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Façade Compatibility Assessment Using Entropy Approach for Infill Buildings in Egypt

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ABSTRACT

The urban context of Egypt is rich in historical conservation areas and valuable listed buildings. However, they are always in a state of change due to new infill buildings.

These infill buildings -specifically their facades- affect the total urban character in a positive or negative way based on the nature of the new infill façade in the absence of clear and objective guidelines that may direct these new designs.

Design review committees are not enough to judge and evaluate the compatibility of new infill facades, because they depend only on professionals ignoring the original receptor of the urban character who is the normal person.

In this research, the collected layperson impressions are compared to professionals' views to test if there is a significant difference in judgement between the two groups.

Additionally, new building facades in a historical settlement in Egypt are investigated, using modern entropy approach and Minitab correlation statistical tools, to compare façade attributes to peoples' perceived compatibility of the building to its context. The façade attributes tested here are building scale, setting, solid /void structure, rhythm, colors and materials.

As a result, the study found a number of negative correlations between entropy in façade attributes and perceived compatibility. These attributes coefficients were valuated altogether to assess the relative weight of each attribute in the infill building façade and predict the people's satisfaction about it to an acceptable extent.

KEYWORDS: Urban Design, Infill facades, Façade design, Design control, Entropy approach, Façade compatibility.

تقييم التناسق البصري لواجهات المباني المستحدثة في السياق العمراني في مصر اعتمادا على مدخل الانتروبي

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الملخص

يذخر العمران المصري بالمناطق التاريخية والمباني المسجلة ذات القيمة التراثية والمعمارية المتميزة. ورغم ذلك، فإن هذا السياق العمراني يعاني من التغيير المستمر بسبب المباني المستحدثة و التي تسمى مباني الملء.

حيث تؤثر هذه المباني، وتحديداً واجهاتها، على الطابع العمراني بأكمله، تأثيرا إيجابيا أو سلبيا حسب تصميم هذه الواجهات الجديدة و التي لا تخضع لاشتراطات واضحة وموضوعية في معظم الأحيان.

وذلك لأن لجان الخبراء التي تقوم بمراجعة التصميمات، وتقيم مدى توافق واجهات الملء المستحدثة مع سياقها العمراني، تعتمد فقط على المختصين مثل المعماريين والمخططين العمرانيين، وتتجاهل المستعمل الأصلي للسياق العمراني وهم المارة العاديون من غير المختصين.

في هذا البحث، تتم مقارنة انطباعات الشخص العادي التي تم استبيانها، مع آراء المختصين لاختبار ما إذا كان هناك اختلاف ملحوظ بينهما.
بالإضافة إلى ذلك، يتم تقييم خصائص واجهات المباني المستحدثة في المناطق ذات القيمة التراثية في مصر، باستخدام نهج الانتروبي الحديث وحساب معامل الارتباط باستخدام برنامج ميني تاب، لمقارنة تأثير خصائص الواجهة على انطباعات الأشخاص عن مدى توافق المبنى الجديد مع سياقه. هذه الخصائص التي تم اختبارها هنا هي ارتفاع المبنى وردوده وتصميم ونسب الفتحات والإيقاع والألوان والخامات.
نتيجة لذلك، وجدت الدراسة عددًا من الارتباطات السلبية بين الانتروبي (الفوضى) في خصائص الواجهة وانطباعات الافراد عن توافق المبنى. كما أعادت الدراسة تقييم هذه العوامل مجتمعة لتقدير الوزن النسبي لكل عنصر من عناصر واجهة مبنى الملء وبالتالي التنبؤ بمدى رضا المستعملين عنها إلى حد ما.

الكلمات المفتاحية: التصميم العمراني، واجهات الملء، تصميم الواجهات، مبدأ الانتروبي، تناسق الواجهات.

INTRODUCTION

Infill building has always been a problem in design schools and design theories. It raises a lot of questions, like should the new building try to keep the built environment consistent or try to create a unique image? Should it try to copy the style of older buildings or reflect its own time? (Imam, 2013).

Therefore, the infill building compatibility to its context has been subject to a growing public satisfaction in the past few decades (Abu-Obeid et al., 2009). Accordingly, many countries began developing and applying new legislations that require solid assessment of environmental aesthetics.

For this reason, city councils all over the world are forced to consider urban development guidelines, regardless of size and culture. These guidelines can cover virtually all external features of buildings(Stamps III, 1997).

The present findings suggest that communities could opt for administrative design controls over discretionary design review. Administrative controls involve less cost and time, and, if the present results are accurate, they produce designs that are judged equal to or better than those obtained through discretionary review (Nasar & Grannis, 1999).

1 RESEARCH PROBLEM

In the Egyptian case, the guidelines ruling infill building facades are based only on values defined by professional urban designers rather than the final users of the new urban areas. This can cause some risks of bias, it can be too theoretical, and non-user functional. Because there is no proof that professionals will have the same impression on compatibility as normal laypersons.

