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BUILDING RENEWAL IN LOW INCOME HOUSING ESTATES – A BRAZILIAN CASE STUDY

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ABSTRACT

This paper exposes a design methodology for building renewal, which is oriented towards adding sustainability, value, and flexibility. It considers environmental and economic feasibility based on embodied energy in materials, conventional budgets and hedonic price models. A process of design simulation was developed, focusing on a typical housing estate, in Porto Alegre, Brazil. The main results of which indicate that there is potential for increasing their value. Building renewal is a form of recycling and has influence on social, economic, and environmental issues. This work contributes to the discussion of alternatives to the low income housing deficit in Brazil.

Keywords: Building industry; low income housing; design; building renewal; sustainable design; waste reduction

1. INTRODUCTION

The construction sector has a significant environmental impact. Resources are needed for construction, operation, maintenance, demobilization and demolition. Moreover, the construction industry is also responsible for consuming energy, water and generating various types of pollutants such as VOCs and CO_2, which occur throughout the life cycle of the building. The construction industry consumes 40% (by weight) of materials used throughout the global economy [1]. The buildings and the built environment are responsible for more than 40% of energy consumption in the European Union [2]. The urban construction also represents a significant portion of greenhouse gas emissions, and a significant consumption of land [3]. According to [1], the construction sector of the European Union generates almost 40% of all waste produced. In relation to the Brazilian reality, some studies indicate that the amount of waste building tracks in several cities in Brazil is 230 to 760 kg / person /

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year [4, 5, 6, 7]. Therefore, the improvement of this sector is essential to contribute to sustainable development [1, 8].

A relatively new approach is the renovation of buildings in large scale. Reusing existing resources, the environmental impact is reduced. There are several benefits derived from the rehabilitation of existing buildings, such as maintaining structures of social or historic value which are already adapted to urban and architectural reality; taking advantage of the energy involved in the existing physical structure with less need for new resources; maintaining social relationships, community and neighbourhood and providing added value to the region and the building itself [9].

Meanwhile, remembering the fact that the degradation of a built up environment causes economic and social waste, building renewal has the potential of improving the quality of life of families affected and of cities as a whole. It is possible to reduce poverty and crime by improving built up environments. Of course, project requirements include sustainability, environmental considerations (preference for low-impact materials), economy (economic viability) and social aspects (low impact on users).

A proportion of existing low income housing estates in Brazil has problems of partial obsolescence and building renewal is an important measure to improve the quality of life of their users. Improving the use of existing buildings reduces the need for new buildings and thereby decreases the need for new urban land, thus, contributing to sustainability.

This paper presents some results of research on sustainable solutions for building renewal. The work begins by listing some elements to construct a methodology and shows a simulation study in a low income estate in Porto Alegre, a Southern Brazilian city. Results indicate good potential to consider renewal as an alternative to contribute to the low income housing issue.

2. THEORY – LITERATURE REVIEW

There are examples of mass housing rehabilitation in developed countries. In North America the main focus is on reducing energy consumption (retrofit). In Europe the problem is also linked to the renewal of a large number of buildings built after the II World War. The standards adopted at the time of construction are not considered suitable for the present day and people are looking for new solutions to expand the built up environment and reduce energy consumption for heating, in addition to recovering the region where the units are installed. The low population growth in developed countries and the search for sustainability does not recommend demolition [10, 11, 12, 13].

Developing countries have different needs, such as production to cover the housing deficit as well as economic viability. A part of the housing issue is linked to insufficient attention towards the demands of users, caused by deficiencies in the original design or aging buildings, in addition to the problems based on the poor quality of low income housing [14, 15].

An aging property is a building with some degree of obsolescence. After [16], the obsolescence of buildings is a phenomena with several aspects, such as physical (deterioration on performance of building itself), economic (changes on interest for potential users), functional

(change in user's objectives and needs), technological, social (fashion or behavioural changes), and legal obsolescence (changes on safety regulations or building ordinances).

The housing deficit in Brazil is about 10%. A part of this deficit is associated with inadequate housing and also the fact that a family may have housing but with low quality or a smaller size that their needs require [17]. Rehabilitation is a way to adjust this part of the deficit. In Brazil, an opportunity for study is in the housing estates built in the period of the National Housing Bank (BNH), from 1964 to 1986. In quantitative terms, this production was significant in several Brazilian cities. In general, these housing estates were originally designed for the low-class or low to middle class sector. Most estates are composed of hundreds of apartments with 2 or 3 bedrooms. They have public areas and parking areas and had, at the time of building, reasonable architectural and building standards. Projects built around the country have many similarities [14, 18, 19, 20, 21].

Too many properties currently present some level of obsolescence and presents lower market values. It has impact on property tax, generating in some cases a lack of interest of the public administration to invest in improvements in the region. Stigmatization of the residents is also common. There is loss in relation to the quality of life for families which extends into the neighbourhoods. This situation occurs in Brazil and in other countries, such as Argentina and Chile [22, 23], with some proposals for renewal [24, 25, 26].

This phenomenon occurs in Latin America and in several developed countries [27, 28, 29]. According to [27], there is evidence that some of the social and economic problems are linked to the repetition of the projects, and there seems to be a relationship between large units of buildings for low income housing and the existence of social problems such as segregation and prejudice. The generation of stigma is most common in large housing estates. In addition to large size and poor quality of design and construction, many residential estates are built on the fringes between urban and rural areas with poor infrastructure, thereby exacerbating the problem.

