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Analysis of visible facades on rural building projects by computer graphics simulation

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This paper was aimed at comparing different construction solutions for integrating rural buildings on its surroundings, taking into account the associated costs. The poll participants compare actual photographs of existing buildings with computer processed images. The poll results were systematically organized by in order to objectively determine popular preferences.

It has been revealed that new rural building facades can be designed for better visual integration with minor additional cost. The study shows that just an average 7.35% cost increase in facades would yield 21.6% visual integration improvement. This work can help to developers, architects and engineers to improve their project's visual integration. The analysis of associated costs has proved that good building integration is very beneficial yet fairly cheap, considering just a 5% overall extra cost can assure proper integration. These results become even more significant if the fact that the cost of the visible building envelope is a minor part of the total project budget is accounted for.

Keywords: Building envelope; Graphics simulation; Rural development; Visual impact.

Análisis sobre la visibilidad de fachadas mediante simulación gráfica en proyectos de construcción rural

Este trabajo se comparó diferentes soluciones constructivas para la integración de los edificios rurales en su entorno, teniendo en cuenta los costos asociados. Los participantes de la encuesta comparan fotografías reales de edificios existentes con imágenes procesadas por ordenador. Los resultados de la encuesta fueron organizados sistemáticamente para determinar objetivamente las preferencias.

Se ha revelado que las nuevas fachadas rurales del edificio se pueden diseñar para una mejor integración visual con el coste adicional menor. El estudio muestra que sólo un promedio de 7,35% de aumento de costos en las fachadas daría un 21,6% de mejora de la integración visual. Este trabajo puede ayudar a los desarrolladores, arquitectos e ingenieros a mejorar la integración visual de sus proyectos. El análisis de los costos asociados ha demostrado que una buena integración de la construcción es beneficiosa y barata, teniendo en cuenta sólo un 5% de costo adicional en general puede asegurar una integración adecuada. Estos resultados se vuelven aún más significativos si se tiene en cuenta el hecho de que el coste de la envoltura del edificio visible es una parte menor del presupuesto total del proyecto.

Palabras clave: *Envolvente del edificio; Simulación Gráfica; Desarrollo Rural; Impacto Visual*

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1. Introduction

Amongst all the human modifications made to the rural landscape, those produced by buildings and other infrastructures are the most relevant, since they tend to be located at visually criteria privileged places (Cañas *et al.*, 1996). More importantly new buildings should be designed and located with the greatest respect for their environment (Tandy, 1979). However, in recent decades rural buildings have proliferated and have frequently done so in a manner discordant with the environment (Montero, 2005). In effect, buildings which cause discordant visual effects would hence be one of the elements to most significantly contribute to the environmental impact (García, 1998).

The promoting of economic development and the improvement of quality of life are typically regarded as main concerns to be faced by rural communities. The challenge is therefore to provide solutions to both and find appropriate quantifying indicators. New interventions in rural territories (a new building, restoration, or expansion of an existing one) should then be focused on the improvement of quality of life, which is determined by investment returns and higher living standards (Sirmans *et al.*, 2005).

Due to the prevailing maximum profit on investment-based approaches, where Function excludes any other design criteria, the emergence of new “cheaper” materials is allowed, with aesthetically expensive consequences (Cañas *et al.*, 1996). This shows a trend where developers have minimized material and execution expenses, eliminating additional costs attributable to aesthetic reasons or integration.

The mainstream has not taken into account that sometimes economic optimization is not the only issue to account for. Other factors like aesthetics and environmental awareness in rural building design play a relevant role. In the long term, more integrated or more construction-friendly environments improve living and working standards for its inhabitants and therefore can be considered more profitable (Sainz de Cueto, 2002).

Developers as well as designers should take this into account, so that new constructions are projected according to requirements involving functionality, environmental integration (García *et al.*, 2006) and economic feasibility.

Although several environmental economic valuation methods have elsewhere been developed up to date (Freeman, 1993, Pearce and Turner, 1995, Garrod and Willis, 1999), they have apparently never been applied for visual integration of rural buildings.

The aim of this paper was to analyse the best constructive solutions which help a good visual integration of a building in the countryside at the lowest cost in Extremadura, a region of southwest of Spain.