The second problem is that there is no scientific objective way to evaluate architectural contextual fit in the current guidelines in Egypt, there should be a way to predict how much people will love the suggested infill design and consider it as compatible or not.

The study seeks to produce an accepted compatibility measurements that can be applied on any new infill façade and assess in a robust scientific way how much it fits in its context. The entropy approach (explained later) is a suggested way to measure the chaos in each façade attribute which, if proven, can be a promising approach for judging new façade compatibility and predict people's impressions.

2 LITERATURE REVIEW

A review of the literature was made to conclude the façade attributes that will be the predictors of contextual fit, it was decided to focus specifically on scale (Gjerde & Vale, 2015), setting (Alfirevic & Alfirevic, 2015), openings (Alkhresheh, 2012) , rhythm (Soosani, 2013) and finish (O'connor, 2006) of the infill facade. These attributes shown in (Figure 1) are also the main components of the architectural character of any building (Bashandy, 1984)

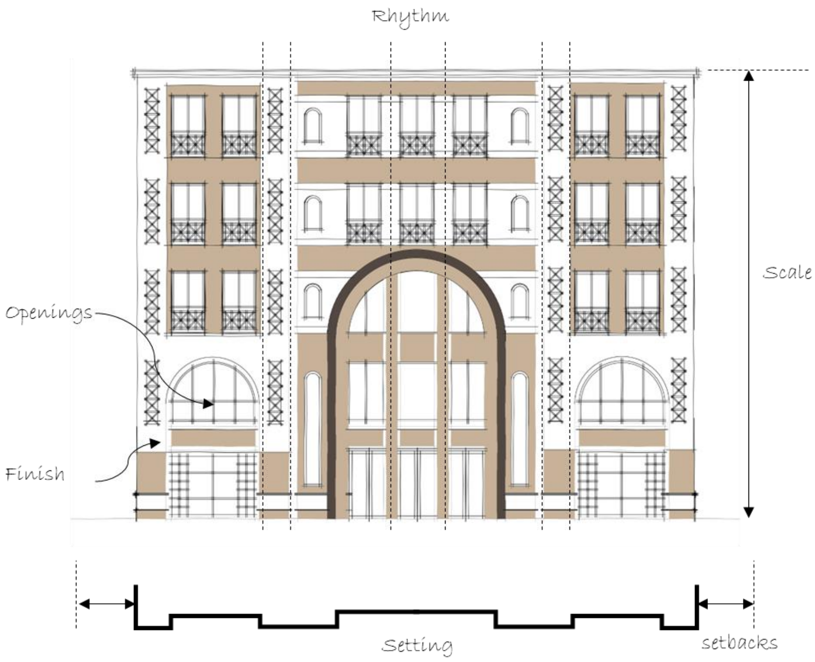


Figure 1. Façade attributes affecting contextual fit.
Source: (Authors)

2.1 Building Scale

The proportion of a building's size and mass to the other structures and the surrounding environment is referred to as its scale. The impact of a building that is too large or too small for its site cannot be compensated for by any other building attribute such as form, design or detailing see (Figure 2) (NSW Heritage Office, 2005).

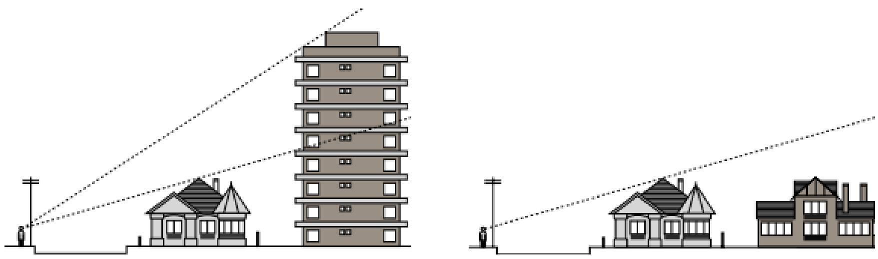


Figure 2. Ugly (left) sidewalls due to lack of scale regard.
Source: (NSW Heritage Office, 2005)

The configuration of rooftops within a neighborhood also has a significant role in shaping the overall character of the area. The design of infill structures ought to be in accordance with the prevailing ridge or parapet lines, roof slopes, and other architectural elements such as party walls and chimneys (NSW Heritage Office, 2005).

2.2 Building Setting

The compatibility of the newly constructed infill structure may be influenced by its proximity to established front and side setbacks (Figure 3) as well as its overall positioning within the site and the manner in which it harmonizes with the adjacent street margins. The use of detrimental re-subdivision or combination practices within conservation areas may potentially have adverse consequences for the homogeneity of the district. (NSW Heritage Office, 2005).

