Methodology Applying PBL and ICT as a Didactic Teaching Strategy for the Design of Vertical Circulation Cores in Hybrid Buildings

Cinthya L. Butrón Revilla [1], Alejandra Carrillo Pinto[1] and Raúl Carlos Javier Damiani Najarro[1]

[1] *Universidad Católica de Santa María, Urb. San José s/n Umacollo, Arequipa, Arequipa, Perú*

Abstract

The didactic methodology is presented as an opportunity to innovate teaching strategies in the Final Project (PFC) course at the Professional School of Architecture (EPArq) of the Catholic University of Santa Maria de Arequipa, Peru (UCSM). This subject is theoretical-practical. Its achievements contribute to the specific competence of planning and design, for which the student develops the ability to develop urban architectural projects that meet social, technical, and aesthetic requirements. This methodology is part of a model that combines two components: problem-based learning (PBL) and information and communication technologies (ICT). The main objective is to develop students' critical-analytical thinking and promote responsibility for their learning using collaborative analysis worksheets designed based on PBL didactic tools and the implementation of ICT. Among the results obtained, the coordination in the architectural design and the collaborative work in the study of the problem, which in this case is presented as the design of the vertical circulation of hybrid buildings, stand out. It is concluded that the implementation of this teaching strategy allows for establishing a logical order in the analysis of vertical circulation axes, as well as supporting the design criteria of a hybrid building, which is considered an architectural device of complex functionality, which allows revitalizing urban centers and potentiating urbanity in contemporary cities.

Keywords

Methodologies, PBL, Hybrid buildings

1. Introduction

According to the needs of the new scenarios evidenced within today's technological development, the architecture career seeks to ensure the formation of competitive professionals. Therefore, the educational system currently faces the challenge of incorporating information and communication technologies (ICT) to support the work of teachers and students in learning and the acquisition of specific and general competencies. In addition to this framework, the incorporation of didactic proposals such as problem-based learning (PBL) is one of the ways of experimenting with educational innovation. In this sense, the present research shows the pedagogical experience developed in the End-of-Course Project (PFC) subject at the Professional School of Architecture (EPArq) of the Catholic University of Santa Maria de Arequipa,

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cbutron@ucsm.edu.pe (C. Butrón-Revilla); ccarrillo@ucsm.edu.pe (A. Carrillo-Pinto); rdamiani@ucsm.edu.pe R. Damiani-Najarro)

0000-0002-5485-9772 (C. Butrón-Revilla); 0000-0002-8531-0045 (A. Carrillo-Pinto); 0000-0002-1754-9513 (R. Damiani-Najarro)

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Peru (UCSM). This subject fulfills the specific competence of planning and design, for which the student develops the ability to develop urban architectural projects that meet the social, technical, and aesthetic requirements of a civic context.

The objective of the academic work is that the student achieves the ability to analyze and interpret regulatory and functional aspects relevant to the design of the vertical circulation axes of a hybrid building located in the Industrial Park of the city of Arequipa. Taking into account the degree of complexity of architectural work, especially when assuming the challenge of designing a hybrid building, which is considered a device to revitalize urban centers and an enhancer of urbanity in the contemporary city, since it houses a diversity of activities. In this context, it is transcendental for the chair to put into practice the knowledge acquired by the students related to the design of circulations and their impact on the functionality of a building that houses a diversity of activities.

For this didactic methodology that combines PBL and ICT, five instruments were used: (i) insertion diagrams, (ii) scale diagrams, (iii) diagrams of programmatic relations, according to four criteria: capacity, relation of activities, anchor activity, intensity, and frequency of use; (iv) diagrams of calculations to measure the capacities of the vertical circulation core, according to four specific environments: lobbies, stairways, elevators, and parking lots; and (v) isometric diagrams of the location and functionality of the vertical core. From the proposed methodology, the results obtained show the ability to recognize the five instruments to design the vertical circulation core of a hybrid building, the ability to program and find programmatic relationships in the design of the vertical circulation core of a hybrid building, and the ability to synthesize and communicate the proposal.

1.1. PBL in architectural design education

Problem-based learning (PBL) is a good methodology to break the vicious circle of general desires and principles about teaching and to be able to experiment with educational innovation [1]. Moreover, PBL allows the development of creativity, systematization, and technical skills through the application of research tools that contribute to the creation of architectural composition projects, putting at the center of decisions the social needs and hopes of the user or target audience [2]. In this sense, for architectural design, ABP learning is key, since solutions to the needs of a society are born from the design workshop subjects [3]. It is in this context that teachers must train professionals with the ability to address social problems through critical, analytical, and creative thinking.