2. Method

In order to compare methodologies proposed in relation to visual impact, public surveys are included in the studies. The main goal of public inquiries is to quantify a set of issues based on qualitative attributes.

The financing of a building project is broken down into two investment categories, i.e. high complexity (arising from the use of a large number of materials in the design process) and variability (derived from costs related to multiple factors such as scale, functionality, or inside and outside wall surface finishes). In order to solve these calculation problems a new concept of *envelope* was proposed, and all short and long term costs and returns were assessed in relative terms. A public survey was conducted to assess the public’s preferences with regard to the proposed landscaping design alternatives.

Far too much of our countryside is currently being severely adulterated.

In order to establish a hierarchy of visual and aesthetic elements within an anthropogenic countryside, a number of elements and features must be described (Smardon, 1979, Español, 1995). In each landscape, the color of the main elements, textures, lines and shapes, amongst other criteria, should be considered. Along with this description a methodology for data acquisition must be made. Table 1 shows the visual and aesthetic elements.

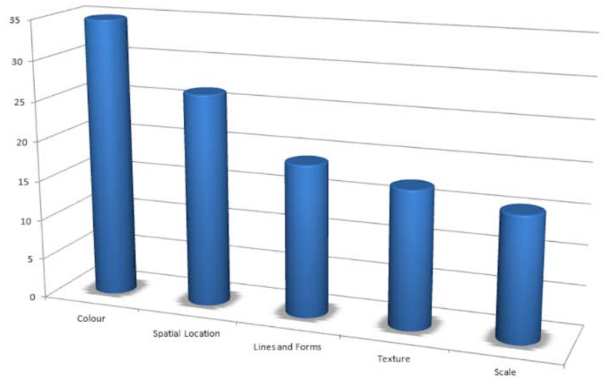
Table 1. Visual and aesthetic elements

Elements	Characteristics
Surface properties	
Color	Spectrum
	Saturation
	Lightness
Texture	Regularity
	Grain size
	Internal contrast
	Formation elements
Line	Sharpness
	Complexity
	Direction
Form	Geometry
	Complexity
	Direction
Composition elements	
Space	Scenic composition
	Scenic background
	Siting of units
Scale	Scenic ocupation
	Contrast of scales

Types of construction materials used in a design, their positioning and repetition, and finally the feasibility of future changes in the building must be analyzed so that the final project better suits the landscape. In many cases just the selection of materials was seen to be sufficient to ensure integration. In some other examples, changes in visual attributes like color and texture are sufficient.

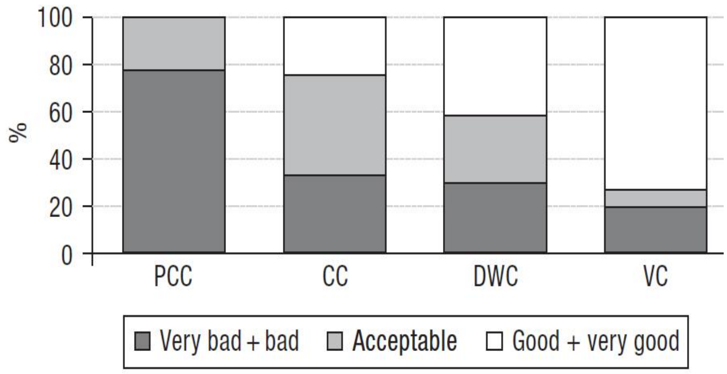
Further studies on color (García *et al.*, 2003) and texture (García *et al.*, 2006) of agro-industrial buildings highlight the importance and influence of visual elements used to integrate buildings into their surroundings. Figure 1 shows the average percentage of instances in which a visual element is identified for modification.

Figure 1: Average percentage of instances in which a visual element is identified for modification.



Sometimes architects do not show a too accurate aesthetic knowledge. In such cases, the use of well-established criteria to ensure visual continuity might lead to higher probability of achieving "good" or "very good" integration standards. Figure 2 shows the relations among integration values and among elements.

Figure 2. Relations among integration values and among elements.



