

Physical feasibility study system for projects with a view to the decision making process

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Abstract – This research presents the modeling and implementation of an information system, called a "A Physical Feasibility Study - PFS." It considers information on the law for land use and occupancy in the city of Belo Horizonte, Minas Gerais, Brazil. The system simulates the PFS construction possibilities and profitability of a given site or region based on the standards and parameters of the land, a fact that directly involves the profitability of the project and the construction companies' decision-making process. It uses concepts and techniques of Building Information Modeling - BIM to model and simulate the construction possibilities. The PFS responds to questions (research questions) on how to define the short term profitability of a site in order to allow company managers to make the decision to invest or not in the purchase of a particular site. The first part considers the parameters and variables concerning the rules of urban works legislation in the municipality of Belo Horizonte. Next comes the analysis, design and development of the PFS system to simulate the possibility of the civil construction project. The system collects input data on the area, front, zoning, type of use and occupancy of the land and the road classification. These data are processed through consulting tables of parameters that form urban regularization and the law on land use and occupation in a region. The system presents output data on the utilization coefficient, occupancy rate, minimum permeable area, clearances and other parameters that dictate what can be built on the land and the topology of the buildings with all their internal areas and respective uses. It then sets out the possible construction options so that the user may choose the desired option. After this, with the definition of the construction costs, you have the profitability of the land. Cost definition is based on the definition of the standard cost amount per meter squared for construction, considering the standard finishing and real estate value in the region. In 58 seconds, the PFS system presents the parameters with information on what can be constructed and the cost of implanting the project. Finally, in order to validate the research and analysis of system functionality, a feasibility study and tridimensional simulation of 113 sites in the Belvedere neighborhood of Belo Horizonte were performed¹.

Information retrieval, information system , physical feasibility study, urban legislation, Building Information Modeling,

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I. INTRODUCTION

The theme of site/terrain physical feasibility study mobilizes professionals and companies in Brazil with the intention of achieving the best utilization of a given site, taking into consideration the multiple parameters that can directly influence construction. Mindful of the over-riding need for quick and precise information these days, it is important to strive for solutions that support the decision-making process.

This article involves the study, design and proposal for a physical feasibility study of building. The research considers concepts and techniques of three-dimensional simulation to evaluate and optimize the possibilities for construction in a given site, in accordance with the rules, master plans and legislation of a region's municipal government. A system that automates the physical feasibility study of sites was implemented. The result of the study generates project construction possibility reports that directly influence in the project decision-making process.

The object of this research is to develop an information system that, using the parameters of urban legislation, assists the manager in the decision-making process.

During research development, we implemented a prototype of a Physical Feasibility Study – PFS computer system that produces a report with the information that managers need to quickly answer questions such as: What are the project options that generate economic yield and better utilization of a particular site/region? What the profitability of the site/region?; What can be built on this site/region?; How many floors is it possible to build? In this context, an analysis of urban indices and occupancy guidelines of a given region can offer the best opportunities for projects by working on the maximum utilization of land for construction, and consequently by extracting socio-economic and environmental impact data with respect to the enterprise project.

Once the analysis parameters have been defined, other questions that arise are the difficulty in interpreting and analyzing these parameters within the context of maximum utilization of the land/site and the construction possibility calculations that meet legislative norms. One manner of reducing the possibility of errors is the automation of the physical implantation feasibility study process of the civil works project, through the database system with access programmed according to site data; this automation makes calculations and carries out studies in accordance with parameters stored in the database and the site's parameters. The

prototype uses database and graphic computing concepts and was developed in the VB/VBA programming language on the .NET platform.

To evaluate the results, a prosperous region in growth and with new urban paradigms was chosen in the Belvedere neighborhood. A feasibility study and tridimensional simulation of 113 sites/terrains was carried out in this neighborhood, located in the southern region of Belo Horizonte, capital of Minas Gerais State/Brazil, a state with 853 municipalities.

II. LITERATURE REVIEW

This research developed a feasibility analysis model for works implantation in accordance with the real estate sector dynamic. According to Gonzalez [1], this sector shows differentiating characteristics, such as the strong influence of location and the diversity of assets, as well as operating under a regime of imperfect competition, which generates problems in the study of feasibility, subjecting the process to evaluation errors and a resultant fall off in the utilization of a site's economic potential.

To explain and evaluate the main theories connected to the study of urban politics, Kelvin [2] clarifies what the methodological approaches are in the urban filed.