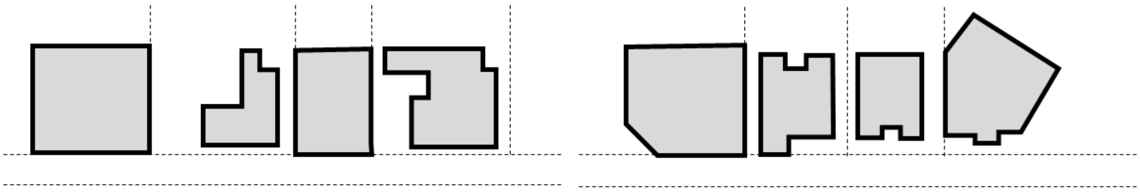


Figure 3. Examples for compatible/non-compatible building settings.
Source: (Authors)

2.3 Façade Opening's Structure (Solid & Void)

The void-to-solid ratio of a building façade may be described as the proportion of the façade area occupied by openings, such as windows, doors, and arches, related to the area of the solid wall. This attribute describes the fenestration-to-wall area ratio refers to the proportion of the total area occupied by fenestrations (such as windows or openings) in relation to the area of the surrounding wall. Certain academics have made reference to the void-to-solid ratio in relation to concepts like as transparency and opacity, lightness and heaviness, or openness and enclosure (Alkhresheh, 2012).

Traditional ratios and proportions of building elements -particularly on the façade- shall be maintained in new construction. In particular, ratios of solid wall space to openings should be compatible with existing patterns; window and door openings should likewise be compatible with existing patterns in placement, scale, and proportions (Figure 4). New construction with elements that fall outside of the acceptable range of precedents affect the overall aesthetic and continuity of the streetscape and are not appropriate. (Planning and building codes department Frankfort, 2015)

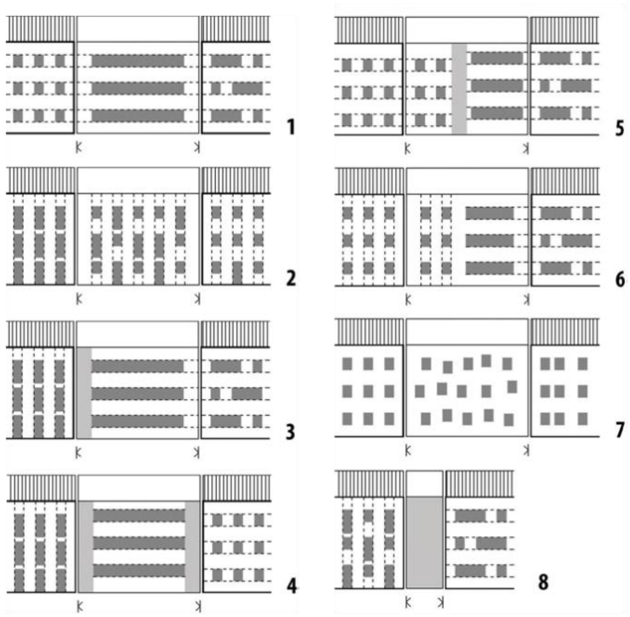


Figure 4. Examples of Solid/Void solutions in the infill façade.
Source: (Alfirevic & Alfirevic, 2015)

2.4 Vertical / Horizontal Rhythm

The concept of rhythm encompasses the architectural components included in a building's facade, which may be subdivided into several intervals. To clarify, the repetition often pertains to the arrangement and dimensions of the architectural elements comprising the outside surface of the building. The ratio between the wall and window areas, as well as the deliberate attention given to the arrangement of windows, have significant importance in establishing rhythm within a building's façade. Additional significances of rhythm in architecture include the accentuation of fenestration through the use of vertical and horizontal features, as well as the manifestation of the building's structural composition within its façade. (Soosani, 2013).

2.5 Façade Colors and Materials

The infill facades usually use the same or similar material used in neighboring constructions and this establishes general artistic unity of the facades. However, if the new object has to be representative or emphasized or an example of author's expression, a significantly different material other than the one domineering the surrounding facades is used, thus visually separating the infill object from the existing objects and dematerializing the boundaries of their physical contact.

In several nations, planning guidelines and development control plans exhibit a tendency towards a high level of prescription, particularly in relation to the recommended color schemes for building facades. These recommendations commonly advocate for the harmonization, compatibility, or sympathetic integration of façade colors with the surrounding environment.

Typically, this does not impose limitations as the research indicates that the spectrum of facade colors deemed harmonious was more extensive than initially anticipated (O'connor, 2006).

As a conclusion, it was found from the literature review that the building scale, setting, openings structure, vertical/horizontal rhythm, colors and materials are the most significant façade attributes that may have an impact on peoples perceived compatibility of new infill building in historical context, thus they should be investigated and tested in the following section using entropy approach.

2.6 Façade Compatibility Assessment Using Entropy Approach

Previous research suggested conducting scientific experiments on public preferences before the regulations are implemented. In this regard, (Stamps III, 2000) has done a large number of practical studies and tests to try to investigate the applicability of the entropy-based theory on environmental aesthetics.