This article focuses on walls, provided they are a building's most visible element and makeup most of the impact on any landscape. Faces were classified into two groups:

a) Ceramic bricks, thermal clay and concrete blocks. These materials come in a huge variety of sizes, finishes, colors and textures. Usually, block walls are refinished or rendered in mortar or "stucco" with smooth and rough textures (Fig. 3).

Figure 3. Cement block warehouse with rough finish.

b) Sheeting or Plates, divided into two subgroups. On the one hand, fibre-cement and metal sheeting, single plates or double layered unitized insulation sandwich wallboards. On the other hand, pre-cast concrete and hollow core panels. The first group presents a variety of colors and corrugations. The pre-cast concrete units come in a variety of surface finishes. Hollow core pre-casts also come in a variety of color, texture, as well as a variety of imitation mortar joints or brick or stone veneers.

In order to ensure consistency of results, the number of buildings to be considered should be large enough to repeat several times the same tests with the same set of original images. However, the number of buildings should also have to be limited, to avoid superfluity and saturation due to overexposure or failing to satisfy unique requirements for particular buildings and situations.

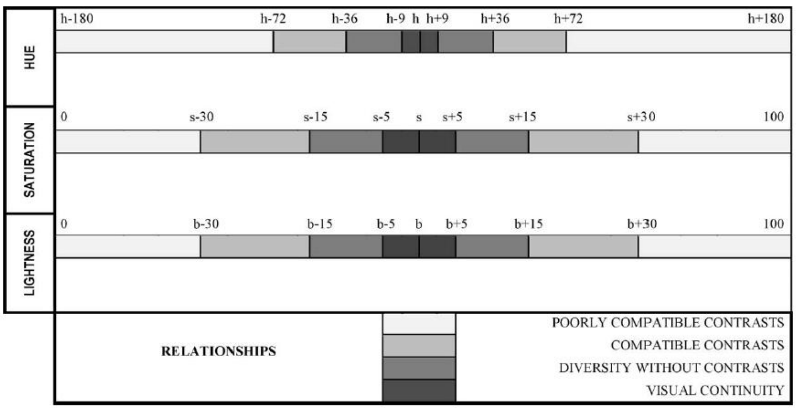
Fifteen projects were carefully selected for the survey in order to account for as wide a territory as possible, with a diversity of landscapes, construction methods and materials, locations, uses and types. They were selected under statistical criteria.

The study was geared to parameters that allow for depicted elements to be incorporated into existing original designs with only aesthetic effects. Therefore, criteria such as location, building shape and orientation gave way to merely consider colors and textures.

Based on well known methods for visual impact improvement, the following criteria for color (García et al., 2003) and texture (García *et al.* 2006) were taken into account in order to generate alternatives aimed at improving the integration of existing buildings–into the surrounding landscape:

a) Color: All colors are defined by three parameters or characteristics: hue, saturation and brightness (Fig. 4). According to those three features, a numerical scale would allow scientific measurement of color perception. Color has a great influence on the relationship between buildings and their surroundings, and is a key point when trying to display a building rooted and integrated on its surroundings (Fraser, 1982, Scottish Environment Department, 1993). Colors cannot be considered independently. Each perception of color is affected by neighboring colors and the overall effect of the environment.

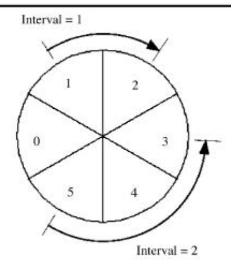
Figure 4. Relations among hue, saturation and brightness.



b) Texture: Texture is defined by four parameters: regularity, density, grain size and internal contrast (Fig. 5). The aesthetic appearance of the building exterior is conditioned by the materials used in its construction. Therefore, the choice of building materials plays a relevant role to achieve environmental integration.

Figure 5. Relations among regularity, density, grain size and internal contrast.

