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COMPARATIVE ANALYSIS OF COSTS AND ENERGY EFFICIENCY BETWEEN CONVENTIONAL SYSTEMS AND STEEL FRAMING IN BUILDING CONSTRUCTION: A CASE STUDY AT ISTM, ANGOLA

ANÁLISE COMPARATIVA DE CUSTOS E EFICIÊNCIA ENERGÉTICA ENTRE SISTEMAL CONVENCIONAL E STEEL FRAMING NA CONSTRUÇÃO DE EDIFÍCIOS: UM ESTUDO DE CASO NO ISTM DE ANGOLA

ANÁLISIS COMPARATIVO DE COSTES Y EFICIENCIA ENERGÉTICA ENTRE EL SISTEMA CONVENCIONAL Y EL STEEL FRAMING EN LA CONSTRUCCIÓN DE EDIFICIOS: UN ESTUDIO DE CASO EN EL ISTM DE ANGOLA

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ABSTRACT
The search for more efficient construction systems that enhance productivity and deliver benefits to the construction sector has driven the adoption of new technologies. In this context, steel has gained prominence in the construction industry, fostering a transition from traditional heavy and slow construction methods to more agile and effective systems. Light Steel Framing, which employs cold-formed steel profiles, has proven to be an effective solution for the construction of low-, medium-, and high-rise buildings, offering advantages such as design flexibility, large spans, low self-weight, and rapid construction. This study presents a comparative analysis between conventional construction systems and Steel Framing, focusing on their feasibility for the construction of a building intended for the Faculty of Nursing at the Instituto Superior Técnico Militar (ISTM) of Angola. The technical advantages and disadvantages of each system are examined, considering criteria such as structural strength, cost, weight per unit area, and construction time. The results indicate that the Steel Framing system is a viable alternative for the construction of the nursing faculty at ISTM, demonstrating economic and safety advantages, particularly with regard to seismic performance. This research provides valuable information for construction professionals when selecting the most appropriate system for their projects.

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Keywords: Construction Systems. Steel Framing. Building Construction. Structural Design. Energy Efficiency.

RESUMO

A busca por sistemas construtivos mais eficientes, que melhorem a produtividade e ofereçam benefícios no setor da construção, tem impulsionado a adoção de novas tecnologias. Nesse contexto, o aço tem ganhado destaque na indústria da construção, promovendo uma transição do modelo tradicional de construção pesada e lenta para sistemas mais ágeis e eficazes. O Light Steel Framing, que utiliza perfis metálicos formados a frio, tem se mostrado uma solução eficaz para a construção de edifícios baixos, médios e altos, oferecendo vantagens como flexibilidade no projecto, grandes vãos, baixo peso próprio e rapidez na construção. Este estudo realiza uma análise comparativa entre os sistemas de construção convencional e Steel Framing, com foco na viabilidade para a construção de um edifício destinado à faculdade de enfermagem do Instituto Superior Técnico Militar (ISTM) de Angola. Serão examinadas as vantagens e desvantagens técnicas de cada sistema, considerando critérios como resistência, custo, peso por unidade de área e tempo de execução. Os resultados obtidos indicam que o sistema Steel Framing é uma alternativa viável para a construção da faculdade de enfermagem no ISTM, apresentando vantagens econômicas e de segurança, especialmente em relação a sismos. A pesquisa fornecerá informações valiosas para profissionais da construção na escolha do sistema mais adequado para seus projectos.

Palavras-chave: Sistemas Construtivos. Steel Framing. Construção de Edifícios. Projecto Estrutural. Eficiência Energética.