Within this context, city expansion planning is necessary, in the sense of achieving the full development of social functions and ensuring the well being of city inhabitants. Based on this, one of the strategies defined to address this situation is through the adoption of specific legislation. With the accelerated growth of large cities, such as São Paulo, Rio de Janeiro and Belo Horizonte, the need arose to control the planning of this growth as a form of ensuring better housing development conditions. For Belo Horizonte, one of the instruments of urban control is the Urban Legislation Applied to Building Projects - laws on the use and occupancy of land.

For Weber [3], the study of typologies becomes important, since as well as indicating the project criteria adopted in a certain time and place, it can serve as parameter for the feasibility studies, in relation to decision making for the implantation of new buildings.

Building Information Modeling - BIM is a new approach that uses a 3D computer model, with semantic contextual intelligence for the spatial coordination of conception, construction and management of buildings. The model contains information related to physical and functional construction in order to facilitate the integration, inter-operability, exchange, and reutilization of information by different users during the life cycle of a building, besides allowing for different visions and data analysis according to the digital information available. [4, 5, 6,7]

To evaluate results, a prosperous region in rapid and large scale growth was chosen, questioning the urban parameters of Belo Horizonte: the Belvedere neighborhood.

Interface and usability techniques were analyzed and utilized, with the objective of making the system easier to use. According to Nielsen [8], usability is an important factor that

aims to measure ease of use: Usability is the characteristic that determines if the handling of a product is easy and quickly learned, not easily forgotten, does not provoke operational errors, offers a high degree of satisfaction in its users and efficiently resolves the tasks for which it was designed.

In current methods, measuring the ease of use level of an application is very important both for the developers, who may evaluate the content developed, and for the end users, who have the opportunity to evaluate how easy the content is to use, check if the operations can be carried out promptly and supply feedback to developers so that there is continuous improvement.

If an application is easy to use and accessible, it means that the user can navigate and consult the content, learn quickly, memorize easily and make fewer errors during operations.

The municipality of Belo Horizonte is divided in five regional administrations: *Oeste*, *Venda Nova*, *Pampulha*, *Centro-Sul* and *Noroeste*. The *Centro-Sul* region is made up of 49 neighborhoods, has a total area of 32.49 Km² and a population of 260,524, according to City Council data. Managed by the *Centro-Sul* Municipal Regional Administration Department, the region was divided in 13 planning units (PUs). The PUs are spatial units that bring together one or more neighborhoods, with homogeneous land occupancy characteristics and respecting physical, natural or constructed barrier limits.

The Belvedere neighborhood is in the *Centro-Sul* region, in the Belvedere PU. Its privileged location allows direct access through the region's busiest roads: direct access to the highway ring roads, an access channel that surrounds the city with exits to the principal regions of Brazil, including Federal Highway BR-040, which links Brasília to Rio de Janeiro; the MG-030 State Highway, which connects Belo Horizonte to Nova Lima; and the *Avenidas Raja Gabaglia*, linking the neighborhood to the center, and *Nossa Senhora do Carmo*, linking the neighborhood to *Savassi*, an important point of commerce in the region. The neighborhood is located near the *Serra do Curral*, one of the most scenic landscapes of Belo Horizonte, considered one of its symbols. As such, Belvedere is implanted in an up-market area of the city with an infrastructure boasting complete services, leisure, public road connection, as well as natural beauty.

According to Amorim[9], another positive characteristic of the area is the services infrastructure, with large scale commercial ventures, such as the BH and Ponteiro Lar Shopping Malls, as well as super markets, car dealerships, building material outlets, specialized hospitals, among other services, such as banks, bakeries and fruit and veg shops.

To simulate urban growth, according to Baracho[10], the utilization of tridimensional parametric modeling generating the information system involves software utilization. Normally, the parameters should be adapted to local norms and conditions where the Project and construction will be executed. Implantation of the system makes it necessary to carry out interoperability tests in order to verify if the exported data can be used directly.

III. BH LAND USE AND OCCUPANCY LAW

The first part of the research project may be defined as an information survey phase in which information is gathered on the relevant urban land use and occupancy law, and the technical manual on urban works legislation for Belo Horizonte/MG. This information forms the consultation base for the calculations to be done by the information system. In this first part, a study of specific legislative terms was developed in order to create concepts for the interpretation of information contained in legislation for use in project development.