Chanagnon et al. state that one of the objectives of the renovation of low income housing in Europe is the increase of their value [30]. Hastings argues that urban renewal must consider the public image of the housing estates along with the physical renewal. There are cases of urban renewal projects developed in Britain in which the poor image remained after the completion of the work [28]. Esteban Galarza discusses some social consequences of urban projects in urban areas, such as increased levels of property prices and attracting groups with higher income levels but at the risk of displacement of the original people [31]. One of the known consequences is gentrification. Gentrification is the conversion of marginal properties for working class areas located in central city areas into new residential uses for the middle or upper class, reflecting a movement of private capital investment. It has been related to the recovery of the architecture of damaged buildings as well as the supply of new services and it usually occurs in the CBD (the city "core"). Lower classes are displaced after the conversion of the region. In some cases improvement is not appropriate because it creates peculiar types of spatial segregation, often with increased income concentration [32, 33].

Some studies have been made about building renewal. One of them presents alternative enlargement or extension of buildings. Authors note that there are requirements of energy optimization that cannot be treated separately because they would not be economically viable. When they are combined with the extension of property, they become more attractive

for users [11]. Two studies made in The Netherlands are in this area. One proposes expansions and upgrading on energy performance in tall buildings [13], and another studied the same issues to two-floor residences [34]. The first study deals with the renovation of buildings, giving priority to the maintenance of the structure to reduce waste production and energy necessary to carry out the refurbishment. The proposed project included front porches and extension of the built up area, while maintaining about 75% of the mass of the building [13]. The focus of the second stage was to reduce fossil fuel use and increase the comfort of users. These authors performed simulations of expansion with minor alterations to the facade but with an increase in the internal area [34].

Bragança et al. presents some studies which examine the design features and alternatives for improvement of façades and roofs of buildings in several European countries, with the aim of reducing energy consumption [10]. Silva presents examples of building renewal that embrace the concept of a double façade with a second skin of glass, changing the external image with virtually no alterations within the buildings [35]. Brunoro studied changes in the vertical envelope, aiming at a passive solar gain also through double façades [36]. Giussani reports a complete renovation project of a set of low income housing in Berlin, for which were proposed façade changes and diversification of the units. The buildings were constructed in the late 1960s and have 15 floors, with 280 units in only three sizes. The renewal proposal was widely discussed with users. Finally, the building was divided into 4 separate blocks and the units were redistributed to form 26 different types of apartments [12].

In Latin America, significant changes occurred in low income housing estates, most of them produced spontaneously by individual initiatives of the users in an uncoordinated way. Most of the examples come from modification of housing regarding the original projects. Reis and Lay developed research in 12 housing estates in Porto Alegre, Brazil, with homes and buildings and showed that the appraisal of the quality of the facades is linked to the their degree of maintenance and also that properties in poor condition are not well regarded by their own inhabitants. These authors also verified that the personalization of the facades contributed to a better aesthetic perception by the users [37]. In the same city, Kessler reported changes in housing projects for the low socio-economic class, noting that approximately 80% of the houses suffered horizontal or vertical expansion. These alterations characterizing a user "need" to promote the differentiation of their property. They were justified by size upgrading in the family (children who marry, for example) [38]. In Argentina, Ganem and Esteves proposed balconies made of glass, as elements for improving internal comfort and reducing energy consumption [24]. In another work, Ganem et al. conducted a study of housing renewal, with a focus on the envelope [25]. Rodriguez and Sugranyes found that 40% of users invest in extensions of their homes, with 59% of households having an average expansion of $21m^2$ and 23% of the houses with extensions of $14m^2$. Some renovation studies have been made [26].

3. SOME ELEMENTS OF BUILDING A METHODOLOGY

A renewal project must be based on certain assumptions, including: (i) technical and economic feasibility, with solution proposals to renew the appearance of buildings, thereby promoting

economic recovery, (ii) use of materials available in the region, which generate less waste, are recyclable and have a low cost, (iii) propose solutions that allow flexibility of use. These three points establish economic, environmental, and social sustainability standards.

The basic premise adopted is that to expand, improve and prolong the useful life of buildings is a form of recycling, avoiding new constructions, and thereby reducing the generation of waste, saving natural and financial resources, energy and urban land. It is assumed that there are economic benefits and better resource use with the renovation of buildings.

3.1 Viable and valued projects

3.1.1 Costs

Construction costs are a very important element in the low income housing sector. In general, there are too few resources and projects attempt to meet too many needs. It is therefore important to examine carefully the costs of renovation projects for them to be economically viable and furthermore, solutions must be technically feasible. Bearing this in mind, costs are calculated by conventional budgets, measuring materials, labour, additional works and administrative and legal costs. This part follows the traditional methods of detailed estimates to budgeting.

A budget is a basic economic analysis of the building. In general, cost estimates use two schemes: conceptual and detailed estimates. Conceptual or parametric estimating is a way to define project' cost based on cost indexes [16]. In Brazil it's very common to use the CUB (basic unitary cost), which is defined by a Brazilian rule [39]. Detailed estimate is a cost prevision determined breaking down the project in several items of work, in an ordered and logical way, and predicting the cost of each one [16].

The feasibility analysis also requires estimates of increase in property values. A basic method is proposed to measure the value, using hedonic pricing models [40, 41, 42]. Thus, increase of value may be measurable by comparing the current situation with the potential situation, which is based on the proposed building renewal scheme.

3.1.2 Housing market and real estate values

Housing market is a segment of the urban economy, and presents a certain complexity to the analysis, due to multiple influences. Overall, the market is a form of coordination of economic activity, seeking balance through a price mechanism. As there are distortions that prevent this balance, usually there are also some planning mechanisms such as regulation through legislation, as defined by various levels of government [43, 44]. The term "real estate" refers to an abstract market, which encompasses several segments. Can be identified parcels that are sub-markets, which operate differently depending on the locations, types of buildings or the forms of transaction. However, the limits of each segment are unclear and often there is interpenetration between these sub-markets. Anyway, the housing market usually does, albeit imperfectly, the functions of a market, although there are authors who claim there is a single housing market in the strict sense of the term [43, 44, 45, 46, 47, 48].