RESUMEN

La búsqueda de sistemas constructivos más eficientes, que mejoren la productividad y aporten beneficios al sector de la construcción, ha impulsado la adopción de nuevas tecnologías. En este contexto, el acero ha adquirido un papel destacado en la industria de la construcción, promoviendo una transición desde el modelo tradicional de construcción pesada y lenta hacia sistemas más ágiles y eficaces. El Light Steel Framing, que utiliza perfiles metálicos conformados en frío, se ha consolidado como una solución eficaz para la construcción de edificios bajos, medios y altos, ofreciendo ventajas como flexibilidad en el diseño, grandes luces, bajo peso propio y rapidez de ejecución. Este estudio realiza un análisis comparativo entre los sistemas de construcción convencional y Steel Framing, centrándose en su viabilidad para la construcción de un edificio destinado a la Facultad de Enfermería del Instituto Superior Técnico Militar (ISTM) de Angola. Se examinan las ventajas y desventajas técnicas de cada sistema, considerando criterios como la resistencia, el coste, el peso por unidad de superficie y el tiempo de ejecución. Los resultados obtenidos indican que el sistema Steel Framing constituye una alternativa viable para la construcción de la Facultad de Enfermería del ISTM, presentando ventajas económicas y de seguridad, especialmente en lo que respecta al comportamiento frente a sismos. La investigación aporta información valiosa para los profesionales de la construcción en la elección del sistema más adecuado para sus proyectos.

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Palabras clave: Sistemas Constructivos. Steel Framing. Construcción de Edificios. Proyecto Estructural. Eficiencia Energética.

1 INTRODUCTION

After the Second World War, steel became a widely available material, and its production advanced significantly as a result of the conflict. This development led to the popularisation of steel as an innovative construction solution, which continues to be used to this day. According to Campos (2014), the Light Steel Framing (LSF) system is widely adopted in countries such as the USA, Europe, Japan, New Zealand, and Australia. In Angola, LSF began to be applied more than two decades ago, initially in residential buildings, introducing new technological trends that differ from traditional techniques and offering substantial advantages for both builders and consumers.

LSF responds to the needs of modern society by promoting construction based on industrialised components, which enables stricter control of the final product and minimises risks associated with material deviations and workmanship during construction. In contrast to masonry, which presents advantages and disadvantages related to completion time, material wastage, labour, and cost, Steel Framing stands out for its lower cost, speed of execution, flexibility, and reduced environmental impact, aligning well with the demands of a developing society.

Initially, the construction system was based on timber, known as Wood Framing, which has been widely used in building construction worldwide. This method, predominantly developed by carpenters, gained significant acceptance within the North American economy and was subsequently extensively studied and adopted in the construction industry (Cangue et al., 2025).

After an extended period of use of timber-based construction methods, the need arose to adapt this process. According to Santiago (2012), the replacement of timber with galvanised steel was officially proposed for the first time in 1993, in Chicago. Specialists argued that steel could perform the same function as timber, but with lower weight and the additional benefit of reducing the exploitation of forest resources. The LSF system is an example of a technology that is well suited to current market demands, offering consumers the most recent technological advances.

Currently, the construction systems available on the market include alternative methods such as LSF; however, demand has not yet been fully met, particularly in countries such as Angola. The lack of skilled labour is one of the main limitations, preventing the construction sector from evolving in line with modern requirements. In addition, companies with greater financial capacity in the country are increasingly demanding faster development

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processes with reduced environmental impact, seeking to minimise material waste and the accumulation of debris; issues commonly associated with conventional construction methods.

The LSF method can be regarded as a form of dry construction, employing a lightweight steel structural system and high-technology enclosure materials. This system promises agility and benefits that have not yet been widely delivered by traditional construction methods.

The objective of this study is to carry out an economic feasibility and construction time analysis for a building intended for the Faculty of Nursing at the Instituto Superior Técnico Militar (ISTM) of Angola. The comparative analysis between the LSF system and the conventional system aims to identify the most appropriate methods and advanced technologies for the project. The proposal is to consider best practices and integrated technologies in order to meet the project requirements in an efficient and innovative manner.

2 CONSTRUCTION SYSTEMS

2.1 CONVENTIONAL CONSTRUCTION SYSTEM

The conventional construction system is widely used worldwide and is predominantly based on masonry and concrete techniques. This method employs bricks, concrete blocks, and cement to form robust structures, valued for their durability and strength (Khan et al., 2018). Masonry construction offers benefits such as fire resistance and thermal insulation, making it a preferred choice for residential and commercial buildings in many regions (Smith, 2016).