The legislation applied to building projects supplies the data in chart form. These charts are divided according to the zone, roadway classification and site use, whereby the data varies according to these parameters.

Legal consultation begins with the identification of a given site. Based on chart consultation, you have the zoning classification (Figure 1). Zoning is a fundamental unit of legislation and is a widely used instrument in master plans, where the city is divided into areas to which differentiated guidelines for land use and occupancy are applied, especially urban indices.

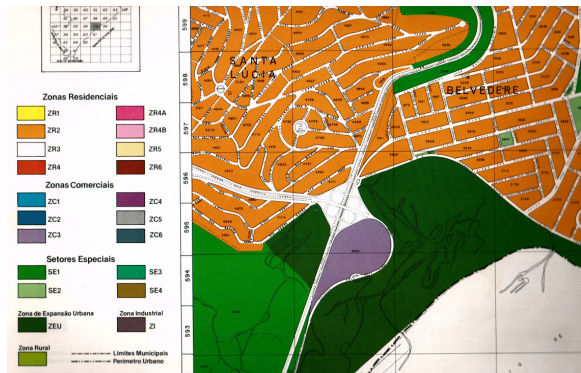


Figure 1. Zones defined by law.

Source: Urban land use and occupancy in Belo Horizonte

With the identification of zoning and use, through consulting the “Zones, Categories of use, Settlement Models”. you arrive at the settlement model that may be utilized. The settlement model defines the parameters to be applied in relation to minimum number of car parking spaces, minimum permeabilization rate, minimum frontal distancing, maximum height of division, minimum side and rear distancing, maximum utilization coefficient and maximum occupancy rate. The parameter for car parking spaces indicates the minimum number of spaces the building should have according to the locality, site area and the use and type of building. The rate of permeabilization indicates the percentage of the site that must be reserved for water absorption by the soil, an area that may not be waterproofed or built on. Minimum frontal distancing indicates the minimum distance that a construction must maintain from the frontal limit of the site. Maximum height of the division defines the height of the building, preserving, for example, heights compatible with the ‘Serra do Curral’, the mountain that borders the Belvedere neighborhood. Minimum side and rear distancing complete this. Maximum utilization

coefficient is the number that, multiplies by the lot area, indicates the maximum quantity of squared meters that may be built on in a lot, adding up the area of all floors. The maximum occupancy rate is the percentage between the building design and the site area. In other words, it represents the percentage of the land that it is built on.

IV. PHYSICAL FEASIBILITY STUDY - PFS

The second part of the project entails the drafting of VB/VBA programming language concepts with the aim of the theoretical arsenal to develop the programming techniques necessary for the creation of a prototype. The VB/VBA language was chosen as it was more efficient in the development user graphic interfaces and had certain applicability with respect to the possibility for application connection and CAD software.

A database was implemented with the possible situations considering the municipality of Belo Horizonte/MG. The database was used to implement data and charts considered as a set of inter-related information, referring to one same subject and organized in a useful manner, with the proposition of serving as a base for the user to recover information, draw conclusions and make decisions.

The database in question has information such as: minimum number of car parking spaces, minimum permeabilization rate, minimum frontal distancing, maximum height of division, minimum side and rear distancing, maximum utilization coefficient and maximum occupancy rate.

The PFS starts on a welcome screen with the names of the researchers, the project name, and the name of the research financiers (Figure 2). The system has an easy to use interface.

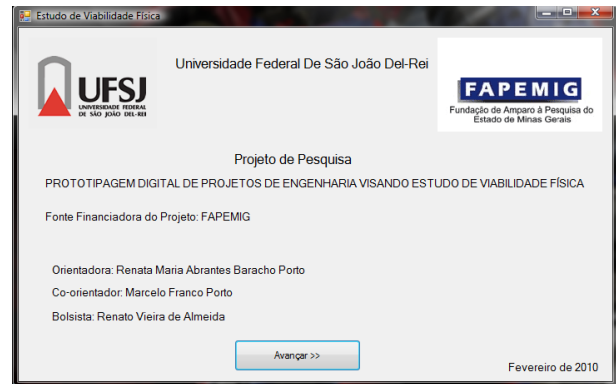


Figure 2. Opening screenshot of the Physical Feasibility Study System - PFS

Source: Prepared by author.