The learning methodologies proposed by the PBL show that students are committed to the problem and are aware of the needs and shortcomings that are established through it. However, the practice of the PBL methodology inverts the current order of a class session, which implies teaching the master class first and then elaborating the practice with the contents extracted from the lesson. The order of a practical class based on PBL techniques presents the reverse order in the following three stages: the statement of the problem, the analysis and identification of the needs, and the search for the theoretical contents necessary for the resolution [1]. In addition, PBL presents the following particular characteristics that differentiate it from traditional methods: learning is student-centered, it is an active method with constant student participation, and the result is enhanced by collaborative work in small groups where the teacher is the facilitator of the learning process.

It is important to emphasize that in the application of PBL in architectural design, there is evidence of multiple solutions; therefore, it is different from what is theoretically proposed. For example, the most useful problems in medicine are those that seek a clear and specific solution, a diagnosis, while in architecture there is not a single valid solution but a multitude of them for the same problem, so that in the design workshop subject the relationship with the various technical modules is strengthened, replicating this way of working in professional studies [1]. The achievements evidenced in architectural design workshop subjects have shown that the application of PBL has a direct and significant relationship with the learning capabilities of 99.8% of students. Likewise, project-based learning has a direct and significant relationship with students' teaching skills of about 99.1% [4]. In addition, the application of active and updated methodologies allows us to reach learning competencies that meet today's needs.

1.2. PBL and ICT as a strategy for educational innovation

We can consider the technological appropriation and use of ICT as a teaching and learning tool that enables teachers and students to integrate new knowledge and skills [5]. However, this is only possible if teachers understand the meaning of technology use and recognize its usefulness in their teaching experiences, including material preparation, digital information management, content presentation, and effective communication with students [6]. dditionally, providing experiences that facilitate the implementation of tools in real-life situations and ensuring their proper use allows for the development of specific competencies in a given subject.

When analyzing the application of PBL with the integration of ICT in university teaching, particularly in the field of architecture, notable experiences at universities such as Delft (Netherlands) and Newcastle (Australia) stand out. These experiences demonstrated diverse and successful results resulting from methodological innovation. The aim is to create a context in which the educational process is enriched, utilizing Problem-Based Learning (PBL) supported by new communication and information technologies (ICT) [7]. his methodology involves the use of technological tools to enhance both the educational and assessment processes, thereby providing students with an experience closely aligned with reality [8]. ermore, as students become familiar with new technologies, the design of learning tools based on technology fosters an attractive and stimulating teaching experience, promoting independent student learning.

The methodological theories that have applied PBL have paved the way for innovation with the theory called project-based learning (PBL), a teaching method centered around the student as the protagonist of their learning. This entails a series of problem-solving tasks through the autonomous involvement of the student in the research process, culminating in a final product presented to the workshop [9]. Furthermore, the implementation of ICT in this process enhances the level of knowledge of students and aligns them with societal demands within the field, making it a significant teaching tool for achieving learning outcomes [10], However, for this to be realized, university teachers are required to reinvent themselves as educators, recognizing that universities serve as incubators for new teaching methodologies [11], and therefore need to prepare for the arrival of new generations demanding non-conventional education with participatory teaching strategies and ICT management.

The paradigm of the design method, both in teaching and professional contexts, has been impacted both positively and negatively by technological progress. The advent of personal computers and specialized programs has replaced manual activities in the design method [11], however, the systematic method known as PBL (Project-Based Learning) endorses the design method as a teaching and learning approach. PBL supports the acquisition of learning skills in architecture students, fostering practical skills for realizing the final product and stimulating self-study, information retrieval, presentation development, teamwork, time management, and effective communication [9]. The dynamic teaching and learning process, along with appropriate teaching materials and process-based and product-based assessment, play pivotal roles in this educational context.

1.3. The design process in hybrid buildings implemented PBL and ICT

he design process for hybrid buildings, implemented using problem-based learning (PBL) and ICT, must be understood within the context of the evolving teaching-learning process. This evolution addresses the opportunities that technology opens up, extending beyond the physical constraints of space and time [5]. Considering the urgent virtualization of university education prompted by the pandemic, it is crucial to implement educational reinforcement devices to enhance the techno-pedagogical skills of teachers in architecture and graphic design programs, while accounting for the didactic peculiarities of project-based disciplines [12]. In this sense, architectural design education is based on strategies that demonstrate the use of ICT by students, especially in specific architectural projects [13]. Furthermore, the planned and strategic development of classroom activities promotes learning [14], by applying the implementation of analysis sheets or representation diagrams.

Architectural design does not begin when manufacturing tools come into action, but rather it begins in the design process [15]. The design itself is a continuous process of selection and organization of elements, trying to establish which ones are the most important and how all of them could play a role in creating the new product, inevitably leading to changes in ideas as possibilities are added or discarded and different proposals are conceived and considered [16]. The typical design development process involves the following actions: analysis, synthesis, evaluation, and feedback, noting that these actions are cyclical and non-linear. Therefore, when faced with the challenge of designing a complex conceptual building, the design process should propose strategies to effectively address each stage [17]. This is the case of the hybrid building, which has two fundamental characteristics: its spatial proposal, which is intimately related to an understanding of the program that goes beyond the form-function dichotomy; and its integration into the urban fabric, making it a building with a public vocation par excellence [18].