	TYPE	NAME	PARAMETERS	RELATIONSHIPS	
GRAIN SIZE			Complete photo area (pixels) / Texture grain (pixels)		
	0	Smooth - continuous	< 100 or > 50.000		
	1	Fine	25.000 - 50.000		
	2	Fine – medium	6.000 - 25.000		
	3	Medium	1.500 - 6.000		
	4	Medium – coarse	400 - 1.500		
	5	Coarse	100 - 400		
DENSITY			Percentage that texture grains take up in total area (%)		
	0	Continuous	< 5 or > 95		
	1	Disperse	5 - 20		
	2	Disperse – medium	20 - 40		
	3	Medium	40 - 60	Interval = 0	VISUAL CONTINUITY
	4	Medium – dense	60 - 80	Interval = 1	DIVERSITY WITHOUT CONT.
	5	Dense	80 - 95	Interval ≥ 2	COMPATIBLE CONTRAST
INTERNAL CONTRAST			Standard deviations of colours (0 – 255 pixels, Adobe Photoshop)		
			Standard deviation of grey (σ_Y)	X = any colour	
			Standard deviation of red (σ_R)	$\|\sigma_{Xi} - \sigma_{Xj}\| < 5$	VISUAL CONTINUITY
			Standard deviation of green (σ_G)	$5 \leq \|\sigma_{Xi} - \sigma_{Xj}\| < 15$	DIVERSITY WITHOUT CONT.
			Standard deviation of blue (σ_B)	$\|\sigma_{Xi} - \sigma_{Xj}\| \geq 15$	COMPATIBLE CONTRAST
REGULARITY	R	Random			
	G	Grouped		≠ differences	VISUAL CONTINUITY
	O	Ordered		* differences	DIVERSITY / CONTRAST



Local predominant colors and textures within the surrounding natural and artificial environment provide for continuity that usually fits a standard observer. An analytical method based on such criteria was developed to objectively assess potential design alternatives presented in public surveys. Photographs were taken consistently with a fixed 50mm focal length camera configured to best simulate human-eye-view. They all were taken from a road or highway (at 1.69 m above ground) with optimizing perspectives which best complemented the targeted building. To minimize contrasts, daylight peaks and zeniths were avoided. Scenes were then digitally configured (Fig. 6) using Adobe Photoshop© software.

Figure 6. Proposed design alternatives. Original photographs and proposed alternatives in left and right columns, respectively.

Each building project was assessed under ten different possible solutions, how is shown in the Table 2.

Table 2. Changes made to original photographs and identification of modified photographs which contain these changes

Changes in visible exterior walls	In photograph
Lime whitewash substituted by paint	1b, 3a, 8b 12d, 15c, 21d, 22c y 22d
Add-ons superimposed over most visible lines and imitation antiquity	1c
Siding and masonry veneer	2d, 9d, 10d, 11c y 15b
Paint substituted by whitewash	4c, 5d y 23b
Change of paint color	5c y 23c
Mortar surface substituted by smooth rendering and lime whitewash	6d y 20b
Metal panel color change	7a, 7b, 13d, 14a, 16d, 17a y 19b
Concrete wall dye or coloring	13d
Metal panel substituted by pre-cast concrete panel	14b
Finished mortar rendering color change	20a, 21a y 21b

The unregistered photographs were the original shots. Image processing of the 15 selected buildings yielded a total of 32 infographics. They were selected under statistical criteria. Together with the original photographs, an album with 47 images was prepared. Only one improvement was overlaid in the original photograph in each infographic, except in one case (13d), where two overlaid improvements were combined. It should be brought in mind that the goal in all proposed alternatives was to improve rural integration. It is remarkable that only two of the proposed changes were not developed in more than one infograpic. Such changes might not therefore be considered as compared to other buildings.

The survey was intended to determine which of the proposed alternatives represented in the infographics were more likely to be assessed as "good" or "very good". Furthermore, to assess whether the proposed alternatives truly meant an improvement over the original, the infographics were presented together with the associated original photos without disclosing to survey participants which were modified or original images. Improvement ratios could be quantified by comparing individual values from each group of images pertaining to a particular project. The survey was compiled by 120 people of all age groups, occupation and origin, that were selected under statistical criteria. All surveys were personally conducted, ruling out other massive participation procedures such as video or internet based. The presentation was prepared in landscape formatted ISO A3 notebooks, each page comprising four images identified with a number and a letter. The respondent was asked to answer the following question:

Rate between 1 to 10 the visual integration of each construction in its surrounding landscape.