Entropy was originally created as a measure of physical disorder, but it was reinvented in 1948 as a measure of disorder in information. The basic equation for entropy is:

$$H_{\text{factor}} = \sum_{i=1}^{n} \text{pi} \log_2(1/\ \text{pi})$$

Equation 1. Entropy calculation equation.
Source: (Shannon, 1948)

In the basic (Equation 1) H is the entropy, p is the probability of occurrence of a level of a factor, n is the number of factors, "i" is an iteration factor, and the summation is over the levels of the factors.(Stamps III, 2004)

In his research, Stamps found that the subjective impressions of diversity can be measured objectively by calculating the statistical entropies of physical design features of a facade. He also found that the relationship between pleasure and entropy is quite different for different kinds of features. He recommended to refrain from enforcing laws based on the criterion of visual diversity until more is known about the underlying relationship (Stamps III 2004).

For instance, a collection of buildings will have no diversity and zero entropy if they are all the same. This would be the condition of total homogeneity. On the contrary, the streetscape entropy will be maximum if all façade elements are different from the context. If these entropy measures are compared to subjective impressions of people and found relative, then entropy could be a strong candidate as a measure of subjective impressions of compatibility.

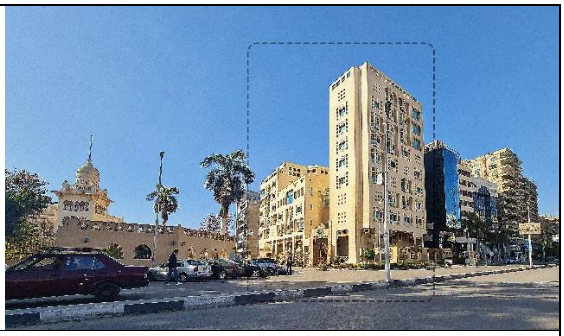
3 RESEARCH METHODS

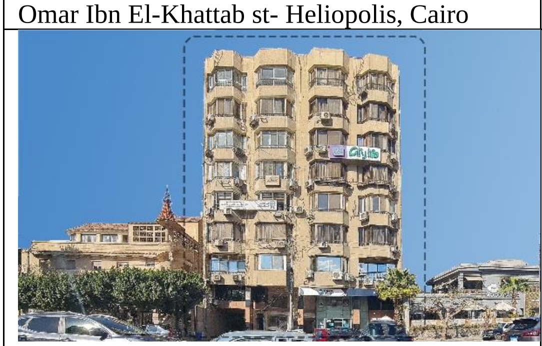
The study strategy is to use visual photographs of existing buildings as stimuli. Each stimulus shows a colored photograph of a suburban block with an infill façade within. The study used 18 different stimuli, 12 from Egyptian conservation areas and 6 from international examples. The stimuli photos are presented to each one of the respondents independently in an online questionnaire. The respondent is asked to rate each photo on how compatible the infill is to its surrounding.

The 12 stimuli from the Egyptian context were selected to reflect different levels of entropy in scale, setting, facade openings, color, rhythm, finish and uses, see Table 1. Moreover, 6 stimuli photos were added from international context that have extreme levels of mimicry (examples 13,15 and 17), as well as extreme levels of contrast (examples 14,16 and 18) see Table 2.

Calculation of entropy requires that the façade elements are expressed in terms of the number of occurrences of levels of factors. For example, the letter string “AAAAA” means there are five buildings sharing the same style and shape, so the equivalent entropy in bits equals 0.00. While a set of buildings of different styles are parsed “ABCAA” if there are 3 buildings of the type A, one building of type B and one building of type C, and will have an entropy of 1.37.

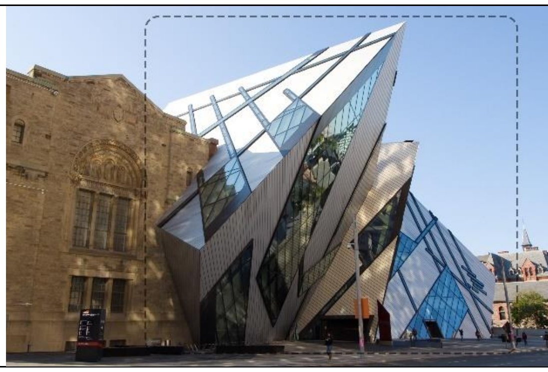
Table 1. Photos of selected stimuli used in the questionnaire from Egyptian context

	
Stimulus 1 Othman Ibn Affan st- Heliopolis, Cairo	Stimulus 2 Al Maahad Al Eshtraki st- Heliopolis, Cairo
	
Stimulus 3 Omar Ibn El-Khattab st- Heliopolis, Cairo	Stimulus 4 Othman Ibn Affan st- Heliopolis, Cairo
	
Stimulus 5 El-Nozha st- Heliopolis, Cairo	Stimulus 6 Fareed Semeika st- Heliopolis, Cairo

	
Stimulus 7 Othman Ibn Affan st- Heliopolis, Cairo	Stimulus 8 Omar Ibn El-Khattab st- Heliopolis, Cairo
	
Stimulus 9 Omar Ibn El-Khattab st- Heliopolis, Cairo	Stimulus 10 El Thawra st - Heliopolis, Cairo
	
Stimulus 11 El Thawra st - Heliopolis, Cairo	Stimulus 12 Al Ahram st - Heliopolis, Cairo

Source: (Authors)

Table 2. Photos of selected stimuli used in the questionnaire from international context.