The PFS system is divided into three stages and a report module; the first stage is called ‘Site’, the second ‘Building’ and the third ‘Profitability’. Each stage makes calculations related to their respective parameters. The three stages are available through the upper menu and its respective tags.

In accordance with the previous section on land use and occupancy law for Belo Horizonte, the necessary variables for data input in the system are defined, through consultation. The variables that need to be defined by the user are: site area, size of site front, type of use, zoning and roadway classification.

The PFS system shows the possible site uses through a consultation of legislation regarding possible uses for a given site. The user then chooses a type within the possibilities shown by the system.

The user starts to use the system through the Site tab, and then fills out the boxes in the order they appear. In the first tab, the program has compulsory data entry boxes: user name, site area, size of site front, site use, zoning and roadway classification of site – the other input data is optional (Figure 3). Figure 3 has the definition of variables on the left, and the frame with report of calculated parameters on the right hand side.

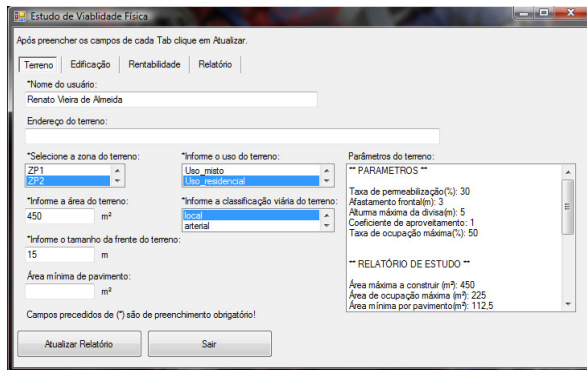


Figure 3. Physical Feasibility Study – EVF: Site tab. Source: Prepared by author

In this table the program provides output data. Parameters supplied by the database consultation: minimum permeabilization rate, frontal distancing, maximum height of division, utilization coefficient and maximum occupancy rate; an initial study report: maximum area to construct; area of maximum occupancy; minimum area per floor; permeable area; construction options: number of floors; area of each floor; construction height (H); minimum number of parking spaces. The second program tab, Building, uses the construction options calculated in the Site tab as input data. The user chooses the option of preference and a table automatically appears with distribution by compartment for that floor. The user can make simulations and change or compare the area occupied by the distribution generated with the maximum area per floor (Figure 4).

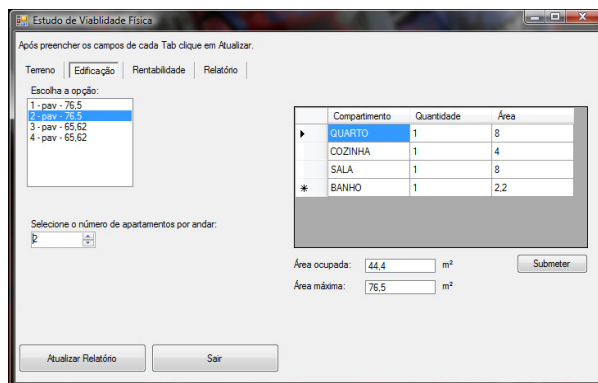


Figure 4. Physical Feasibility Study – PFS: Building Tab Source: Prepared by the author

In the third tab, Profitability, the users enters the meters squared construction amount in the site region, normally stipulated in a chart and released in specialized media on civil construction. The PFS system calculates the construction cost of each floor and the total cost of the works (Figure 5).

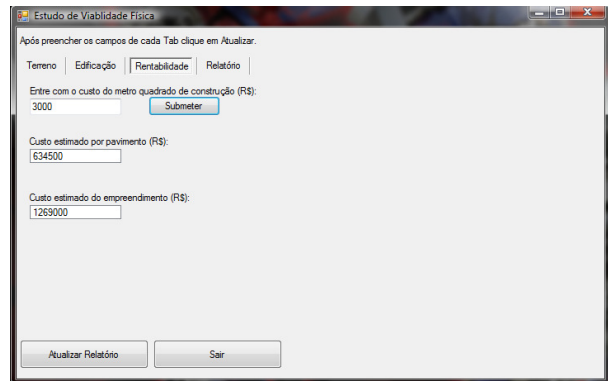


Figure 5. Physical Feasibility Study – PFS: Profitability Tab. Source: Prepared by author

The final report appears as the result of the study and the calculations executed by the PFS system. In this report, all the data generated by the PFS system are shown, as well as all the relevant information contained in the urban legislation database. Figure 6 shows the screen with report. The PFS system generates a report with all the parameters and calculations showing the result for site profitability.