Supply and demand are relatively fixed in the housing market in the short period because of immobility and the period of maturation of new construction. Therefore, price and quality do not change simultaneously in response to changes in demand, and balance adjustments

occur primarily in the general price level [46, 49]. The high cost of housing is related to the need for credit to purchase real estate, and there is also influenced by government action, especially in macroeconomic issues. It is the most valuable asset that most people acquire in their lives [50]. There is a wide variety of products. For example, the properties have large differences in size, age and quality of construction, which are reflected by variations in market prices [46]. Real estate is a "composite good" in the sense that several features contribute to the formation of prices. The variety of goods make uneasy the comparison among different properties, and buyers are often poorly informed about the general conditions of supply. Thus, buyers can not classify the degrees of utility property, or even decide what the most appropriate price for each property. For these reasons, and because there is a deficiency of information and inequality of property, real estate market works in a level of imperfect competition [43, 51].

There are some important features in the prices of housing properties that differ from other goods. Properties are fixed in geographic space, durable, high-cost and very heterogeneous. Both characteristics affect the functioning of the housing market [51]. A key feature is the location. The immobility of housing causes a strong dependence of the attributes of neighbourhood and accessibility in prices. Most authors in the field of urban economics emphasize this aspect (e.g., [45, 46, 51, 52]. To illustrate, [53] states that the dominant rule in real estate is "location, location, location". Urban market is spatially dependent in the sense that the location is very important in setting the price of land and buildings. Location can be divided into two parts, equally important, with aspects of neighbourhood and accessibility. There are environmental aspects involved in these factors such as noise, pollution, education, and also accessibility to shoppings, local employment and leisure, for example [54, 55].

The models relating to the price of a property with their characteristics are known as hedonic pricing models, which are econometric models and have a long history of application in economic studies and research [41, 50]. The hedonic price theory was originally presented by Court in 1932 and spread by Griliches [56] and Rosen [41]. In an article on hedonic price indices for cars, Griliches said that "it is a common industry practice to adjust prices to variations in the quality of goods" [56]. Soon Rosen developed a new view of the hedonic price. For him, "A class of differentiated products can be completely described by a feature vector objectively measured. The observed prices and quantities of product-specific characteristics associated with each good define a set of prices 'hedonic' or implicit". The units of the housing market may be viewed as a set of "housing services" or a "feature vector" of characteristics of these properties. In this sense, property prices are understood as resulting from the balance of market forces of supply and demand for each particular feature of the property [41]. Because each building has a different suite of features, will offers to a different price. The accuracy of the pricing models based on hedonic theory depends on the solutions to two main problems, according to [56]:

- Identify the relevant attributes (in this case, the properties and attributes of the market);
- Find the true shape of the relationship between prices and these attributes;

These issues are usually resolved empirically, through data collection and statistical analysis. The hedonic models have been used for decades, especially in studies examining

the effects of various attributes on housing prices, but the literature shows that researchers in the field of urban economics have used multiple paths for this type of analysis, without a definitive result is found [57, 58, 59, 60, 61]. In real estate area, there are several attributes that should be considered simultaneously, assuming different amounts in the formation of prices in each case. To build pricing models, data should be collected in the segment of interest and then generating the corresponding models. The hedonic pricing models consist in the representation of the attributes of the property, basically as in Equation 1:

$$\text{Price} = f(\text{physical attributes, locational attributes, conditions of the transaction}) \quad (1)$$

Physical attributes represent the characteristics of the property itself, such as total area, number of bedrooms, building standard, among others. The location aspect brings to mind the fixity of the product, representing the conditions of neighbourhood and accessibility. Terms of the transaction, such as payment method and time of sale, may also affect prices.

Multiple regression analysis is a technique that seeks to connect the independent variables to a dependent variable (in this case, the market value) through a numerical equation. The goal is to develop a numerical model to explain the relationships. The general hedonic price function in Equation (1) can be proposed as in Equation (2):

$$\text{Price} = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + ... + \alpha_k x_k + \varepsilon_\alpha \quad (2)$$

Where $x_1,...,x_k$ are the attributes (characteristics of the property); $\alpha_0,...,\alpha_k$ are the coefficients of this equation and ε_α is the error term. The coefficients are usually estimated through regression analysis. There are several conditions (assumptions) that should be checked to ensure the quality of the numerical model generated. Among them, the most important are homoscedasticity, linearity of the relationship on (2), lack of multicollinearity and absence of outliers [63, 64, 65].

3.2 Sustainable projects

The influence of buildings on the environment is very clear. The buildings require significant resources for their construction, as well as for operation and maintenance. The built up environment accounts for almost 50% of emissions of greenhouse gases and a similar fraction of energy consumption and water [1, 3].

The issue of sustainability in construction has a link to sustainability in general, including problems of degradation of the natural environment, climate change and the greenhouse effect, for example, and has three basic aspects: economic, environmental and social. These aspects should be pursued consistently [3].

A clear objective in building renewal is to reduce energy consumption. Ham and Schamhart [13] argue that renewal allows for the utilization of existing infrastructure and structure, with less waste generation and lower energy consumption. Martínez-Camarero et al. [65] argue that renovation should include sustainable design features. Renovation is a form of recycling the building, which attempts to use the existing structure of the building and infrastructure in the region, with less waste generation and lower energy consumption in the life cycle of the building.

