Social Preference of Building Materials: Decision-Making towards Low Carbon Housing Constructions

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Rodrigo Alba
University of Liechtenstein

Sebastian Bobadilla-Suarez
University College London

Social Preference of Building Materials:

Decision-Making towards Low Carbon Housing Constructions

RODRIGO ALBA KRASOVSKY[1], SEBASTIAN BOBADILLA SUAREZ[2], DIETRICH SCHWARZ[1]

[1]Institute of Architecture and Planning, Universität Liechtenstein, Vaduz, Liechtenstein
[2]Department of Experimental Psychology, University College London, London, UK

ABSTRACT: Material considerations are essential while trying to achieve low energy and carbon constructions. According to our preliminary findings, decisions regarding materials in new buildings are mostly done by clients or by self-builders often without the aid of an architect or planner. Therefore, community studies are important to understand today's building dynamics. In this exploratory study - carried out in USA and Mexico - we analysed the public's preferences for building materials for the exterior of dwellings and the factors that have more influence over their decisions while choosing the materials. We also studied the update in the subjects' preference after receiving certain information concerning the materials. We wanted to know if the environmental factors play an important role in today's public preference in the building sector and what type of information could greater affect their beliefs. Preliminary results for Mexico and after a follow up analysis for USA show that acknowledging unfamiliar information (e.g. carbon emissions or price) might have a greater influence on the public's update of preference of materials. This could have implications for the construction market dynamics in the usage promotion of low carbon building materials.

KEYWORDS: Building materials, decision-making, low carbon, social cognition

1. INTRODUCTION

To achieve a low energy and carbon construction, there are several considerations to take into account. One, which has an important influence on the total energy consumption and carbon emissions during the building's lifecycle, is the use of building techniques suited to locally resourced materials [1-2]. Research regarding this topic is usually carried out from an objective perspective underlining the benefits of using low energy and low carbon materials, but studies on consumers and users' cognition are generally not considered [3].

As architects and planners, we are usually confronted during the building design process with the actual needs and preferences of the potential users and clients. Therefore, we should consider the social preference of such techniques and materials, and the reasons behind it. A number of studies have addressed the issue by analysing cases where the architects or designers have primary decision-making authority for material selection [4]. Nevertheless, there is a great proportion of constructions worldwide that are done by self-builders or only with the aid of contractors, and therefore the user or developer mainly takes the decisions. In developing countries like Mexico, this phenomenon grows proportionally with the informal settlements; while in countries with developed economies like the USA, self-builders emerge looking for alternatives to the mainstream market [5-6].

Decisions about characteristics of materials such as: physical properties, costs, cultural context and appearance among others are regularly present during the design process while choosing the materials to be used [4]. However, other environmental factors should be considered; specifically those related to building materials' life cycle, such as embodied energy and carbon emissions.

In this study, we carried out online questionnaires based on the hypothetical case of building a new housing construction. We assessed real behaviour through a speculative scenario, a common methodology in decision research [7]. We aimed to answer mainly two questions: (1) Which factors most influence the decision-making process of people while choosing building materials? (2) How do people update their preferences after acknowledging facts about the chosen materials?

2. THE STUDY

100 participants living in the United States of America (USA) and 100 living in Mexico partook in the study. The participants were recruited through the crowdsourcing online platform Clickworker (www.clickworker.com). Internet-based studies have demonstrated to be as accurate as laboratory experiments in behavioural research, plus it allows access to a large volume of subjects [8]. Our sample is limited to the users of this platform, which are mainly economically active adults. We decided not to exclude any participant based on previous knowledge, location or other demographic factors since these variables could not correlate with the randomized conditions by design (see below). The survey took approximately 5 minutes to complete and we set the minimum time threshold for valid results in 2 minutes (participants who completed the study in less than 2

minutes were excluded from analyses). The study was carried out between the 25th of January and the 28th of February 2018. EUR 0.30 were paid to each participant after completion.