Another result is the use of the report to simulate urban growth and generate supplemental data for studies on regional growth and social, economic and environmental impacts in a region. As research methodology strategy, a simulation of how to use the system was performed in a region of Belo Horizonte. The choice of the Belvedere neighborhood, in Belo Horizonte, as object of the study was made due to its rapid growth and the impact caused in the region. The speed of growth and real estate speculation provoked great debate between professionals involved in urban growth and buildings.

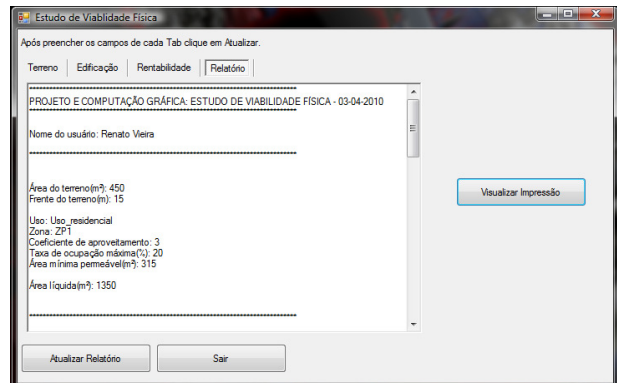


Figure 6. Physical Feasibility Study – EVF: Report Tab Source: Prepared by author.

Initially, a feasibility study of part of the Belvedere neighborhood was done; the neighborhood’s zoning and the region’s plan were researched. The plan was acquired through a consultation with the data processing company PRODABEL,

Belo Horizonte, who are in charge of this information. The plan was transferred from pdf to CAD 2D format.

With the information generated by the PFS system, a simulation of the constructions within each lot was created, so as to modify the 2D plan and obtain a tridimensional - 3D simulation (Figure 7), in which you have a tridimensional virtual image of a part of the neighborhood; this view shows blocks that simulate the constructions with maximum possible utilization of the site.

Based on the definition of a set of lots in the Belvedere neighborhood, the PFS System was used to generate charts with information on the number, address, area and front of lots; the construction options possible were simulated, with the definition of numbers of floors, area of each floor and total construction area. The estimated project cost is related for each one of the options.

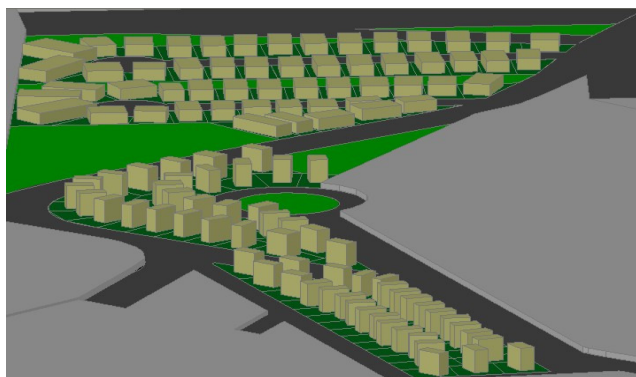


Figure 7. Tridimensional simulation, result of PFS system – View 1. Source: Prepared by author.

V. RESULTS

A step by step simulation carried out with the PFS System is shown below for the number 11 lot, located at Rua Juvenal de Melo Serra, Belvedere. The result of this simulation is described in the example that follows and the data summarized in Chart 1.

Input parameters – Site Tab: Area: 528m², Front: 16.5m, Zoning: ZP3, Use: Residential, Roadway classification: Local, Output parameters – Site Tab: Utilization Coefficient: 1.5, Maximum occupancy rate (%): 50, Minimum permeable area: 158.4m². These parameters generate nine construction options as defined in floor numbers 1 to 9 (Chart 1)

Chart 1 – Physical Feasibility Study, study of 1 lot

Floor Num.	Floor Area	Area to Construct	Height	Num. Spaces
1	264.00	246.00	2.90	1
2	264.00	524.00	5.8	2
3	264.00	792.00	8.7	3
4	198.00	792.00	11.60	4
5	158.00	790.00	14.50	5
6	132.00	792.00	17.40	6
7	113.00	791.00	20.30	7
8	99.00	792.00	23.20	8
9	88.00	792.00	26.10	9

Input Parameters – Building Tab: Choice of option generated: 2; Number of apartments per floor: 1; Compartments: 1 BEDROOM - 8m²; 1 KITCHEN - 4m²; 1 LIVING ROOM - 8m²; 1 BATHROOM – 2.2m²; Observation: The values shown for each compartment are minimum default amounts obtained based on Urban Legislation Applied to Architecture Projects.