There are several available criteria and principles for measuring sustainability in construction, based on life cycle analysis, recycling of materials, components or construction and calculation of embodied energy [66]. The exploitation of natural resources significantly reduces the natural reserves of materials. It can be seen that the materials used in construction are greatly responsible for environmental impacts. There are several methods for environmental assessment, some of which have been developed specifically as a tool for selecting environmentally friendly materials and others that can function as such. They are classified into three groups: energy involved, instruments based on life cycle analysis (LCA) and identifying the impact through simplified procedures [67].

All materials have some environmental impact and there are no methods to accurately assess the full impact of a building. Individual analysis of the materials is complex. Energy embodied is the most important measurement for environmental impact assessment because the use of non – renewable energies is the main reason for global environmental degradation, e.g. global warming through CO_2 release - and other emissions that cause acid rain [68].

A significant amount of energy is consumed in the production, transport, and application of building materials. The choice of materials and components can be made, based on the analysis of the energy consumed in production. Embodied energy can be defined as the amount of energy consumed to produce a product, material or the construction itself. It may include raw material extraction to the distribution of the product in the market. The best materials consume less energy in their production processes and application in buildings [69].

Energy consumed in the built up environment can be divided into two categories: (i) the energy consumed in the production of construction, including the energy needed for production and material handling, assembly or application in the works; and (ii) the energy required for operation and maintenance of the building throughout its life cycle and for the demolition and removal of waste.

Moreover, there are large differences in energy consumption, due to technological differences within one country. In Brazil, some specific studies have been made, such as those of [71, 72, 73], but there is still a long way to go.

Given these characteristics and information obtained in the literature, embodied energy values were obtained from several references, preferably from Brazilian studies. Table 1 shows some values of embodied energy in some of the materials used in buildings, obtained from some studies [68, 71, 72, 73]. Embodied energy in these materials includes raw material extraction and transport to the construction site.

From Table 1 it is clear that steel, followed by cement, is the single largest consumers of energy. Yet for a proper analysis it is necessary to calculate the total quantities of each material. For this, the design of each building option is required. Furthermore, in a country of large dimensions, transport distances play a key role. For the specification of new materials the choice based on the energy involved in each option was adopted, considering also the costs and the need for resources in the life cycle [67].

Table 1: Embodied energy in some building materials on Brazil [b]

#	Materials	Density (ton/m^3)	Embodied energy (GJ/ton)
1	Portland cement	1,500	6,0 GJ/ton
2	Lime	1,500	5,6 GJ/ton
3	Sand (local)	1,500	0,0285 GJ/ton
4	Aggregate	1,500	0,15 GJ/ton
5	Steel – bar – partially recycled	7,800	16,7 GJ/ton
6	Steel – profile	7,800	30 GJ/ton
7	Galvanized steel - wire	7,800	33,8 GJ/ton
8	Nails	7,800	31,0 GJ/ton
9	Lumber	0,500	1,5 GJ/ton
10	Plywood	0,550	8,0 GJ/ton
11	Ceramic bricks - 10x15x20 cm	1,700	2,5 GJ/ton
12	Ceramic floor	2,000	5,0 GJ/ton
13	Ceramic tiles	2,000	6,2 GJ/ton
14	Gypsum wallboard	0,800	6,0 GJ/ton
15	Glass	2,500	18,5 GJ/ton
16	Acrylic paint	1,300	61,0 GJ/ton
17	Latex PVA paint	1,300	65,0 GJ/ton
18	Aluminium	2,700	98,2 GJ/ton
19	PVC	1,300	80,0 GJ/ton
20	Manufacture of mortars	1,250	0,0020 GJ/ton
21	Materials and manufacture of concrete	2,300	2,5 GJ/ton
22	Concrete transport and pumping	-	0,0050 GJ/ton

[b] **Sources: see text.**

3.3 Flexible projects

The repetition of the project can be considered as a cause of devaluation of low income housing. In general, the mass housing market is seen as low quality housing, monotonous and intended for low-income populations [27, 28, 29].

Kleinhans [74] recommended the diversification of housing types and the encouragement

of various economic activities (shops, offices, services), in order to attract a population with different socio-economic conditions. These are important initiatives to reduce crime and pollution and to expand and qualify the transport and urban infrastructure. Verhage [29] also maintains that building and urban renewal should encourage diversity of typologies to attract different people and thus reduce the possibility of segregation.

Another premise is that the building should accommodate users along its life cycle and not vice-versa. For this, the design must incorporate some degree of flexibility. The research line "Open Buildings" continues from the studies of Habraken [75, 76] and represents a strategy of design, construction and operation of the built up environment, looking for flexibility (increasing the ability to adapt to the changes that occur throughout the life cycle of a building). From this point of view, the building has basically two parts: shell (constructive form with durable characteristics) and infill (internal parts that can be constructed with lightweight materials and should provide flexibility for adaptation). This concept applies to new projects, where one can specify the structures, fences and building systems in a simple manner and yet, adaptation or renovation projects of buildings can (or must) take into account flexibility [76, 77, 78]. Studies have been made for the low income housing sector in Brazil, such as [79, 80, 81].

4. RESULTS: A SIMULATION STUDY IN PORTO ALEGRE

This part of the work presents a study on the possibility of renewal of a housing complex in Porto Alegre, Brazil. The investigation was conducted following the principles presented, through simulation of alternative projects with actual costs and market values.

The original projects usually follow a common pattern [19]. There is hundreds of this kind in Brazil and in many cases they are in dubious conditions or they have no requirements that families need today. It is important to think about collective solutions through a strategy that will allow differentiation of the properties without losing the characteristics of the housing estate.