After a series of demographic questions, participants were asked to give information about their type and condition of dwelling and if they would rely on an architect, a contractor, family or just on their own while building a new house or building. For the next phase, preferences regarding different materials that are commonly used on the building's substructure and in the shell as exterior and interior finishes were elicited. Regardless of the configuration, a building's embodied impact concentrates on the materials of the substructure and the cladding of the shell [9]. Depending on the country, ratings for the most commonly used materials according to their census were elicited, respectively. Participants were asked to rank these materials in order of preference for the exterior of their dwelling. They were also asked to rank the four factors that affect their choice of material the most; these factors were physical properties, costs, cultural context, appearance, and environmental factors. The study then included an experimental section. After indicating their choice, the participants were randomly assigned to one of four groups. A standard construction of one square foot/meter of the shell of a building was compared based on four factors: typical durability (physical property), price (costs), trend (cultural context) and embodied carbon emissions (environmental factors). The four factors can be seen in fig. 1-4. The information showed to the participants in Mexico, changed for trend and price based on data collected specifically for that country. After receiving the information, the participants were finally asked once again to rank the materials according to preference to measure their update in preferences after seeing the information provided to them in each condition.

Our objective was to determine which of the facts would have a greater effect on the participants' update of material preference. Based on a previous study (see [10]), we entered the results into an analysis of variance (ANOVA) with fact type as a between-subjects factor with four levels (trend, durability, price, and carbon emissions) with participants' update as the dependent measure. Update was defined as: 1-(Pearson correlation of the first rating with the second rating). We also included as a covariate the nuisance variable of estimation errors, which is necessary for the effect of updates being greater for the sole reason of being farther away from the presented fact.

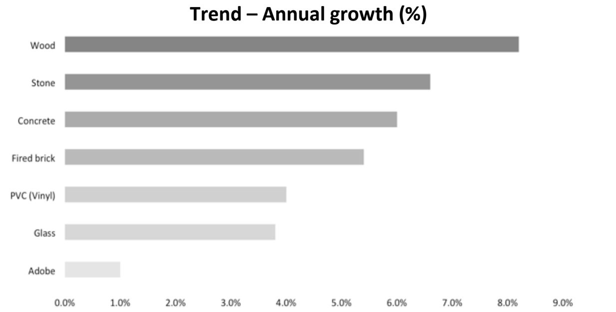

Figure 1: Trend – Annual growth of material sales within the building sector, which can be an indicator of a current popular trend. Graph made by authors with information taken from GrowthBuilder [11].

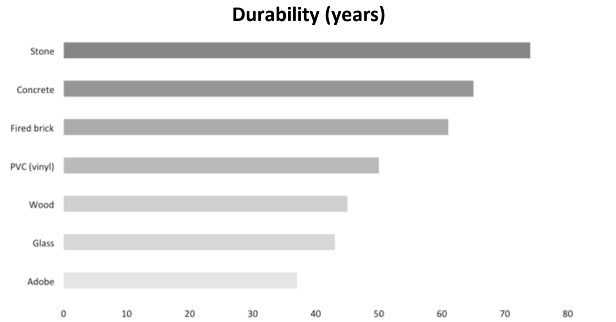

Figure 2: Durability, which can be an indicator of a desired physical property. *Graph made by authors with information taken from eTool [12].*

Figure 3: price per square foot. Graph made by authors with information taken from RS Means [13].

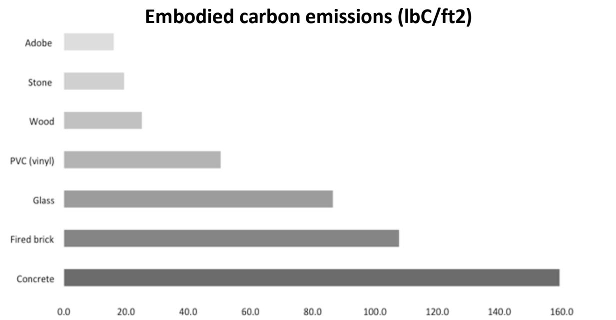

Figure 4: Embodied Carbon emissions per material per square foot, which can be an indicator of an environmental factor. *Graph made by authors with information taken from the Inventory of Carbon and Energy [14].*

The estimation errors were defined as: 1-(Pearson correlation of first estimate with the presented fact in each condition). We also analysed how the influencing factors are related to other covariates such as gender, age, and income level with a follow up analysis based on multiple linear regression.