	
Stimulus 13 Murcia City Hall – Murcia,Spain **Source:**(Moran, n.d.)	Stimulus 14 Royal Ontario Museum –Toronto– Ontario, Canada **Source:**(Elliot Lewis, n.d.)
	
Stimulus 15 Bloomberg Head Quarters – London, UK **Source:**(Prisco, 2018)	Stimulus 16 The extension of Musée d'arts de Nantes, France **Source:** (Hufton+Crow, 2017)
	
Stimulus 17 Selfridges new entrance building – London, UK **Source:**(Menges, 2018)	Stimulus 18 Hotel Topazz – Vienna, Austria **Source:**(Lenikus GmbH, 2012)

Source: Mentioned below each photo

The entropy values of each component in the stimuli were calculated using an online entropy calculator (Planet Calc, 2021).The calculator uses the same entropy equation mentioned earlier.

This online calculator computes Shannon entropy for a given message. In which, entropy is calculated from: $H=[x\log_2(1/x)+y\log_2(1/y)+ z\log_2(1/z)+\ldots]$, where x,y,z are the different possibilities of the attribute (Shannon, 1948)

That resulted in creating lists of entropy values for building features in each of the selected stimuli as shown in Table 3, Table 4 and Table 5. The calculated values were rounded to two decimal places for purposes of practicality and precision.

Table 3. Calculated entropy values for scale of buildings in each stimulus.

Stimulus no.	Scale					
	Ground floor height	Total height	Floor heights	No. of floors	Building roofline	Total scale entropy
S1	1.37	1.37	2.32	1.92	2.32	9.30
S2	1.58	2.58	1.58	2.58	1.92	10.24
S3	0.81	0.81	0.81	0.81	0.81	4.05
S4	0.92	0.81	1.5	0.81	1.5	5.54
S5	1.52	1.92	1.37	1.92	1.92	8.65
S6	0	1.92	0	1.92	1.79	5.63
S7	1.58	0	0.92	0.92	1.58	5.00
S8	0	1.58	0.92	1.58	1.58	5.66
S9	0	0.92	0	0.92	0.92	2.76
S10	1.58	1.58	1.58	1.58	1.58	7.90
S11	1.58	1.58	0.92	1.58	1.58	7.24
S12	2	2	2	2	2	10.00
S13	1.58	0	0.92	1.58	0.92	5.00
S14	1.58	1.58	1.58	1.58	1.58	7.90
S15	0	0.92	0.92	0.92	0	2.76
S16	0	1.92	1.58	1.58	1.58	6.66
S17	0	0.92	0.92	1.58	1.58	5.00
S18	2	2	2	2	2	10.00

Source: (Authors)

Table 4. Calculated entropy values for setting, solid & void of buildings in each stimulus.

Stimulus no.	Setting				Solid & void		
	Side setbacks	Front setback	Ground floor extrusions	Total setting entropy	Openings percentage	Openings shape	Total solid & void entropy
S1	1	0	0	1.00	0.81	2.51	3.32
S2	1.58	1.58	1.58	4.74	0.92	2.02	2.94
S3	0.81	0.81	0.81	2.43	0.92	1.95	2.87
S4	0.81	0.81	1.5	3.12	1.5	1.81	3.31
S5	0.72	1.92	1.37	4.01	1.92	2.78	4.70
S6	0	1.52	1.92	3.44	0.72	2.14	2.86
S7	1.58	1.58	0.92	4.08	1.58	2.71	4.29

Stimulus no.	Setting				Solid & void		
	Side setbacks	Front setback	Ground floor extrusions	Total setting entropy	Openings percentage	Openings shape	Total solid & void entropy
S8	0.92	0.81	0.92	2.65	0.92	2.03	2.95
S9	0	0	0.92	0.92	0	1.38	1.38
S10	1.58	1.58	1.58	4.74	0.92	2.94	3.86
S11	1.58	1.58	1.58	4.74	0.92	1.42	2.34
S12	2	2	2	6.00	2	1.67	3.67
S13	0	0.92	1.58	2.50	0.92	2.26	3.18
S14	1.58	1.58	1.58	4.74	1	1.41	2.41
S15	0	0	1.58	1.58	0.92	2.13	3.05
S16	0	0	0.92	0.92	0.92	1.53	2.45
S17	0	0	0	0.00	0.92	0	0.92
S18	0	0	0	0.00	1.58	1.44	3.02

Source: (Authors)

Table 5. Calculated entropy values for rhythm and finish of buildings in each stimulus.

