall Size ratio (Large ($30\% < X$))	Small ($30\% > X$)	1	0.18	0.09	4.12	<0.05	1.195	1.01–1.42
10. Articulation (side recesses)	Flat	1	0.30	0.09	12.41	<0.001	1.358	1.15–1.61

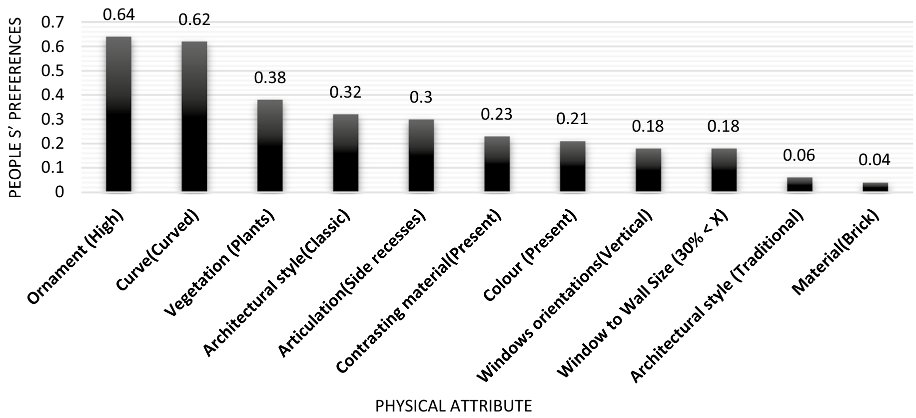

Fig. 4 People s' preferences of the physical attribute based on Table 2

percentage of $30\% < X$) were also preferred over small windows (HR = 1.195, $\chi^2 = 4.12$, $df = 1$, $p < 0.05$). In Fig. 5 shows the least (left) and highest (right) preferred of building facades.

3.2 Relationship between physical attribute and perceived visual complexity (H2)

As the second step, the role of physical attributes of the preferred building facade on perceived visual complexity was evaluated. Although material and traditional architecture were not significant predictors of preference, they were considered as physical attributes of preferred buildings facades base on literature review. Table 3 shows that all attributes except for color, architectural style and Window to Wall Size were found the significant attributes on perceived visual complexity. Figure 6 also shows the attributes ordered from the most influential to not influential. The results indicated that the most

Fig. 5 The building facade with the least and highest preference

Table 3 Perceived visual complexity (utility estimates) of physical attribute of preferred urban building facades

Design characteristic	Reference level	*df*	Utility	SE	x^2	*p*	HR	95% Ci HR
1. Material (Brick)	Stone	1	0.50	0.09	28.54	< .0001	1.655	1.38–1.99
2. Contrasting material (Present)	Absent	1	0.43	0.10	19.69	< .0001	1.535	1.27–1.86
3. Color (Absent)	Present	1	0.032	0.10	0.10	0.7544	1.033	0.84–1.27
4. Architectural style (classic style)	Modern	1	0.54	0.12	21.35	< .0001	1.717	1.37–2.16
Architectural style (traditional)	Modern	1	0.12	0.11	1.08	0.2976	1.123	0.90–1.40
5. Ornament (High)	Low	1	1.22	0.11	129.36	< .0001	3.405	2.77–4.22
6. Curve (Curved)	Straight	1	0.75	0.10	50.66	< .0001	2.115	1.72–2.61
7. Vegetation (plants)	No Plants	1	0.28	0.10	7.01	< 0.001	1.318	1.08–1.62
8. Windows orientations (Vertical)	Horizontal	1	0.30	0.10	9.71	< 0.001	1.353	1.12–1.64
9. Window to Wall Size ratio (Large (30% < *X*))	Small (30% > *X*)	1	0.13	0.10	1.65	0.1995	1.135	0.94–1.38
10. Articulation (side recesses)	Flat	1	1.30	0.11	142.18	< .0001	3.680	2.98–4.54