The ability of hybrid buildings to address a wide range of contemporary issues has made them popular in recent decades. Architect Steven Holl has investigated the study and design of these buildings, recognizing their potential as condensers of activity and urbanity. In the design process, Holl uses porosity as a tool to integrate architecture and urbanism [19] generating structures capable of reproducing the intensity and complexity of the city, which has complexified the way circulation and accessibility to buildings are designed [18]. This highlights the complexity in the design process, as the circulation of a conventional building is approached from conventional diagrams and organizational charts; however, the circulation design of a hybrid building requires

greater complexity in functional, spatial, and formal analysis. As can be seen in the figure below, the typical design process is developed from analysis, synthesis, evaluation and feedback using tools such as diagrams, calculation tables or programmatic tables. However, the design process that starts from a complex conception, such as that of a hybrid building, requires the development of integrated problem identification, establishing a hypothesis, identifying objectives, synthesizing the research and discussing the process, using specific diagrams for each action.

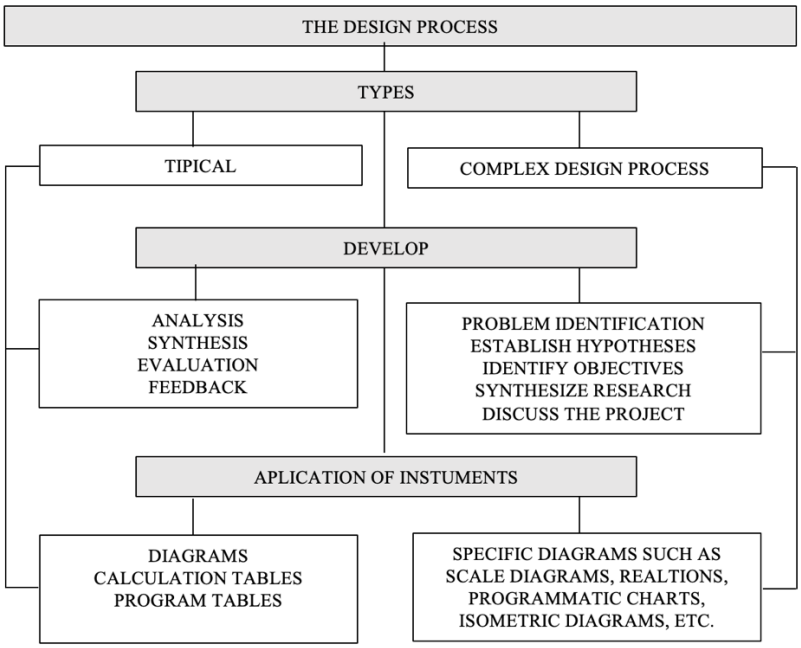

Figure 1: Tipical vs. complex design process

2. Methodology

The methodology is based on combining PBL methods with ICT tools. This methodology identifies that in the PBL process, there are two types of problems: open and structured. An open problem is characterized by not having a clear solution and therefore requires in-depth analysis and debate by the student. Whereas a structured problem follows a sequence of what will be investigated. In this process, the student is given a structured problem indicating the sequence of analysis to propose the vertical circulations of a hybrid building. Furthermore, literature on PBL processes indicates that there are several methods to work in the classroom [13]. uch as the 7-step method, the 8-step method, the 9-step method, and the 5-phase method, each of which is described in Table 1. Enclosed, please find Table 1. This combined methodology that addresses the hybrid building design process implements the 5-phase method. Supported by recent studies [16,17] where it is indicated that the design process is developed around the analysis and identification of the problem and design objectives, as well as the investigation, synthesis, appraisal, feedback and discussion of the designed projects.

On the other hand, this methodology also combines the relationship with the constructivism of ICT tools, which promotes collaborative work, information search, and interaction among individuals within the teaching-learning activity [13]. The following ICT tools are used in the teaching-learning process according to some authors: internet browsers, technological devices (laptops, mobile computers,

projectors), word processors (text editors and text creators using technological devices: office package, Libre Office, etc.), spreadsheets (data organizers using tables), video conferencing platforms (virtual real-time intercommunicators such as Microsoft Teams, Zoom, Meet, etc.), bibliographic databases (scientific article database storages such as Scopus, Scielo, Direct Science, Google Scholar, etc.), educational platforms (tools that incorporate resources for the teaching-learning process such as Moodle, Classroom, Edmodo, Mahara, Docebo, etc.), social networks (web pages and applications to interact and share information such as Facebook, WhatsApp, LinkedIn, etc.), data storage (applications to save data on the internet such as Dropbox, MEGA, MediaFire, Google Drive, etc.), presentation designers and graphic organizers, editors and presentation creators such as Power Point, Canva, Genially, Prezi, Cmap, Edraw, etc., Computer Aided Design (digital tools for technical drawing such as CAD, Sketchup, BIM, Autodesk Inventor). From this relationship, the most used tools in the design process are word processors, spreadsheets, presentation designers and graphic organizers, editors and presentation creators, and computer-aided design, with each tool described in Table 2.