To build the proposals, good examples of low income housing built in Brazil and other countries were considered [82]. It is important to note that the architectural quality of the project alternatives itself, is not discussed. In addition, a more precise analysis of a building renovation project must involve the users [12, 83].

4.1 Description of the housing blocks

The case study is about the Rubem Berta settlement, which is considered the largest housing settlement of the state of Rio Grande do Sul and one of the largest districts in the country. This district has a built up area of 8.7km² and about 80 thousand inhabitants. The occupation in this region began in the 1950s, to be formally established by a municipal law of Porto Alegre in 1968. It is a neighbourhood occupied almost entirely by vertical buildings. Figure 1 show an aerial image, where one can see the density of occupation in the neighbourhood, and a set of blocks in detail, with some façades. This set is located on the 22nd Street (“Rua Vinte e Dois”). It was completed in March 1980 with the economic financing of the BNH and consists of 4 blocks with 4 levels and 8 apartments per floor, within a total area of 5,872 m^2 and 128

units. The region has several blocks of similar size and standard.

Figure 1. (a) Aerial image and (b) façade – 22nd Street-Rubem Berta settlement.

Figure 2 shows the original floor design. It has three types of apartments: with one bedroom ($35m^2$), two bedrooms ($44m^2$) and three bedrooms ($56m^2$). Each level has $367m^2$, with 5 double bedroom units, 2 units of 3 bedrooms and a single bedroom unit. Construction is on a conventional reinforced concrete structure and masonry brick walls covered with mortar; the windows are built on steel tubes, the roof has asbestos-cement shingles, and the rooms have parquet in the non-private areas, and ceramic tiles in the utility areas. There is no lift in the building.

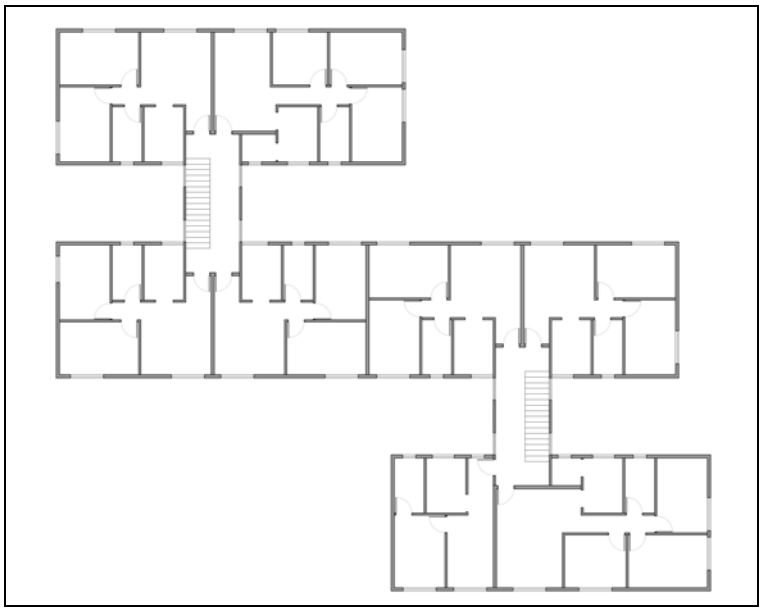

Figure 2. Original floor design – with 1, 2 and 3 rooms

4.2 Elements for viability study

(a) Cost and incorporated energy analysis

In Table 2 we present detailed budget and embodied energy actual estimates for one housing block (1,468 m^2). Then building costs to new building of this standard is about 550 Euros/m^2. On the other hand, general embodied energy was calculated and it is about 5.0 GJ/m^2. This figure is similar to obtained in other national studies [84, 85, 86].

Table 2: Budget and embodied energy component summaries – for one block (1,468 m^2)

Component	Cost		Embodied energy	
	€	%	GJ	%
Site Preparation	15,533.20	1.9	365.580	4.9
Foundations	32,300.00	4.0	164.639	2.2
Vertical and floor structures	161,480.00	19.9	987.834	13.3
External walls and interior partitions	68,629.00	8.4	1,870.319	25.1
Windows, doors and glazing	58,940.20	7.3	734.000	9.9
Roof structure, roofing and waterproofing	16,148.00	2.0	100.925	1.4
Floor, wall and ceiling finishes	85,584.40	10.5	550.500	7.4
External and internal painting	28,259.00	3.5	711.980	9.6
Stairs and vertical transportation	22,185.00	2.7	282.928	3.8
Plumbing and electric systems	95,223.20	11.7	1,247.800	16.8
Fire protection systems	44,407.00	5.5	179.530	2.4
Site paving and landscaping	20,985.00	2.6	252.750	3.4
Project, tax and management	122,150.00	15.0	-	0.0
Contractor's overhead and profit	40,370.00	5.0	-	0.0
Totals	812,194.00	100.0	7,448.784	100.0
Unitary figures	553.26 €/m^2		5.074 GJ/m^2	

(b) Market analysis

A pricing model for the corresponding property sector was developed, according to traditional procedures for hedonic pricing models. The coefficients of the regression equations are the implicit prices of each of these attributes, also called hedonic pricing or "shadow prices" which are the prices associated with each of the attributes of the buildings. The hedonic pricing models can be understood as a means of evaluating the requirements and preferences of the buyer indirectly. They can assist in feasibility analysis (estimating the total price) and the definitions of project (indicating the options as value-added).

The information about sales data was obtained from Sales Tax files in the Porto Alegre Tax Department and statistical analysis was developed with 24,577 sales data distributed in the period from 1998 to 2010. Data available has information about the following characteristics: sale price (Price), gross property size in square meters (Building_Area), property quality/building pattern – after Tax Department standards (Building_Standard), age in years (Building_Age), sale date and address. However, important characteristics such as the number of bedrooms and parking facilities were non-reported in original database.