Input parameters – Profitability Tab: Cost per meter squared of construction in the region: R\$ 1,200.00; Observation: the cost per meter squared of construction in the region was obtained from the Belo Horizonte Municipal City Council. Output parameters – Profitability Tab: Cost per floor: R\$ 316,800.00; Total project cost: R\$ 633,600.00.

In order to validate the PFS System, 113 simulations were carried out according to the example above. Lots in the ZP2 zone of Belvedere were considered. A second analysis was done in the ZP3 zone varying the number of lots between 1 and 4, these lots to be linked, creating a larger lot with an area equal to the sum of the areas of the adjacent lots. This second analysis was done so that the area of the lots would allow for larger buildings to be simulated.

Input parameters – Site Tab: Area: 1056m², Front: 33.0m, Zoning: ZP3, Use: Residential, Roadway classification: Local, Output parameters – Site Tab: Utilization co-efficient: 1.5, Maximum occupancy rate(%): 50, Minimum permeable area: 316.8m². These parameters generate 14 construction options according to the definition of floor numbers 1 to 14 (Chart 2)

Chart 2 – Physical Feasibility Study - PFS, study of 2 lots.

Floor num	Floor Area	Area to Construct	Height	Num. Spaces	Cost R\$
1	528.00	528.00	2.90	1	633,600.00
2	528.00	1056.00	5.80	2	1,267,200.00
3	528.00	1584.00	8.70	3	1,900,800.00
4	396.00	1584.00	11.60	4	1,900,800.00
5	316.00	1580.00	14.50	5	1,896,000.00
6	264.00	1584.00	17.40	6	1,900,800.00
7	226.00	1582.00	20.30	7	1,898,400.00
8	194.00	1552.00	23.20	8	1,862,400.00
9	176.00	1584.00	26.10	9	1,900,800.00
10	158.00	1580.00	29.00	10	1,986,000.00
11	144.00	1584.00	31.90	11	1,900,800.00
12	132.00	1584.00	34.80	12	1,900,800.00
13	121.00	1573.00	37.70	13	1,887,600.00
14	113.00	1582.00	40.60	14	1,898,400.00

The program generates the profitability calculation of implanting such works. Along with this, the environmental impacts of the works may be calculated, since based on the parameters of the site and the zoning, we can define, for example, the rate of water absorption by the soil in the site analyzed; as a consequence of a study such as this, one could rethink the structural policy of works for sanitation and channeling of rain water, generating the consequent reduction of flooding points, the improvement of social conditions of the

population and a reduction of public money being spent on sanitation and health.

A physical feasibility study digital prototype was constructed for part of Belvedere neighborhood, as shown in Figure 11, seeing as tridimensional visualization is a very useful tool in the context of data analysis when dealing with the works process and civil optimization.

VI. CONCLUSION

The study offers a new method for information retrieval based on visual content for architectural/engineering projects and starts an innovative line of research. With the Physical Feasibility System – PFS, in just 58 seconds, you can get the physical feasibility study result for a site in which you can find out all the construction and site parameters, simulate the construction options possible, as well as the project cost. A study of a block with 28 lots may be executed in 27 minutes and 4 seconds; that is, a study that would take days to complete without using this automated method. The expected research objective of using graphic computing techniques and a digital prototype to optimize and consistently improve the study process of civil works projects and physical feasibility studies of sites was achieved. In doing so, we built a physical feasibility study prototype for sites, with part of the Belvedere neighborhood, in Belo Horizonte/MG serving as digital prototype. Through this digital prototype you can simulate and calculate project parameters, creating a model and a general scheme for optimizations in project development. A physical feasibility study prototype was implemented with the development of a computational system in VB/VBA language; simultaneously, the architectural project of part of the Belvedere neighborhood was implemented using graphic computing software. The digital prototype was done with a tridimensional simulation of the architectural project; Reports on studies and final results for feasibility study possibilities were prepared, and through the simulations and calculations performed, information on the parameters and possible options that interfere, or could interfere, in the project concept was gathered.

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