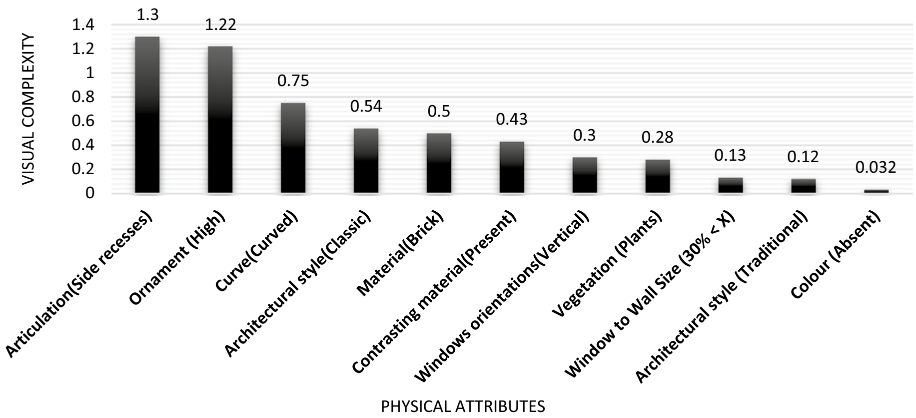

Fig. 6 Perceived visual complexity of physical attributes based on Table 3

important attributes were articulation and ornament on perceived visual complexity. The HR factor showed that the articulation attributes with balconies and ornament of façade facade, increase the complexity perception of the facade by more than three times.

The presence of a curve in the facade made the respondents consider these facades as more complex than facades with straight lines. Also, the effects of material attributes, material contrast, architectural style, vegetation, and window orientation were also significant on perceived visual complexity. However, there was no significant difference between the different levels of color, modern style, and traditional style and window to wall size ratio on perceived visual complexity. In other words, the difference between the levels of these attributes did not affect the increase in perceptual complexity. Regarding the materials attributes, brick had a greater impact on complexity compared with stone (HR = 1.655, $\chi^2 = 28.54$, $df = 1$, $p < 0.001$). Moreover, the contrast in materials also increased the perceived visual complexity (HR = 1.535, $\chi^2 = 19.69$, $df = 1$, $p < 0.0001$). The classic style had a greater chance of increasing perceived visual complexity compared to modern architectural style (HR = 1.717, $\chi^2 = 21.35$, $df = 1$, $p < 0.0001$). The results indicated a significant relationship between the presence of vegetation and increasing complexity (HR = 1.318, $\chi^2 = 7.01$, $df = 1$, $p < 0.001$). Similarly, regarding the window orientation attributes, vertical windows had higher perceived visual complexity than horizontal windows (HR = 1.353, $\chi^2 = 9.71$, $df = 1$, $p < 0.001$). In Fig. 7 shows the least (left) and highest (right) perceived visual complexity of building facades.

4 Discussion

The present study aimed at understanding the relationship between the physical attributes of preferred buildings facades in different levels and perceived visual complexity. Thus, the basic questions are: Do the preferences for buildings facades depend on the physical attributes? Do the perceived visual complexity for buildings facades depend on the physical attributes?

Fig. 7 The building facade with the least and highest perceived visual complexity

4.1 Relationship between physical attributes in different levels of urban building facades and preference

Thus, first the relationship between physical attributes in different levels of urban building facades and people's preference was investigated. The results confirm that some levels of physical attributes significantly affect the visual reactions of people and their preferences. This outcome agrees with various studies that indicated that people preferred a facade with a high-ornament facade with curved lines, vegetation, classical style, articulation, contrast between materials, colors, as well as vertical and large windows (Ghomeishi, 2021; Loodin & Thufvesson, 2022; Pan et al., 2022; Prieto & Oldenhave, 2021; Sadeghifar et al., 2019; Zhen et al., 2020). This outcome validates the first research hypothesis.