1 (very poor) 2 3 4 5 6 7 8 9 10 (very good)

According to results from the two pictures –original and infographic-, valid design criteria could be achieved. The two photographs were reviewed by 240 rural residents. A total of 5640 responses were computed, which represented a statistically valid sample (Hernández *et al.*, 2001). Even though answer options were presented as a discrete set –integer values ranging from 1 to 10-, a normal distribution was observed for the scores associated to each image. Note tail values were removed.

Budget evaluation was performed establishing necessary modifications to solve a particular conflictive construction project, using Archimedes SA CYPE © budgeting software. However, the program's default database was not used. Instead, EXTR05 database developed by the Regional Government was used, provided it fits more successfully the target geographic area. However, a large number of new items had to be created to address the wide range of construction solutions implemented in the selected buildings. Each budget proposal had to identify, quantify and assess requirements regarding manpower, work equipment and materials.

Once all the budgets were processed, those referring to the original photographs were compared to those of the alternative projects. Additional costs (positive or even negative) associated to the development of the various project alternatives were then calculated. Finally, it should be noted that the costs involved for each image are themselves fully measurable objective values. Potential errors or omissions were blurred by percentage estimate of such costs.

3. Results y discussion

Survey results allowed for calculating improvement percentages for proposed landscape integration, which meant simply comparing each proposed alternative to the original case. Calculated budgets were then added to these percentages. This way, final information provided data that linked the effects of the proposed alternatives on landscape integration to their associated costs. Table 3 shows cost/benefit ratios for each of the proposed alternatives. Rows correspond to former state of buildings under study, while columns stand for the proposed design alternatives. Results are presented using double input cells, in which higher and lower values represent variation over original cost and variation achieved when evaluating integration into landscape, respectively.

Table 3. Results obtained by different solutions used for wall for improving integration

Variation in cost (%) / Variation integration (%)	Appropriate Design Alternatives Which Improve Integration						
Design alternatives	Appropriate painting	Add-ons	Siding and panels	Mortar rendering and lime whitewash	Siding and Metal panel color changes	Appropriate mortar surface color	Appropriate color for Pre-cast concrete panels
Mortar rendering and lime whitewash	+5.09 / +24.92	+5.05 / +14.61	+37.97 / +14.54				
Inappropriate paint color	0.00 / +44.97			-2.47 / +29.97			
Inappropriate mortar surface color				-5.10 / +11.44		0.00 / +18.06	
Inappropriate metal panel color					0.00 / +27.75		+22.54 / +15.29

With regard to the associated costs, negative/possitive values indicate less/more expensive solutions than the original, respectively. A series of valuation range guidelines had to be established in order to qualify the numerous proposed solutions. Cost increases at or below 5% were considered “irrelevant”. Those close to 10% "cheap", at around 20% "significant changes" and those over 30% “expensive”. On the other hand, environment integration costs valuated close to 10% were labeled as "acceptable", around 20% "good" and values close to 30% "very good".

Results for each of the proposed constructive solution are shown in detail.