A location variable was considered assigning the units to districts and using a measure based on household income, housing pattern and general quality of neighbourhood to each one (Settlement_Quality). The boundaries of the districts are legally defined in Porto Alegre (for administration purposes) and the measures were assigned using these constraints. Time of sale was included using a continuous scale of months, beginning in the month of the older sale in the sample (Sale_Month=1 to August 1998). The spatial positioning of the properties was considered using co-ordinates measured using a Cartesian grid with origin in the City Hall. The distances from main commerce places (Distance_to_Shopping_Centres) and from urban parks (Distance_to_Parks) were calculated, measured in kilometres. Sale price (Price) was originally in Brazilian currency (Reais), and was converted to Euros using exchange rate of July, 2011. Some statistical measures are presented in Table 3.

Table 3: Statistical measures of data collected

Variable	Type	Unit	Min	Max	Average	σ
Price	C	€	8,043.96	292,263.74	50,203.57	36,728.85
Building_Area	C	m^2	30.59	149.98	58.26	20.61
Land_Area	C	m^2	48.00	91,416.00	8,638.27	12,061.40
Building_Age	C	years	0	58	18.69	9.04
Sale_Month	C	months	1	147	75.88	37.72
Building_Standard	C	–	2	6	3.10	0.96
Settlement_Quality	C	–	13	23	16.99	1.65
Distance_to_Parks	C	km	0.39	5.44	1.92	1.10
Distance_to_Shopping _ Centres	C	km	1.68	8.35	4.69	1.31

The basic equation is as follows (Equation 3):

$$\text{Price} = (a_0 + a_1 * \text{Building\_Area} + a_2 * \text{Land\_Area} + a_3 * \text{Building\_Age} + a_4 * \text{Sale\_Month} + a_5 * \text{Building\_Standard} + a_6 * \text{Settlement\_Quality} + a_7 * \text{Distance\_to\_Parks} + a_8 * \text{Distance\_to\_Shopping Centres}) \quad (3)$$

Where: the attributes (characteristics of the property) are the above detailed, and a_i are the

coefficients to be calculated. The model in Equation 3 was estimated and adopted before being proven by the conventional tests, such as ANOVA, significance of the variables and behaviour of the errors. Cases identified with large residuals in both techniques were removed of analysis (using limits of 3 standard deviations, in view of large scope of data). The results of regression model are in Table 4. Some variables had non linear effect and we proposed squared root transformations.

Table 4: Behaviour of independent variables – dependent variable: $Price^{0.5}$

Variable	Coefficient	t [a]
Constant - a_0	73.59658	41.316
Building_Area	0.98101	323.144
$Land\_Area^{0.5}$	0.01836	4.449
Building_Age	-0.83540	-68.610
Sale_Month	1.02090	12.791
$Sale\_Month^{0.5}$	-4.21273	-5.754
Building_Standard	6.22984	47.526
Settlement_Quality	0.48867	41.980
Distance_to_Parks	-3.75147	-21.003
Distance_to_Shopping_Centres	-1.23628	-9.062

[a] All with <1% statistical significance

The coefficient of determination was considered. This ratio is an indicator of the accuracy achieved in the model. When it is equal to unity, the regression explains all the data. The coefficient of determination, adjusted for degrees of freedom, is $R^2_a = 0.906$, indicating that the model explains over 90% of the variability in sales prices.

The hypothesis of validity of the model was tested by analysis of variance, through the distribution of Fischer-Snedecor (F), which enables a conclusion about the significance or uncertainty of the regression model. The calculated value for this model is F_{calc} = 22,817.686, which exceeds the common requirements ($F_{0,05} = 1.88$), indicating that the hypothesis in the absence of the proposed relationship may be rejected.

The test of independent variables for the model was made by comparing the test statistic (t_{calc}) calculated for each variable against a parameter for the desired minimum level. For this sample and the variables, the critical value of the statistic is $t_{0,05} = 1.96$. When the statistical value calculated for each variable is greater than this value, the uncertainty (level of significance) is less than 5% and confidence in the inferred value is higher. In this case, the behaviour of the variables is shown in Table 4. All independent variables were accepted, with a confidence level over 95%, exceeding the normal requirements. This test also allows for the adoption of the model. The resultant equation, based on Table 4 and Equation 3, is as follows (Equation 4):

$$\text{Price} = (73.59658 + 0.98101 * \text{Building\_Area} + 0.01836 * \text{Land\_Area}^{0.5} - 0.83540 * \text{Building\_Age} + 1.02090 * \text{Sale\_Month} - 4.21273 * \text{Sale\_Month}^{0.5} + 6.22984 * \text{Building\_Standard} + 0.48867 * \text{Settlement\_Quality} - 3.75147 * \text{Distance\_to\_Parks} - 1.23628 * \text{Distance\_to\_Shopping\_Centres})^2 \quad (4)$$

The analysis of basic assumptions indicates no strong correlations between the explanatory variables. The coefficients are below 0.50, excluding the problem of multicollinearity. The residue analysis is also favourable. The standard error values are small, which indicates no statistical problems. Outliers were not detected in final sample. Graphical analysis of errors showed no breaks in the condition of normality. Finally, data sample and the time period are large in size, allowing for reasonable confidence about market behaviour coverage.