The reason for choosing two different countries for the study is to understand the differentiation of building dynamics and update of preferences depending on the culture and to analyse if the study can be replicated by adapting the variables to a specific context. The statistical classification and the information showed to the participants were based on data collected per country and therefore the surveys slightly differed from one another. Thus, even though the methodology is the same, the context and the results will be presented separately. Further on, both countries will be compared to evaluate results of the dependent variable.

2.1 Study in Mexico

2.1.1 Context

According to INEGI (Mexico's census authority), detached single-family houses accounted for 92.2% of the total housing constructions, followed by apartment units with 5.2% and units in a *vecindad* with 2%. The materials that are used the most in new constructions are: 1.concrete 2.burned brick 3.stone 4.adobe 5.wood 6.bamboo or straw [15]. Even though glass is not included in the census as a building material, it has earned popularity as a main façade element, causing an important repercussion in the building's costs, durability and carbon emissions and it was therefore considered for the surveys.

In Mexico, 65% of the total housing constructions are done by the residents themselves. From that number, around 50% is self-construction and the other 50% is done with external aid and the other 35% of the total is usually built by developers [16]. This reflects the great social division that exists in the country, but it also shows that the decision-making process in the construction sector in the country falls on a greater proportion on the residents of the houses.

2.1.2 Participants

The specific characteristics of the participants living in Mexico were as follows: gender: 68 males and 32 females; age: 54 were 18-29 years old, 42 were 30-49 years old, and 4 were 50-64 years old; occupation: 20 were employed in education or health, 32 in technical or professional services, 3 in farming, fishing or forestry, 7 in sales or tourism, 11 in construction or maintenance, 3 in production or transportation, 4 in the government, 2 worked as freelancers, 23 were students and 4 were unemployed; household monthly income: 4 earned less than MXN 2K, 4 earned MXN 2K-3.9K, 6 earned MXN 4K-5.9K, 22 earned MXN 6K-9.9K, 28 earned MXN 10K-$19.9K, 26 earned MXN 20K-$49.9K and 9 earned more than MXN 50K; type of home: 69 were living in a single family-house detached, 19 were living in an apartment in a multi-storey building, 7 were living in a multiplex house (row house, duplex, triplex, etc.) and 4 were living in a *vecindad*. The average household size reported by the participants was 3.37 persons per unit.

2.1.3 Material preference

When hypothesizing about building a new house or building, 63 participants reported that decisions regarding building materials would solely be taken by their own or a family member, 19 would also include an architect or a contractor in the decision-making process and only 18 would leave the decision exclusively to the architect or contractor.

When ranking the materials of preference that they would use the most on the shell of their dwelling, these were: 1.Concrete ($\bar{x}$ 2.31, s = 1.79) 2.Fired brick ($\bar{x}$ 2.9, s = 1.79) 3.Stone ($\bar{x}$ 3.26, s = 1.4) 4.Wood ($\bar{x}$ 3.83, s = 1.38) 5.Adobe ($\bar{x}$ 4.49, s = 1.75) 6.Glass ($\bar{x}$ 5.13, s = 1.67) 7.Bamboo/Straw ($\bar{x}$ 5.82, s = 1.55). When ranking the factors that affected their decision the most, these were: 1.Physical properties ($\bar{x}$ 1.91, s = 1.15) 2.Costs ($\bar{x}$ 2.61, s = 1.28) 3.Appearance ($\bar{x}$ 2.64, s = 1.25) 4.Environmental factors ($\bar{x}$ 3.57, s = 1.08) 5.Cultural Context ($\bar{x}$ 4.14, s = 1.13).

2.1.4 Update in preference

We conducted a one-way ANOVA (see Fig. 5). For this model, the between-subjects factor of fact type was significant (F(3, 95) = 5.108, p = 0.003, partial eta squared = 0.139) and so was the estimation error nuisance variable (F(1, 95) = 8.132, p = 0.005, partial eta squared = 0.079).