Table 1
Types of PBA methods

Method of the 7 jumps	Method of the 8 steps	Method of the 9 steps	Method of the 5 phases
1. Problem Statement 2. Classification of the important terms of the problem 3. Problem Analysis 4. Possible explanations/hypotheses of the problem 5. Determination of subject matter and learning objectives 6. Consultation of literature or subject matter experts 7. Final discussion and hypothesis verification	1. Exploration of the problem and creation of hypotheses 2. Attempting to solve the problem with previous knowledge. 3. Identification of knowledge needed to solve the problem 4. Defining learning objectives 5. Preparation and study 6. Socialization of information among the group 7. Application of the new information to solve the problem 8. Evaluation of the process, knowledge and resolution of the problem	1. Preparing students for PBA 2. Problem presentation 3. Defining what is known and what is not known to address the problem 4. 4. Define the problem statement 5. Collect relevant data 6. Form possible solutions to the problem 7. Evaluate the solutions formed 8. Evaluate the performance of the process 9. Summarize the experience achieved	1. Read the problem 2. Brainstorming and hypothesizing 3. Identify learning objectives 4. Individual research 5. Group discussion

Table 2
Technological tools, resources, and applications for ICT in the design process

Text Processors	Spreadsheets	Presentation designers and graphic organizers	Computer Aided Design
Text editors and creators using technological devices: office package, Libre Office, etc.	Data organizer using tables.	Power Point, Canva, Geneal.ly, Prezi, Cmap, Edraw, etc	Digital technical drawing tools such as CAD, Sketchup, BIM, Autodesk Inventor, etc.

For this didactic methodology that combines Project-Based Learning (PBL) and Information and Communication Technology (ICT), five instruments were used: (i) insertion diagrams, (ii) scale diagrams, (iii) programmatic relationship diagrams, based on four criteria: capacity, activity relationships, anchor activity, and intensity and frequency of use, (iv) calculation diagrams to measure the capacities of the vertical circulation core within four specific environments: lobbies, staircases, elevators, and parking lots, (v) isometric diagrams of the location and functionality of the vertical circulation core. Each instrument is described in Table 3.

Table 3
Table of instruments with the combined methodology of PBL phases and ICT tools

	Instruments	Specific analysis criteria	5 phases of PBL	ICT tool
1	Inset diagrams	Representative proportions of the terrain. Structural modulation trend of the terrain. Urban parameter synthesis. Relevant accessibilities.	Phase 1. Read the problem	Design of presentations and computer graphics
2	Scale diagrams	The proportions of the terrain with urban parameters Formal trends regarding terrain dynamics Trends in solar radiation subtractions	Phase 2. Brainstorming and hypothesis establishment	Design of presentations and computer graphics
3	Programmatic relationship diagrams	Capacity, Activity relationships Main activity Intensity and frequency of use	Phase 3. Identification of learning objectives	Spreadsheet Computer-aided design Presentation designers and graphic computers.
4	Calculation diagrams to measure vertical circulation core capabilities	Lobbies Staircases Elevators Parking lots	Phase 4. Individual research l	Spreadsheet Computer-aided design Presentation designers and

5	Isometric diagrams of the location and functionality of the vertical circulation core.	Phase 5. Group discussion	graphic computers. Computer-aided design Presentation designers and graphic computers.

3. Results

The proposed methodology yielded results that demonstrate the students' work in applying each instrument to analyze the vertical circulation of the hybrid building to be designed. The first result from the insertion diagrams instrument entails the analysis of (i) representative proportions of the terrain, (ii) the trend of structural modulation of the terrain, (iii) the synthesis of urban parameters, and (iv) relevant accessibilities. The analysis that has the greatest impact on the proposal for vertical circulation corresponds to item four, which pertains to relevant accessibilities. In this case, three modes of accessibility are identified: access from pedestrian pathways, from collector roads, and arterial roads. See Figure 1.