Stimulus no.	Rhythm			Finish			
	Vertical rhythm	Horizontal rhythm	Total rhythm entropy	Color	Material	Ornaments	Total finish entropy
S1	0.81	0.81	1.62	2.73	1.79	0.81	5.33
S2	1.58	1.58	3.16	1.52	0.81	1.5	3.83
S3	0.92	0.92	1.84	0	0	0.92	0.92
S4	2	1	3.00	0.81	0	1	1.81
S5	2.58	1.52	4.10	2	1.25	1.25	4.50
S6	1.92	0	1.92	0	0	1.92	1.92
S7	1.58	1.58	3.16	2.25	1.46	1.5	5.21
S8	1.5	1.5	3.00	0	0	2	2.00
S9	0	0	0.00	1.5	0	0	1.50
S10	0.92	1.58	2.50	1.58	1.58	1.58	4.74
S11	1.58	1.58	3.16	0.92	0	1.58	2.50
S12	2.58	2.58	5.16	2	1.92	1.5	5.42
S13	1.58	1.58	3.16	1.5	0.92	1.58	4.00
S14	1.58	1.58	3.16	1	1	1.58	3.58
S15	0	0	0.00	1.5	0.81	1.58	3.89
S16	0.92	0.92	1.84	0	1.5	0.92	2.42
S17	0	0	0.00	1.46	1.46	0.92	3.84
S18	1.58	1.58	3.16	1.5	1.5	1.58	4.58

Source: (Authors)

Entropy values in tables 3,4 and 5 show that the selected stimuli cover a wide range of entropies in all attributes of infill facades, the stimuli S9 and S17 are the extreme examples of imitation to adjacent context, where entropy values are the least.

While stimuli S14 and S18 are the ones with extreme contrast to the context and highest values of entropy. The rest of stimuli have intermediate and variable values in all aspects of entropy in the façade attribute.

Entropy values are used as an objective measurement of visual chaos, that the research will compare with peoples' subjective responses on compatibility of the building to its context. If significant correlations are found between entropy values and peoples' subjective responses, then entropy can be used to measure compatibility of new buildings.

Respondents were asked to specify their level of agreement to a statement that the building is compatible with its context following a five points Likert scale, in which the five points are: (1) Strongly non-compatible; (2) non-compatible; (3) Average; (4) Compatible; (5) Strongly compatible.

The responds will be used statistically to find if there is a correlation between how compatible the building is and the entropy values of the features of each photo. Answers should also show if there is a significant difference between normal layperson and professionals' perspective to such matter. Additionally, a combined correlation analysis will be used to determine the most significant factors that should be taken into consideration when judging infill facades.

The online questionnaire was sent digitally to clustered random respondents that were majorly divided into two groups; professionals' group (112 responder including urban planners, architects and fine artists), and non-professionals' group including 112 respondents. All of them rated each of the 18 blocks for compatibility. The 224 responses are enough to gain 95% confidence level according to sample calculation formula known as Andrew Fisher's Formula, with confidence interval of 6.52.

After data gathering, Microsoft Excel software was used to run a t-test to compare the two response groups and see if there is a significant difference between them. A linear regression analysis was done on Minitab software to investigate the correlation between entropy factors and peoples' judgement on compatibility and find out the relative weights of each predictor related to the others.

4 RESULTS

4.1 Differences Between Laypersons and Professionals

The research first question to investigate is whether there is a significant difference between laypersons and professionals regarding their judgement on the different stimuli. The t-test showed that there were significant differences between the two groups in eight stimuli out of 18 (Table 6 and Table 7).

Table 6. Responses comparison between laypersons and professionals showing significant differences.

	Stimulus	S1	S7	S9	S12	S13	S15	S17	S18
Laypersons	Mean	2.53	3.65	3.52	2.31	2.88	3.49	3.95	2.03
	Std. Dev.	1.15	0.90	0.92	1.02	1.06	1.07	0.94	1.02
	Median	2.00	4.00	4.00	2.00	3.00	4.00	4.00	2.00

	Mode	2.00	4.00	4.00	2.00	2.00	4.00	4.00	2.00
Professionals	Mean	2.12	3.24	3.10	1.96	2.46	3.10	3.69	1.69
	Std. Dev.	1.05	0.98	1.03	0.96	1.02	1.16	1.04	0.91
	Median	2.00	3.00	3.00	2.00	2.00	3.00	4.00	1.00
	Mode	1.00	3.00	3.00	1.00	2.00	3.00	4.00	1.00
t- test p-value		0.01	0.00	0.00	0.01	0.00	0.01	0.05	0.01

Source: (Authors)

Table 7. Responses comparison between laypersons and professionals showing non-significant differences. Source: (Authors)