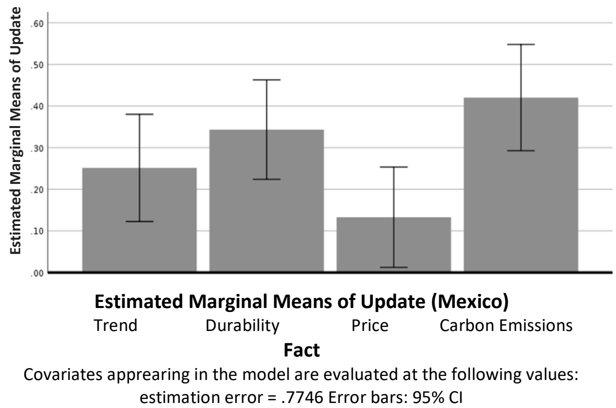

Figure 5: The estimated marginal means of update for each condition given by fact type (trend, durability, price, and carbon emissions) for the Mexican survey data. The error bars are 95% confidence intervals of the marginal means.

To follow up on these results, we conducted a series of multiple linear regressions implemented with the backward elimination method (see [17]) in SPSS. The full model included as predictors the estimation error nuisance variable, gender, age, income level, the five influencing factors (i.e., physical properties, costs, cultural context, appearance, environment), and three of the four independent variables (i.e., durability, price, carbon emissions) using the trend variable as a baseline for the model. The best performing model resulted in one with age (B = 0.01, t = 3.063, p = 0.003, 95% CI = [0.004, 0.017]), price (B = -0.255, t = -3.85, p < 0.001, 95% CI = [-0.387, -0.124]), and estimation error (B = 0.267, t = 5.026, p < 0.001, 95% CI = [0.162, 0.373]), as predictor variables. Care should be taken when interpreting these effects due to the multiple comparisons nature of the backward elimination method.

2.2 Study in USA

2.2.1 Context

By 2011, detached single-family houses accounted for 62.7% of the total housing units in the United States followed by apartment units with 24.6%, mobile homes with 6.8% and multiplex attached houses with 5.9%. The percentage of single-family detached homes has remained similar over the past 70 years [18]. The type of home preference is expected to change in USA, mainly due to a demographic shift that will lower the average household size, and therefore the market will prefer smaller units in apartments and attached houses [19].

According to the 2016 Census, the preference of building materials for new single-family detached constructions on the shell of the building were: 1.vinyl (PVC) 2.stucco 3.brick 4.concrete/fiber cement 5.wood 6.stone [20]. Stucco was not considered in the survey as it is a material that can be implemented in many surfaces and therefore the values for carbon emissions, price and durability are not representative. Adobe, even though it is not considered in the U.S. Census, is gaining interest in North America and has started to be introduced in the building codes [21], therefore it was included.

2.2.2 Participants

The specific characteristics of the participants living in the United States were as follows: gender: 47 males and 53 females; age: 32 were 18-29 years old, 56 were 30-49 years old, 11 were 50-64 years old and 1 over 64 years old; occupation: 25 were employed as managers or professionals, 13 in services, 3 in farming, fishing or forestry, 12 in sales or office, 5 in construction or maintenance, 7 in production or transportation, 5 in the government, 8 worked as freelancers, 10 were students, 4 were retired and 15 were unemployed; household yearly income: 23 earned less than USD 20K, 21 earned USD 20K-39K, 24 earned USD 40K-59K,15 earned USD 60K-79K, 5 earned USD 80K-99K, 10 earned USD 100K-149K and 1 earned more than USD 150K; Type of home: 54 were living in a single family-house detached, 33 were living in an apartment in a multi-storey building, 8 were living in a multiplex house (row house, duplex, triplex, etc.) and 4 were living in a mobile house. The average household size reported by the participants was 2.8 persons per unit.

2.2.3 Material preference

When hypothesizing about building a new house or building, 37 participants reported that decisions regarding building materials would solely be taken by their own or by a family member, 46 would also include an architect or a contractor in the decision making process and only 17 would leave the decision exclusively to the architect or contractor.