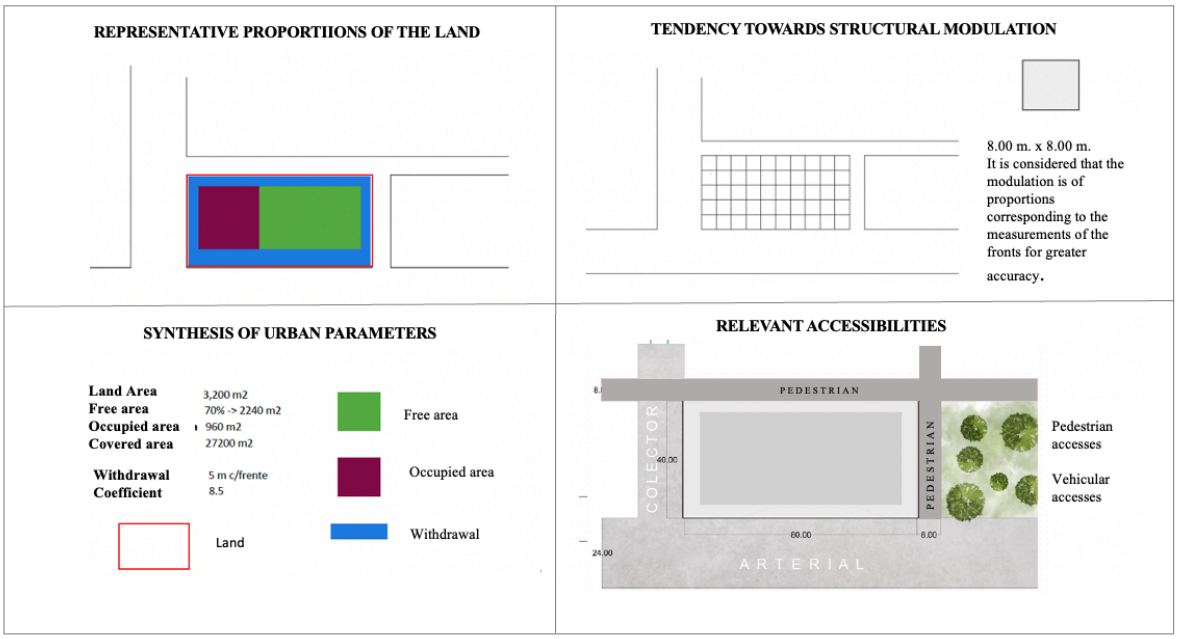

Figure 1: Instrument 1 insertion diagram
*The graphs represented in this image are authored by the students of CFP2022

As a second result, the application of the instrument called scale diagrams is evidenced, from which the analysis is obtained: (i) the proportions of the terrain with urban parameters, (ii) the formal trends regarding terrain dynamics, (iii) trends in solar radiation subtractions. This last instrument contributes to decision-making for the application of the next instrument, as it allows us to consider what will be the useful area to be programmed. See Figure 2.

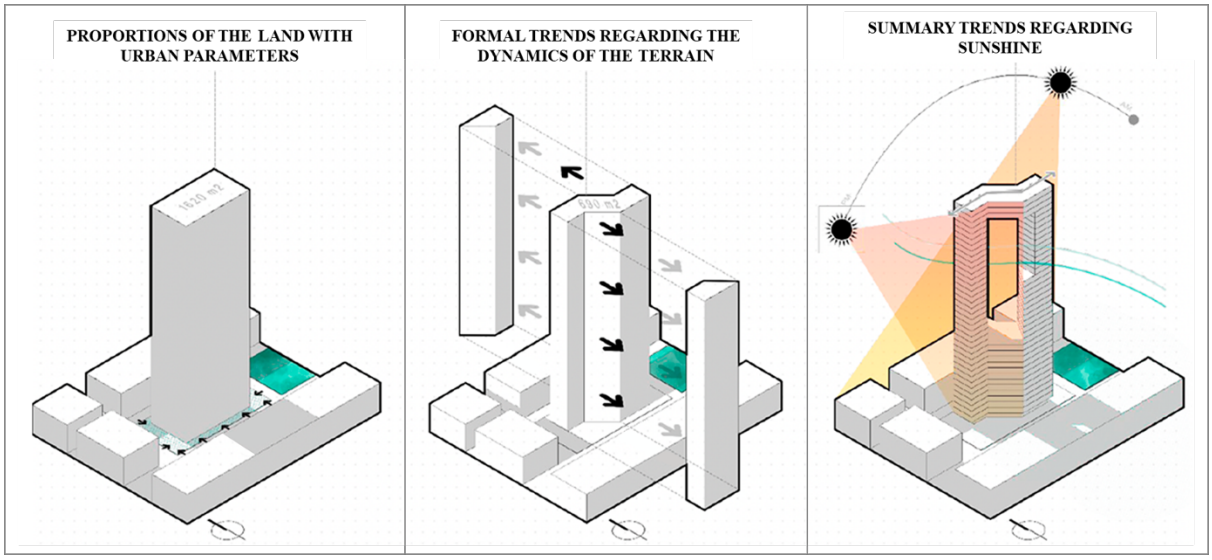

Figure 2: Instrument 2 scale diagrams
*The graphs represented in this image are authored by the students of PFC 2022.