	Stimulus	S2	S3	S4	S5	S6	S8	S10	S11	S14	S16
Laypersons	Mean	3.37	3.12	2.52	2.41	3.09	2.88	3.76	2.46	1.71	2.02
	Std. Dev.	0.99	1.13	1.11	1.07	1.14	1.11	0.97	1.09	1.09	1.00
	Median	4.00	3.00	2.00	2.00	3.00	3.00	4.00	2.00	1.00	2.00
	Mode	4.00	4.00	2.00	2.00	4.00	3.00	4.00	2.00	1.00	2.00
Professionals	Mean	3.33	2.86	2.46	2.22	2.91	2.81	3.56	2.21	1.85	2.04
	Std. Dev.	0.93	1.05	1.15	0.94	0.97	1.02	1.01	1.03	1.11	1.02
	Median	3.00	3.00	2.00	2.00	3.00	3.00	4.00	2.00	1.00	2.00
	Mode	3.00	3.00	2.00	2.00	3.00	3.00	4.00	2.00	1.00	1.00
t- test p-value		0.78	0.08	0.67	0.17	0.22	0.60	0.12	0.09	0.34	0.88

Source: (Authors)

As shown in the following bar chart (Figure 5), the responses differ significantly in 8 out of the 18 stimuli, so that it is statistically approved that layperson response to asses compatibility of new buildings in historical context will differ in around 45% of cases from the response of professionals.

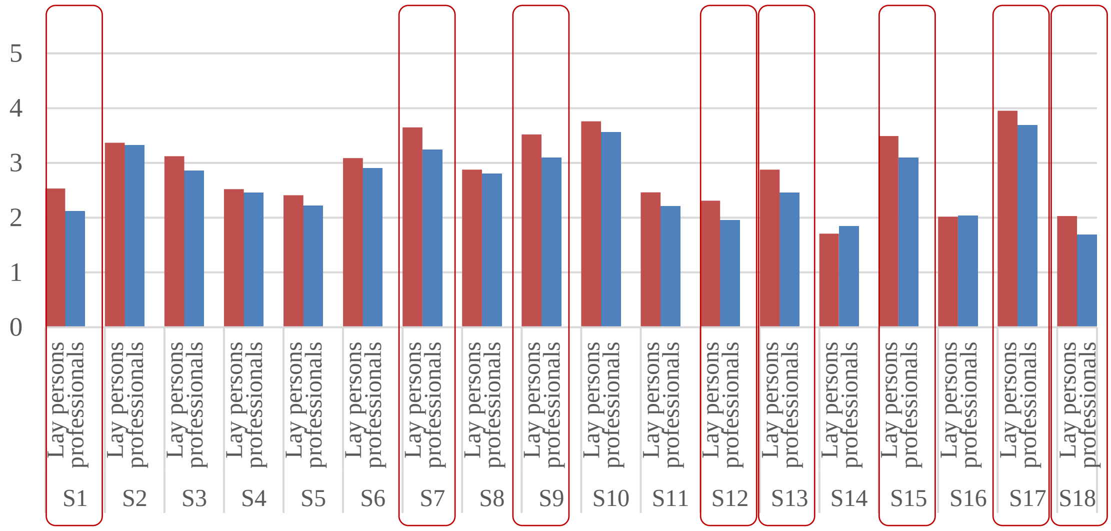


Figure 5. Bar chart comparing between two group of responses on the questionnaire. Source: (Authors)

4.2 Scale / Setting Correlation With Compatibility

Responses were checked for correlation between each factor in the façade entropy and people's impression on its contextuality, in order to determine which factors have the largest impact on contextualism of infill facades.

The calculated entropy values were tested for correlation with questionnaire responses measuring people's subjective impressions against how compatible is the new building with its context.

Table 8. Correlation between scale/ setting and compatibility.

Correlation with Response	Scale					Setting		
	Ground floor height	Total height	Floor heights	No. of floors	Building roofline	Side setbacks	Front setback	Ground floor extrusions
r	-0.199	-0.174	-0.263	-0.134	-0.187	-0.046	-0.033	-0.014
p-value	0.000	0.000	0.000	0.000	0.000	0.004	0.037	0.364

Source: (Authors)

From Table 8 we could conclude that all scale factors have significant negative correlation to responses, which means that the more the entropy in scale, the less people will identify the building as compatible with its context. It was also found that entropy in setting, doesn't have significant impact on people's reactions on compatibility.

That doesn't mean -necessarily- that the building setting has nothing to do with compatibility, but rather means that the setting factors have less significance compared to other factors when it comes to people's reaction on compatibility.

4.3 Solid/Void and rhythm correlation with compatibility

From the correlation analysis, it was found that entropy in openings percentage only has a negative significant impact on how people judge new building compatibility.

Table 9. Correlation between solid/void, Rhythm and compatibility.

Correlation with Response	Solid & void		Rhythm	
	Openings percentage	Openings shape	Vertical rhythm	Horizontal rhythm
r	-0.20	-0.021	-0.267	-0.269
p-value	0.000	0.190	0.000	0.190

Source: (Authors)

Results in Table 9 suggest that openings shape is not a significant factor when it comes to judging new buildings compatibility.