(c) Proposal

This study seeks to use the existing structure, while generating differentiation in the buildings. Alterations from the original floor plant have been proposed. The internal diversification of the apartments has been explored, recombining existing units to form lofts, horizontal and vertical duplexes, adding a greater variety of floor plans in the building (Figure 3). The project includes the expansion of the blocks, including a new level. The flexible plan allows residents of the building to change property type without changing their address. Thus, neighbourly ties are not lost and the community remains united. Energy analysis indicates a preference for metallic material (such as steel balconies) in view of the major recycling possibility, and design goes for this way.

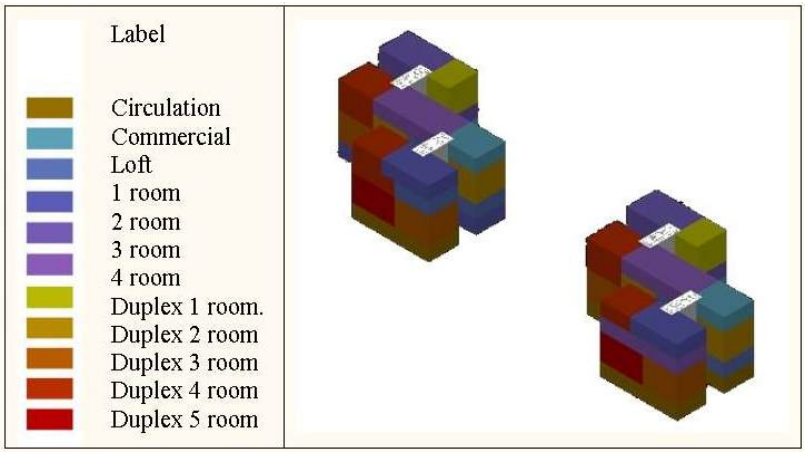

Figure 3. Different building types – Two block example

4.3 Façade renovation

The proposal adopts steel elements connected to the building's façade, including open or closed balconies. All the balconies incorporate barbecue equipment (grill), which is a very important element in local culture. The part of the balcony positioned side by side to the living room is open while the part at the side of the bedroom is s closed by a mobile brise (Figure 4). It was designed to obtain major environmental comfort for the bedroom, which

reduces sunlight and at the same time, permits fresh air circulation. The direction of the wind can be varied according to the needs of the residents, maintaining the same building pattern (Figures 4 and 5).

Figure 4. Different façade options – building with and without balconies; open and closed balconies

4.4 Fifth level addition and roof renovation

The project includes the expansion of the blocks, including a new level in some blocks. The original reinforced concrete structure is conventional. It is 30 years old and was calculated according to old customs and design rules, perhaps more demanding than today. The quality and status of this structure was checked through field inspections. It can be observed that the structure is too extra-dimensioned in relation to newer/contemporary concrete structures. Under these considerations, we concluded that a further layer can be added in the block without loss of structural performance. The income from the sale of new units may finance all the renovation work, but it was proposed as an independent project regarding first option. The differentiation of units can be made without undoing the basic features of the housing estate, which maintains a regular appearance (Figure 5).

Figure 5. Buildings with different levels – 4 and 5 stories

The roof also contributes to the upgrade of the facade. We propose two options for roofs. In the first, the cover remains as originally and on the other it is covered with a green protection producing a thermal effect for the last level apartments (Figure 6). This green roof collects rainwater for re-use, reducing user's costs. They have similar construction costs.

Figure 6. Roofs – Option A (conventional) and B (green roof)

(d) Viability analysis

The economic viability of the renovation project plays an important role. There are many different options of building renewal, but two options have been presented to examine the feasibility and to demonstrate the methodology of analysis. The first one is the simplest (assumed to be the most likely option in a real case): the inclusion of balconies with barbecue equipment, a very important element in local culture.

The costs were calculated by apartment (average by unit), and it was considered for the buildings with one or two/three bedrooms. Costs are about 9 and 11 thousand Euros per unit, respectively. Also was calculated the embodied energy for both options, and they are about 40 GJ for apartments with one room and 48 GJ for apartments with 2 or 3 rooms (Table 5).

In the sequence the added value was calculated using Equation 4. The market values for each apartment were calculated using the actual data of each type of building for the month of July, 2011. These values were obtained for the current state of the building ("original value" in Table 6). In a second stage, it is proposed lowering the age from 31 to 15 years and increasing the standard of level from 2 to 3, because updating and renovation of façade effects (compare Figures 1 and 5, 6). Change on age is related with the concept of "apparent age", as used in commercial appraisals [43]. The change of standard is justified by the addition of the balcony with barbecue equipment. In addition, the effect of increasing the area by the addition of the balcony was calculated. The calculated values for each unit are shown in Table 6 ("value with renovation"). Then "valorisation" was calculated by value with renovation minus original value. As the valorisation is greater than the costs, the economic viability is demonstrated. There is an advantage of about € 1,155 to € 1,975 per

unit with the renovation project (valorisation minus construction costs – on Table 5).

Table 5: Budget and embodied energy component summary – of façade renovation – average by unit

Rooms / Component	Simple (R1)			Double (R2) or Triple (R3)		
	Dimension	**Cost (€)**	**Embodied energy (GJ)**	**Dimension**	**Cost (€)**	**Embodied energy (GJ)**
Foundation – radier in concrete	3.5 m^3	900.00	8.750	4.0 m^3	1,000.00	10.000
Steel balconies: structure, floors and laterals	490 kg	3,950.00	14.700	650 kg	5,250.00	19.500
Aluminium brises	6.0m^2	1,350.00	3.000	8.0m^2	1,800.00	4.000
Interior changes (masonry, carpentry) – changes in windows, changes on the external walls	-	810.00	5.500	-	820.00	6.000
General painting	47.0m^2	910.00	7.990	49.0m^2	970.00	8.330
Project, taxes, management	12.5%	880.00	-	12.5%	1,120.00	-
Unit costs (€/residential unit) and energy (GJ)		8,800.00	39.940		10,945.00	47.830

Table 6: Economic analysis of façade renovation.