On the other hand, the instrument called programmatic relationship diagrams allows for the analysis of: the capacity of the building, the intensity and frequency of space usage, activity relationships, and the anchor activity. See Figure 3.

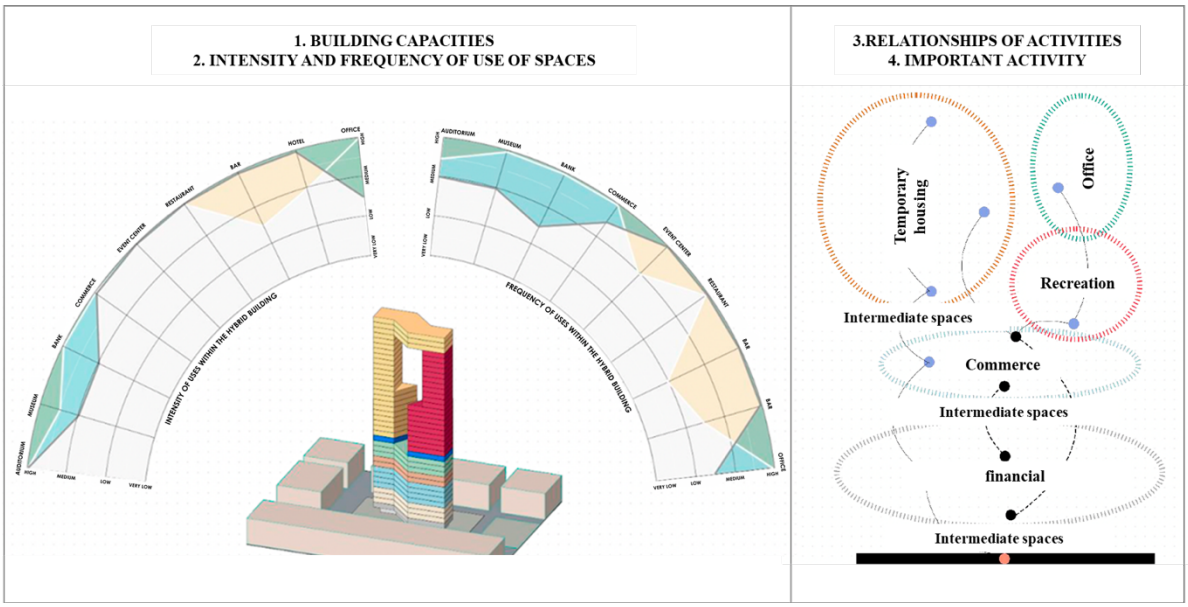

Figure 3: Instrument 3 - Programmatic Relationship Diagrams.
*The graphics presented in this image are authored by the PFC 2022 students**.**

From the instrument of calculation diagrams to measure the capacities of the vertical circulation core, the calculation and analysis of the number of lobbies, staircases, elevators, and parking spaces needed for the building are obtained. See Figures 4 and 5.