In consistence with previous studies, the decorative attributes (ornament and curves) had the highest effect on preferences (Ilbeigi & Ghomeishi, 2017; Loodin & Thufvesson, 2022; Stamps III, 1999a). This outcome means that the sensory value of decorations as architectural detail would be reflected on other attributes (Prieto & Oldenhave, 2021) and it is an influential factor on the facade of buildings. These studies also indicate that prefer the use of Curve lines clearly. These results are consistent with Ghomeishi (2021) studies that find among the various physical features of the view, viewers have a high understanding of the curve, and the facade with the presence of the curve gained the most preference.

Strong positive linear relationship between the presence of Vegetation and preferences was also found. Therefore, respondents preferred green decorated facades to the absence of greenness. This outcome agrees with previous studies that people prefer natural landscapes to urban facades and these environments evoke more positive emotions (Ilbeigi & Ghomeishi, 2017; Kawshalya et al., 2022; Van Oel & van den Berkhof, 2013). Consistent with result of researches on facades the architectural style had a significant effect on preferences (Loodin & Thufvesson, 2022; Pan et al., 2022; Prieto & Oldenhave, 2021; Zhen et al., 2020). In previous studies, there was no clear agreement between the preferred styles. For example, an experiment conducted by Ng et al. (2020) showed that people are increasingly interested in modern style buildings, while in the present study, agreement to Loodin and Thufvesson (2022) the classical style was preferred. This result means that when judging the assessment of individuals 'visual preferences, researchers should pay close attention to differences in cultural experience and viewers' lives, rather than rushing to conclusions.

The results show that contrasting material, color, use of vertical windows and large windows also affects the increase of preferences. However, they were less important visual elements in preferred building facades. Nevertheless, their influence should not be understated in the future studies. For example, color is a characteristic in most studies and shows results ranging from highly significant (Sadeghifar et al., 2019) to the least significant(Lorenz & Kulcke, 2021), but it is still considered by many scholars regarding building facades. Prieto and Oldenhave (2021) stated that the importance of color is not just the coating of paint on the surface of the building, but its value is to create contrast with other visual elements. Thus, this view offers a deeper understanding of color and its role in the facade.

Although studies showed the influence of materials on the peoples' preferences (Obaleye et al., 2021; Sadeghifar et al., 2019), materials did not predict preferences in this study. It may initially be related to the fact that the respondents did not have a clear agreement between preferred materials (Ilbeigi & Ghomeishi, 2017); secondly, the attribute visualized in the images may not be consistently implemented.

4.2 Relationship between physical attributes of preferred building facades in different levels and perceived visual complexity

Following that, the relationship between physical attributes of preferred building facades in different levels and perceived visual complexity was investigated. Although some attributes were not significant in explaining preference, due to their importance in previous studies, they were also considered in this analysis. Findings showed that all physical attributes of preferred building facades (materials, contrast of materials, architectural style, ornament, curve, vegetation, windows orientations, and articulation) except for color and fenestration could be a predictor of perceived visual complexity.

The results of this study were in line with the results of previous studies that some physical attributes significantly affect the perceived visual complexity (Hussein, 2020; Peeters et al., 2021; Stamps III, 1999a). This outcome validates the second research hypothesis. Literature review emphasized to the perceived level of visual complexity in building facades has a significant effect on its preference (Lorenz & Kulcke, 2021; Wahdattalab et al., 2020; Zuliana et al., 2022). In other words, visual complexity indicates the richness of environmental information (Ma et al., 2021a, 2021b). However, how and what aspects of visual environments affect the perception of complexity is not entirely clear.

The attributes of articulation and ornament were the most influential in perceived visual complexity. This relationship means that the two variables remarkably affect the judgement of participants on the perceived visual complexity. Respectively, architectural style (classic style), articulation, and contrasting materials also affects perceived visual complexity. This finding offers new insight (DCE) to estimate the perceived visual complexity of building façades.

4.3 Comparing preference and perceived visual complexity of building façades

Traditional style did not predict Preference and perceived visual complexity. Furthermore, Color and windows to wall size did not predict Preference and Material did not perceived visual complexity.