Apartment type	Original area (m^2)	Original value (€)	New area (m^2)	Value with renovation (€)	Valorisation (€)	Cost (€)	Profit (€)
Single room – R1	35.00	40,110	40.60	50,790	10,680	8,800	1,880
Double room– R2	44.00	43,730	53.50	56,650	12,920	10,945	1,975
Triple room – R3	56.00	48,790	63.50	61,400	12,610	10,945	1,665

The second analysis is about building expansion with the addition of a new level. Budget and energy summaries are in Table 7. As the premise adopted is that existing structure may support the fifth level, there are not costs on foundations, and structure costs are only for fifth level structure. There are some demolitions on roofs but lift and stairs have only adjustment costs. Budget includes external painting for all block. Results indicates costs and embodied energy a few better than original (as new) building.

Table 7: Budget and embodied energy component summaries – for one level (367 m^2)

Component	Cost		Embodied energy	
	€	%	GJ	%
Site preparation/demolitions	5,230.00	2.7	86.163	4.8
Foundations	-	0.0	-	0.0
Vertical and floor structures	40,335.00	20.7	222.070	12.3
External walls and interior partitions	17,157.25	8.8	420.822	23.3
Windows, doors and glazing	14,735.00	7.6	183.499	10.2
Roof structure, roofing and waterproofing	16,148.00	8.3	100.925	5.6
Floor, wall and ceiling finishes	20,396.00	10.5	131.192	7.3
External (all block) and internal painting (one level)	15,323.75	7.9	347.471	19.2
Stairs and vertical transportation	2,750.00	1.4	35.071	1.9
Plumbing and electric systems	18,550.00	9.5	243.078	13.5
Fire protection systems	9,055.00	4.6	36.608	2.0
Site paving and landscaping	-	0.0	-	0.0
Project, tax and management	25,277.50	13.0	-	0.0
Contractor's overhead and profit	9,792.50	5.0	-	0.0
Totals	194,750.00	100.0	1,806.899	100.0
Unitary figures	530.65 €/m^2		4.923 GJ/m^2	

Economic analysis was calculated using original area, age, and building standard (Table 8). There is some improvement on building appearance because of external painting, but the effects upon value are smaller than first option. Economic viability also is demonstrated in the second option of building renewal, with a profit of more than 160 thousand Euros. This economic surplus can permit the execution of the first option of renewal without need of user's contributions. Finally, one can conclude that proposal is sustainable, while embodied energy is a few smaller than to similar new buildings.

This new level follows several purposes: to differentiate the blocks (4 and 5 levels), provide different units of existing applications (eg, vertical or horizontal double unities, with different areas, adapted for people with special needs), and provide a financial gain to the building, creating a surplus that would overhaul and painting of the facades, and the inclusion of green cover, with use of water to the condominium (reducing the monthly cost of use). In this scheme, the addition of balconies would still like the option they chose, but with a lower cost. Other alternatives can be proposed, such as the following. It can also be proposed to use part of the new area for common uses such as laundry, which can also generate a gain (space) to all users of the building.

Table 8: Economic analysis of fifth level/green covering addition

Apartment type	Area (m^2)	Value (€)	Cost (€)	Profit (€)
Single room – R1 (x1)	35.00	40,100	18,573	21,527
Double room – R2 (x5)	220.00	218,650	116,744	101,907
Triple room – R3 (x2)	112.00	97,600	59,433	38,167
Totals	367.00	356,350	194,750	161,601

5. DISCUSSION AND CONCLUSIONS

The Brazilian housing estates developed during the BNH period were built from the late 1960s to the beginning of the 1980s, along with thousands of similar estates. Today some of them present opportunities for renewal. This study used simulation building renovation proposals with maximum use of existing infrastructure. Design alternatives with budgets based on real costs were developed. The cost of the building renewal project was compared with the predicted value calculated by hedonic price models. The hedonic model was based on a large data sample (in terms of size and time period), generating confidence about market behaviour coverage.

The renewal proposal adds differences to the housing estate. The overall appearance of a monotonous, repetitive complex, with equal blocks, as shown in Figure 1, is changed to a set that has common design features but which have different characteristics in each block, such as balconies (Figure 4), different heights (Figure 5), conventional or green roofs (Figure 6), and so on. In addition, there are buildings with different numbers of rooms, making it possible for families of different sizes to share the same urban space (Figure 3).

Sustainability analysis of the renewal project was performed after criteria defined above. Economic and energy feasibility was verified. The design process incorporated sustainability features with the analysis of energy involved - preference for materials of lower total energy and greater potential of recycling - and economic viability analysis, which confronted the costs of implementing the building renewal.

Feasibility has been demonstrated in both renewal options. Economic analysis also allows for conclusion by viability of the proposal. Besides being economic feasible to change the facades, in terms of benefit/cost (expansion of the market value is greater than the cost of works), was proposed an option to expand the building, adding a fifth level, which is also feasible. Design strategy allows for the differentiation of the blocks without discharacterization of the housing estate. This research has already shown that it is possible to renew old buildings and block designs with flexible design units with vertical or horizontal flexibility. The quality of life for the residents is improved with the addition of balconies and brises, and by improving the thermal comfort of the units.

However, the small difference among original and proposed projects (Tables 6 and 8) decrease the risk of gentrification, why not bring a significant enhancement to the property

in terms of market value. There is an improvement on quality of life, but properties maintain affordability and the target group is also not removed from their dwellings after the renovation.

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