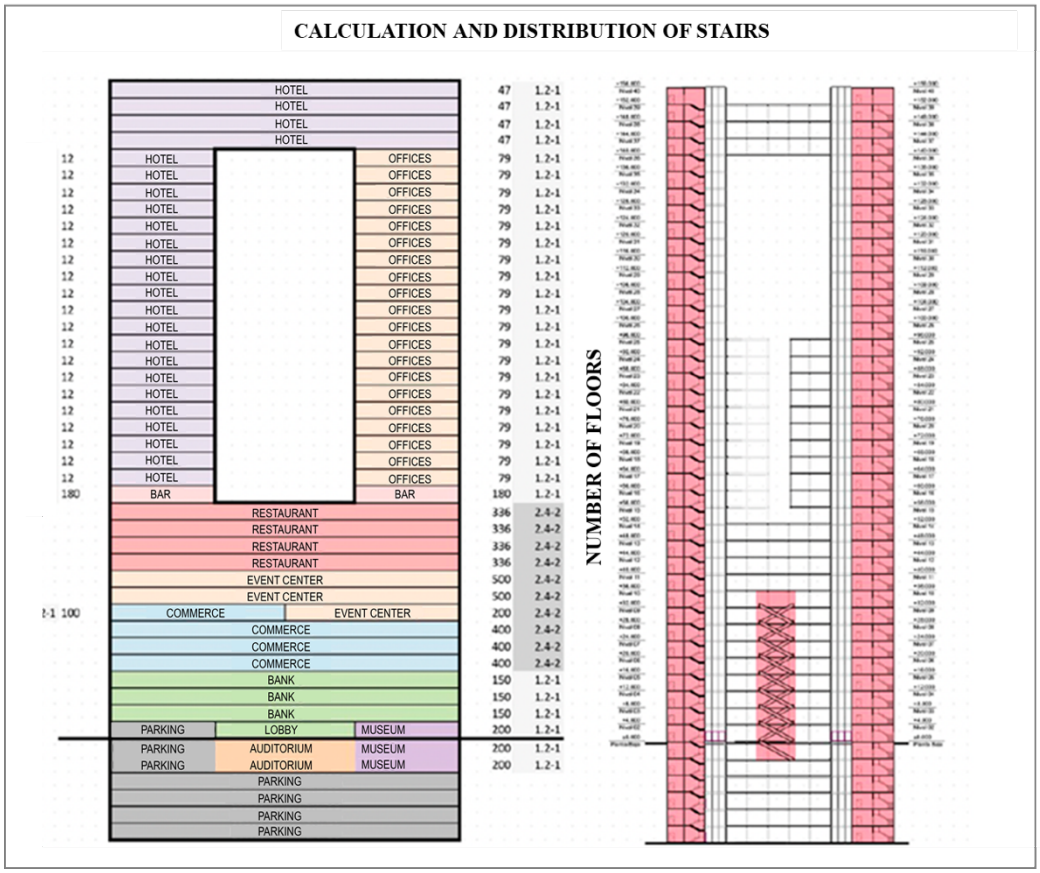

Figure 4: Instrument 4 - Calculation diagrams for the vertical circulation core regarding the number of staircases.
*The graphics presented in this image are authored by the CFP 2022 students.

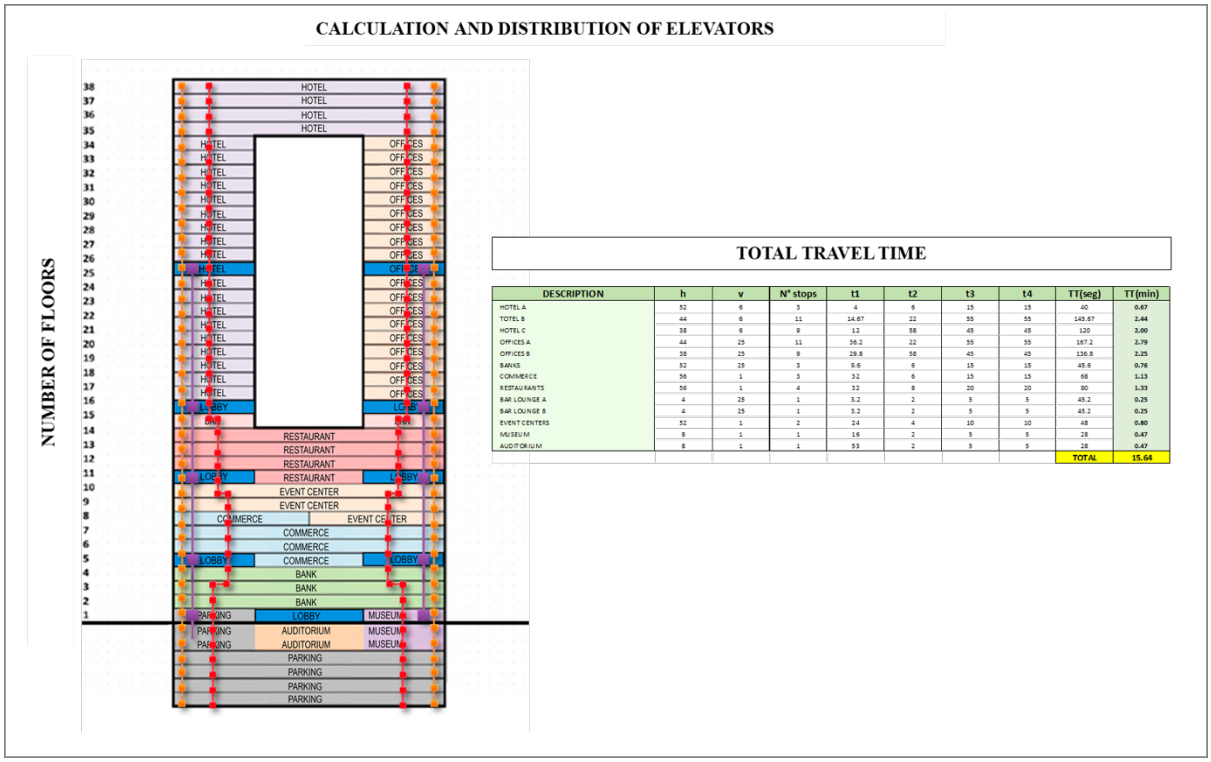

Figure 5: Instrument 4 - Calculation diagrams for the vertical circulation core regarding the number of elevators.
*The graphics presented in this image are authored by the PFC 2022 students.

Finally, the results from the isometric diagrams of the location and functionality of the vertical circulation core demonstrate various design solutions regarding the architectural program. In the application of this instrument, the student manages to characterize the vertical circulation axes and the approximate areas for each of the activities identified for the hybrid building. See Figure 6.