When first ranking the materials of preference that they would use the most on the shell of their dwelling, these were: 1.Stone ($\bar{x}$ 2.44, s = 1.36) 2.Fired brick ($\bar{x}$ 2.51, s = 1.47) 3.Wood ($\bar{x}$ 3.42, s = 1.64) 4.Concrete ($\bar{x}$ 3.46, s = 1.68) 5.PVC ($\bar{x}$ 5.17, s = 1.73) 6.Glass ($\bar{x}$ 5.25, s = 1.60) 7.Adobe ($\bar{x}$ 5.72, s = 1.35). When ranking the factors that affected their decision the most, these were: 1.Physical properties ($\bar{x}$ 1.94, s = 1.35) 2.Costs ($\bar{x}$ 2.66, s = 1.27) 3.Appearance ($\bar{x}$ 2.68, s = 1.22) 4.Environmental factors ($\bar{x}$ 3.42, s = 1.28) 5.Cultural Context ($\bar{x}$ 4.30, s = 0.9).

2.2.4 Update in preference

As we did with the Mexican survey data, here we also conducted a one-way ANOVA (see Fig. 6). For this model, neither the between-subjects factor of fact type was significant (F(3, 95) = 0.672, p = 0.571, partial eta squared = 0.021) nor was the estimation error nuisance variable (F(1, 95) = 0.172, p = 0.679, partial eta squared = 0.002).

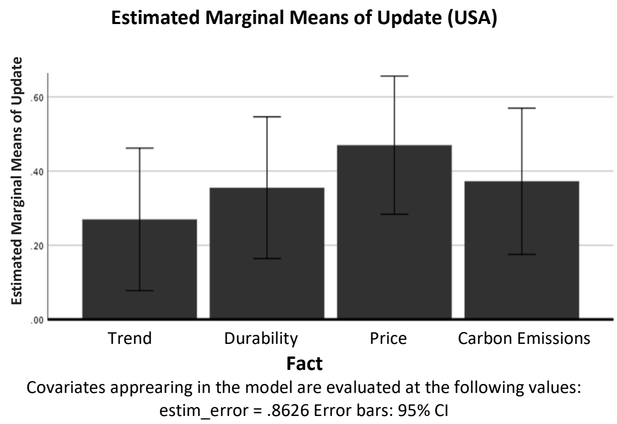

Figure 6: The estimated marginal means of update for each condition given by fact type (trend, durability, price, and carbon emissions) for the survey data from U.S.A. The error bars are 95% confidence intervals of the marginal means.

Consistent with the follow up analysis done for the sample from Mexico, we also conducted a series of multiple linear regressions implemented with the backward method in SPSS. The best performing model resulted in one with the physical properties influencing variable (B = 0.088, t = 2.464, p = 0.016, 95% CI = [0.017, 0.159]) and gender (B = 0.151, t = 1.872, p = 0.064, 95%

CI = [-0.009, 0.312]). Only the physical properties variable has a significant effect. As above, care should be taken when interpreting this effect due to the multiple comparisons nature of the backward elimination method.

2.3 Comparison between Mexico and USA

To compare the survey data between Mexico and USA, we ran a two-way between-subjects ANOVA (see Fig. 7) with one factor being the same as in the above ANOVAs (fact type) and another factor being country (either Mexico or USA). However, the fact type for this analysis was reduced to only two levels of interest: price and carbon emissions. The reduction in levels was a decision made post hoc, after observing the main results reported above. This means this analysis is done for exploratory purposes only and care is advised when making inferences here. For this model we also included the estimation error nuisance variable.