1. Replacement of traditional whitewash with modern sustainable paint: Most buildings in Extremadura’s countryside, in many cases built of earthen material, remain today with only their original lime whitewash, crusty and peeling away. This particular action meant "negligible" economic increase whilst getting a "good" grade in countryside integration.
2. Adding on studded siding or sideboard/wallboard constructions or masonry veneer over a small part of an existing building in order to improve overall integration. The worst case examples are the modern metallic warehouse constructions that today litter Extremadura’s countryside. These conflicting structures may have rooflines and corners modified to simulate more traditional and integrated buildings. This activity entails a "negligible" increase in budget whilst rating as "acceptable" in landscape integration. This demonstrates that merely “rounding off” or “breaking up” the most outstanding “hard” lines in any poorly integrated building is a very cost effective approach.
3. Applying siding, wallboard or masonry veneer: over entire buildings. If instead of breaking up a facade or roofline by intervening in a precise part of an existing building, it was decided to allocate a budget for a complete restoration of the entire building exterior, the budget skyrockets and the identification “expensive” appears as quite logical. This is nevertheless striking, because the cost increase for very limited partial modifications truly becomes “negligible” in return for the “very good” integration results obtained.
4. Replacing paint with liming or whitewash. This fix only has significant building integration results when its existing color is very inappropriate, especially when lacking earth shades when located in barren terrain. In this case, associated costs are minimized with "very good" landscape integration values.
5. Changing paint color: Note the results of the previous proposal cannot be added on to the first category even though they are conceptually similar. By choosing appropriate colors, instead of simply rewhitewashing building facades, the same costs were entailed but with a “very good” landscape integration valuation.
6. Restoring deteriorated plastering and whitewashing with cement mortar rendering or “stucco”. This solution is more expensive than a lyme whitewashing but at least adequate color can improve the building’s integration to an "acceptable" level.
7. Color change of metal parapets and/or visible structure framework: Very low cost activity with “very good” landscape integration rating.
8. Adding colorant to a new concrete wall construction: this action is not reflected in Table 3 since it is the only one featured as a “double changed” proposal. This example is linked to picture 13d. A very simple technique with a big integration effect was achieved when applied to a concrete grain silo. The die or colorant resulted in only 0.6% extra cost but the finished outcome gained 22.87% with a “good” integration valuation grade. Metal parapets and framework colors were also changed.

9. Replacing parapets with pre-cast concrete panel walls: In the same case as the grain silo project, instead of dieing visible concrete metal parapets were covered by earthen colored pre-cast concrete panels. Although landscape integration was “significant”, the associated cost was “expensive”. However, integration achievement would have been nearly equal if only horizontal framework pieces had been used whilst costing considerably less.
10. Dieing or colouring mortar rendering “stucco”: In this case an acceptable improvement in landscape integration was achieved at the same cost.

Overall, an average increase of 7.35% was found to yield 21.6% average improvement for visual integration valuation.

4. Conclusions

The analysis of associated costs has proved that good building integration is very beneficial yet fairly cheap, considering just a 5% overall extra cost can assure proper integration. These results become even more significant if the fact that the cost of the visible building envelope is a minor part of the total project budget (and usually a very small part of it) is accounted for. Due to the wide variety of sizes, shapes and uses of these buildings it would be ill advised to look for cost percentages for out-of-sight elements even though the percentages would be a fraction of that calculated for just their envelopes.

Regarding color, it should be noted that bright and fleetly color implementation impedes landscape integration. Earthen tones blend into barren environs and assure visual continuity. Saturated colors, whether bright or dark, do not get good integration grades and only help to make matters worse with the exception of white. Green color deserves special mention since there seems to prevail a myth that painting anything green will achieve good integration when nothing could be further from the truth. Ironically, this color is even proposed by some regulations affecting these buildings. On another note, even though the presence of texture is much less visual than is the perception of color (García *et al.*, 2006), aspects such as wall density and regularity must be taken into account to ensure continuity between building and surrounding.

Results do not allow to claim that the buildings under study were fully integrated into the landscape since far-reaching parameters like lines, shapes, scales and spatial location have been ignored. In this sense, estimated costs would also depend on specific cases. The more a case is studied the less variable become the estimated costs. This means that, with respect to the original image, a good improvement in building integration has been achieved, without ever modifying form, volume or location.

With these rules in hand, a designer or developer might effectively address integrating his project into the surroundings, knowing *a priori* cost-benefit ratios and affordable choices for assuring his project enjoys visual continuity in its rural settings.

- The best (and most expensive) building integration is observed to be achieved by carefully selecting appropriate materials. However, a cheap and simple action like changing the color of the finish coat of paint would drastically affect landscape integration.
- Certain building materials are seen to be very functional for construction purposes and integrate fairly well with the landscape.
- The cost of visible exterior walls does not necessarily determine their potential for landscape integration. Roofs and walls can be designed with better odds of an optimized integration into the surroundings with a very small extra cost, often with no additional cost at all, and sometimes even lowering costs.

Although this study was carried out in Extremadura, its results are applicable to similar places in countries like Italy, Portugal and Greece, and they are in line with other studies on bibliographically done in similar environments. As futures lines of work is to extend the study to other regions and other types of construction in Spain.

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