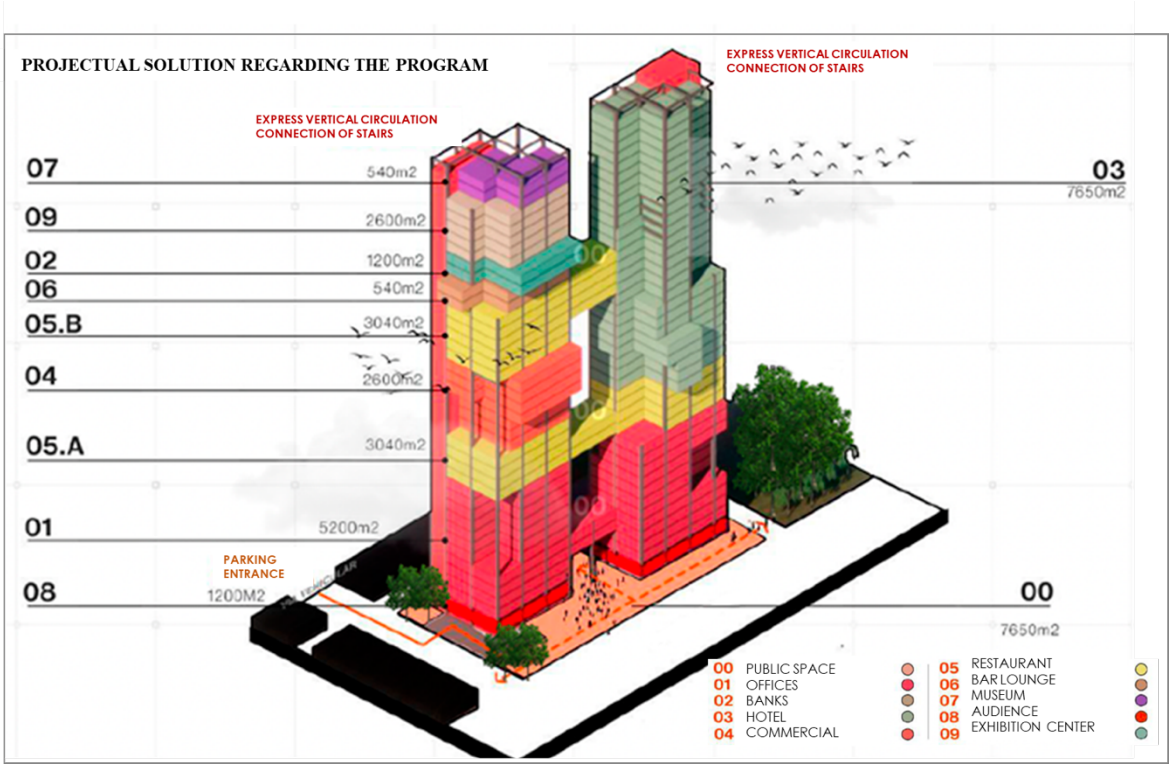

Figure 6: Instrument 5 isometric diagrams of the location and functionality of the vertical circulation core.
*The graphics represented in this image are authored by the students of CFP 2022

4. Discussion and conclusions

In this context, the department needs to put into practice the knowledge acquired, so the urban architectural project developed in this subject has the challenge of demonstrating the student's mastery of design and planning about the demands of the current market. Considering that the current architectural market requires high levels of profitability, applicability, and efficiency in virtual and/or face-to-face communication of projects. Therefore, the exercise demanded the conception of the architectural fact and the understanding of spaces in correlation with circulation. In this sense, the application of this methodology implies various pedagogical tools such as critical thinking, constructionism, or flexible learning, specific to architectural design subjects.

The implementation of the Hybrid Exercise Project as practical work, supported by virtual means, through which symbolic and verbal interaction allowed for multiple possibilities of mutual enrichment, through the different options that the virtual space offers in terms of image, sounds, and representation strategies [20], from which knowledge can be energized and transformed into a social fact that will continue to

enrich the interrelation of individuals among themselves and with knowledge in a digital world; [21, 22], accompanied throughout the creation and production process, considering specific variables proposed by the department as challenges, which the young people were able to solve with multiple and different solutions in each case developed, with positive and satisfactory results.

A learning environment is where students and teachers come together to interact psychologically regarding specific contents based on established didactic criteria [5, 23], to acquire knowledge, develop skills, attitudes, and aptitudes to achieve competence according to educational purposes [24], allowed us to consolidate experimentation, learning by doing, and the use of ICT as design strategies that enable the student to achieve high levels of creativity and enthusiasm with the use of ICT. Likewise, they demonstrated greater openness, willingness to access information and knowledge, and an active role, expressed in communicative representation strategies, used as facilitators of learning."

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