Regarding rhythm, it was found that entropy in vertical and horizontal rhythm have almost the same negative significant impact on how people judge compatibility, and the impact is relatively large.

4.4 Finish Correlation with Compatibility

It was found that none of the finish factors had significant impact on people's judgment on compatibility of new buildings within the context (Table 10).

Table 10. Correlation between finish and compatibility.

Correlation with Response	Finish		
	Color	Material	Ornaments
r	0.035	-0.077	-0.053
p-value	0.028	0.000	0.001

Source: (Authors)

4.5 Combined Effect of Significant Factors on Compatibility

It was of a great importance to investigate the effect of all these factors together on the compatibility of the new building with its context. That's why, a non-linear regression analysis was performed on Minitab software to find out the relative weights of each predictor related to the others as per Equation 2 :

Response = **A**(constant) - **B** *(ground floor height entropy) - **C** *(total height entropy) - **D***(floor heights entropy) - **E** *(no of floors entropy) - **F*** (building roofline entropy) - **G***(openings percentage entropy) - **H** *(vertical rhythm entropy) - **I***(horizontal rhythm entropy)

Equation 2. Response equation used to calculate relative weights of façade entropy factors.
Source: (Authors)

The following list of values were obtained from the Non-linear regression analysis:

Table 11. Relative weights of entropy factors affecting compatibility.

Factor	Estimated value	Estimated Standard Error	Relative weight
A (constant)	3.12852	0.0742565	
B (ground floor height entropy)	-0.04791	0.0454764	1%
C (Total height entropy)	0.15551	0.0444336	5%
D (Floor heights entropy)	0.83164	0.0543105	25%
E (No. of floors entropy)	-0.38986	0.0696887	12%
F (Building roofline entropy)	-0.21937	0.0555985	7%
G (Openings percentage entropy)	-0.65299	0.0714219	20%
H (Vertical rhythm entropy)	0.80682	0.0528459	24%
I (Horizontal rhythm entropy)	-0.18921	0.0524514	6%
Total absolute entropy	٣,٢٩٣٣١		100%

Source: (Authors)

Table 11 shows the relative weight of each element of entropy that proved correlation with compatibility. Floor heights entropy has the highest impact (2٥% of the total effect), followed by vertical rhythm (2٤%), then the openings percentage representing (20%). The entropy in the number of floors is responsible for 12% of the impact on compatibility. These are the highest 4 elements of entropy that showed great impact on entropy.

The remaining four factors showed minor impact on compatibility which are; building roofline entropy (7%), horizontal rhythm entropy (6%), total height entropy (5%) and ground floor height entropy had almost no effect when combined with the other entropies.

5 DISCUSSION

The study results show that laypersons impressions differ significantly in 8 out of the 18 stimuli, those 8 stimuli included 3 out of the 4 extreme examples of mimicry or contrast (S9, S17 and S18). This finding supports the point of view that guidelines or panel review committees ruled only be professionals, can be too theoretical, and non-user functional.

The entropy correlation study found a negative correlation between most of the entropy factors and people’s perception, which advocates previous studies of (Stamps III, 2004), (Nasar, 1994), (Stamps III and Nasar 2009) that was implemented in USA, and studies of (Mısırlısoy, 2017) in Turkey.

Lastly, the research analyzed in a combined way all the previously proven factors affecting compatibility of infill facades to their context, by correlating the entropy of façade factors to people’s perception of compatibility. Studying all the factors together using modern statistical tools instead of studying one factor at a time could enable us to figure out the relative weight of each factor of entropy that affects building compatibility from the eye of professionals and normal laypersons.

The highest elements of entropy that proved correlation with compatibility are floor heights entropy, vertical rhythm, followed openings percentage then the number of floors. Other factors showed minor impact on compatibility such as; building roofline entropy, horizontal rhythm entropy and total height entropy.

6 CONCLUSION

This study aimed at investigation the applicability of information entropy approach as a measurement of visual chaos to assess the compatibility of new infill buildings facades in Egypt.

This research used the entropy approach to test the effect of all the combination of façade attributes which may contribute to its compatibility, the research used also real-world photos as stimuli instead of illustrations used in previous research.

The results proved in a quantitative scientific way that:

- The entropy of the building façade attributes could be used as a tool of assessment that is less driven by personal impressions.
- The scale of the new building (i.e. floor heights, number of floors and building total height) is the most significant attribute that affect people’s impression of compatibility and then should be highly considered in regulations governing new infill buildings.
- The vertical rhythm and opening percentage are the second most effective attributes that matches the new building with its context.
- The attributes of façade color and material were not of significant importance while they are the most common in Egyptian codes and regulations governing historical contexts.

This should be a good step if used in local municipalities when judging new suggested facades, resulting in higher satisfaction of viewers, and a fair, well-organized approach for façade design reviewing system.

This research may also help in generating digital or manual tools that can judge compatibility of the infill building façade to its context without the need to question people every time.

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