In the comparison between the physical attributes affecting preferences and perceived visual complexity, all of physical attributes predicted both of them expect color and windows to wall size in predicting Preference and Material in perceived visual complexity. Traditional style did not predict Preference and perceived visual complexity. Result also showed that ornament and curves play a significant role in explaining them. agreement with other studies, which suggest over-simplified building facades as a monotonic pattern do not give us much preference and lead to boredom-indifference (Memari & Pazhouhanfar, 2017). It also agrees with some researches which supports that Kaplan's Information Processing Theory, the complexity of facade given the presentation of more information can increase preference by encouraging exploration and offering immediate engagement with the environment (Hussein, 2020; Wahdattalab et al., 2020).

The results show that the effect some of physical attributes on perceived visual complexity and preferences is dissimilar. For example, Vegetation has more important on preferences than complexity. This result is consistent with the Ma et al., (2021a, 2021b), which supports that vegetation usually has a dense and delicate texture, but generally does not require brainpower and visual attention to process. This outcome means that the use of this attribute can be appropriate for designers to increase the preferences of the facade while maintaining their complexity.

On the other hand, articulation and material have more important on perceived visual complexity. Thus, their excessive use can raise the risk of visual disturbance and lower the preference. This suggestion is consistent with the optimal range of perceptual receptions (level of arousal) as mentioned in previous studies, in which both seemingly simple and highly complex visual fields are often not preferred (Akbarishahabi, 2021; Berlyne, 1960). This helped designers to better understand the impact of each character on the building's preferences and discover mechanisms for evaluating the viewer.

This understanding fills a void in the literature and provides an important guideline to design building facades. It suggests that designers need to deal with the Perceived visual complexity of physical attributes and the relationships between them as relatively the as a most critical aspect of design. Designers can then move to handle the physical attributes and lastly control the preference of building facades.

This study proposes an objective application of DCE to evaluate the perceived visual complexity in building facades based on physical attributes in different levels. In other words, DCE aim at understanding and predicting choice behavior and provide quantitative measures of the relative importance of the physical attributes to evaluation perceived visual complexity and individuals' preference.

4.4 Limitations

The present study had limitations which should be addressed in the future. Firstly, this study focused on the role of ten physical attributes of building façade in different level on people's preferences and perceived visual complexity. However, questions remain about the role of the other physical attributes and extent and combination of specific elements in prediction of preferences and perceived visual complexity unknown. Secondly, although this study focused more on an individual evaluation of urban facade, the effects of demographic characteristics of participants such as age, gender, place of residence, education, and occupation were not examined on their responses. Thirdly, the perceived visual complexity based on discrete choice experiment is one aspect of the built environment assessment, where it needs to be connected to other advanced technology such as virtual reality, simulators and eye-tracking to further evaluate the quality of the built environment. Fourthly, this study has focused on the facades of residential buildings, future researches can include building facades with other functions such as shop, malls, commercial, and offices. Finally, there are also limitations related to the discrete selection method, which is associated with a limitation in the number of attributes. Because increasing the number of scenarios also increases the quality of respondents. But due to the time-consuming and increased time and cost, the number of alternatives in the selection set was considered to be the least number and in such a way that it gives the most reliable result.

5 Conclusion

This study proposes an objective application of DCE to evaluate the perceived visual complexity in building facades based on physical attributes in different levels. In other words, DCE aim at understanding and predicting choice behavior and provide quantitative measures of the relative importance of the physical attributes to evaluation perceived visual complexity and individuals' preference. Result showed that some of level of physical attributes of preferred building facades predicted perceived visual complexity. This research can help city planners, landscape architects and developers to better understand people's views about building facades and proposes an objective method to manipulating complexity. As a result, in this study reveal that used to identifying its positive points through the preferences of people toward building facades can be considered as constructive steps to create building facades which are aesthetically rich in visual values were attractive to citizens. Furthermore, the information may be useful for designing new facades or modifying existing facades in the cities where people live, work.

Declarations

Conflict of interest On all authors, the corresponding author states that there is no conflict of interest.

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