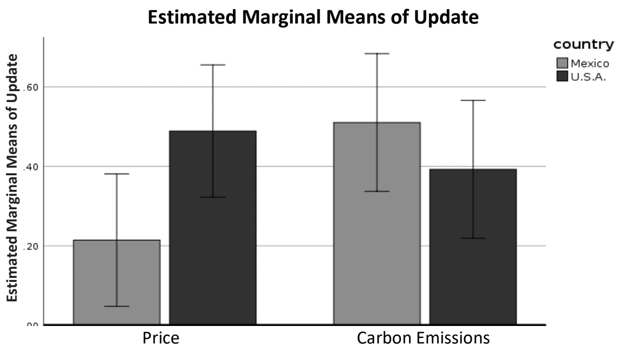

Figure 7: The estimated marginal means of update for price and carbon emissions levels of fact type for both countries; Mexico and U.S.A. These are marginal means since they account for the effect of the estimation error nuisance variable. The errors bars are 95% confidence intervals of the marginal means.

In this analysis we do not observe a significant effect of estimation error ($F(1, 95) = 0.069$, $p = 0.794$, partial eta squared = 0.001), fact type with only price and carbon emissions as levels of interest ($F(1, 95) = 1.359$, $p = 0.247$, partial eta squared = 0.014), nor main effect of country ($F(1, 95) = 0.836$, $p = 0.363$, partial eta squared = 0.009). However, we do observe the crossover interaction between fact type and country ($F(1, 95) = 5.259$, $p = 0.024$, partial eta squared = 0.052). As mentioned before, this post hoc analysis should be interpreted with care given that the significance value does not survive Bonferroni correction assuming that all six possible pairs of levels from fact type would have been compared in the same way; the corrected significance value in such a case would be $p = 0.05/6 = 0.0083$.

3. CONCLUSIONS

This exploratory study was focused on potential decision-makers in the building industry, regardless of occupation or previous knowledge, and their update of preference after receiving certain information. Our preliminary findings show that most of the participants would rely on their own decisions while choosing materials to build a new housing construction. The presented materials were taken based on representative values from the national census from the two countries where the surveys were conducted. These results can provide initial guidance when evaluating current preferences and use of materials. However, we wanted to assess the factors that might greater influence future decisions within consumers. Even though our results might have limitations because they are based on verbal reports and a hypothetical scenario, we expect a correlation with real behaviour.

We found out that physical properties, such as durability, were the most influential factors reported by the participants. Nevertheless, the update in preference was influenced more by other factors. For example, in Mexico, acknowledging evidence concerning carbon emissions of materials can have a greater influence on the update of preference in comparison to other types of evidence like durability, trend or price. The latter had almost no influence on the participants' update of preference in Mexico, whereas in USA, this was the information that affected their update the most. These results could be explained by a confirmation bias, since recognizing information about an existing belief generates less influence on our change of mind than on receiving information about which we know less [22]. This was probably the case with environmental awareness, which is directly related to the economic level of the population [23], which could mean that there is less knowledge in Mexico about this topic than in USA. The converse could be true for building material pricing, as there is a bigger rate of self-construction in Mexico, people are more familiarized with costs there than in USA.

4. EXPECTED CONTRIBUTIONS

With this research, we want to dig into the challenges for low energy and low carbon constructions while trying to overcome social barriers in the building sector. This study could serve as a basis for material producers to understand the factors to focus on while developing a sustainable product. Our findings show that focusing on information that is not common for the decision-makers might result in a higher influence for the update of preferences. This might also have implications for policy makers, to know on what factor to focus to promote the use of low carbon materials or products.

Nowadays, a great proportion of the constructions worldwide are done by self-builders and therefore many of the decisions are taken by the population in general. Nevertheless, There are many cases where architects and planners are involved in the decisions. In that sense, this research is useful to have a better understanding of the clients' needs and preferences and to know what type of information has more influence over the clients' decisions. We think that architects have a crucial role in the influence over clients and users to promote building techniques suited to locally resourced materials.

The update of preference was the main variable to test in this study within a national context, thus, location within each country was considered random. However, future studies regarding the use of building materials are needed within a more local context. There are also other variables that could be considered depending on what is measured, like supply and availability of materials, aesthetic attributes, or specific building regulations, as consumers' choice may vary greatly depending on the location. Yet, we think that this study can serve as a reference, which takes us one step forward in understanding behaviour within decision-makers, and therefore brings us closer to have a greater influence towards low energy and carbon constructions.

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