The application of the conventional construction system varies according to the availability of materials and local technology. In developed countries, advanced techniques—such as the use of precast concrete and ventilated façade systems; are common. In contrast, in developing countries, traditional practices and simpler methods still prevail (Barker & Sutherland, 2020; Li et al., 2019). The efficiency of the conventional system is often affected by the quality of materials and the skill level of the workforce, directly influencing construction cost and duration (Jones, 2017).

In Brazil, the conventional construction system is extensively used in residential buildings. This method employs reinforced concrete beams and columns, with infill walls made of ceramic or cement blocks laid with mortar. The structural system consists of columns, beams, and slabs of reinforced concrete, which transfer loads to the foundations.

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Structural steel and formwork are commonly used in the construction of beams and columns. However, this method is known for its low productivity and high levels of material waste (Cassar, 2018; Cruz, 2021; Quissanga et al., 2022).

Foundations in the conventional system are robust due to the weight of structural elements. Infill walls are built with ceramic blocks, requiring surface finishes such as roughcast, plastering, and rendering, which is a time-consuming process and consumes large volumes of materials. Electrical installations are carried out using conduits embedded in walls, slabs, beams, and columns, while hydraulic and sanitary systems follow a similar process but cannot be embedded in beams and columns, generating a significant amount of construction waste (Cruz, 2021). According to NBR 6118:2003, slabs in conventional systems may be solid or precast. Solid slabs are executed in reinforced concrete, while precast slabs consist of concrete joists and infill blocks made of concrete or ceramic. The costs associated with these slabs can be high due to the extensive use of concrete and steel. For roofing, timber is often used for structural elements such as trusses and props, with ceramic and fibre-cement tiles being the most common coverings (Cassar, 2018).

2.1.1 Economics

In civil construction, costs are a major concern, and Light Steel Framing (LSF) was developed to reduce material waste and construction time. While some studies report higher initial costs for LSF; 16% for a 41.16 m² dwelling (Kumar et al., 2020), 8.6% for 122.16 m² (Cassar, 2018), and 7% for 55 m² (Harris and Tarefder, 2017 apud Mendes, 2021); others show savings, such as 7.5% for 58.64 m² (Kumar et al., 2020) and 32.9% for 62.78 m² (Miranda, 2018). These variations highlight that LSF costs depend on region, project size, and period, though its efficiency and operational benefits often justify its adoption.

2.1.2 Productivity

Productivity is a crucial factor in civil construction, directly impacting costs. Although the LSF system requires more specialised labour, it offers shorter execution times. According to Meireles (2018), approximately 10 days are required to construct a 44.78 m² house using LSF, compared with about 19 days using the conventional method. Fernandes and Campos (2021) indicated that the structural work and enclosure of a 213.75 m² commercial project took approximately 60 days using the conventional system and only 20 days with LSF. Kumar et al., (2020) also observed that LSF was faster, with a difference of

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15 days for a 221.89 m² project. Oliveira (2013) reported that the time required to construct the superstructure and complete painting for a 42 m² house using LSF was six days, compared with 20 days for the traditional method.

2.1.3 Environmental Impact

According to CONAMA Resolution No. 1 of 23 January 1986, environmental impact refers to any alteration in the properties of the environment caused by human activities that affect public health, safety, and well-being, as well as sanitary conditions and the quality of natural resources. The construction sector, which accounts for approximately 15% of national GDP, consumes around 75% of extracted natural resources and generates about 80 million tonnes of waste annually (CBIC). The Brazilian Chamber of the Construction Industry (CBIC) highlights the importance of energy, water, and material efficiency, emphasising the need for innovative solutions to improve the use of scarce resources and the long-term performance of buildings (CNI, 2017).

2.1.4 Conventional Construction System in Africa and Particularly in Angola

Conventional construction in Africa is predominantly based on masonry and concrete systems, valued for their robustness and durability but associated with significant challenges (Petersen et al., 2021). The widespread use of cement blocks and bricks is mainly driven by material availability and long-established construction practices (Gomez & Smith, 2020). In Sub-Saharan Africa, these systems have helped meet growing housing demand, especially in urban areas; however, limitations such as inconsistent material quality, lack of standardisation, and rudimentary techniques often compromise durability and performance (Nkosi & Mabena, 2022; Silva et al., 2021).

In Angola, conventional construction based on cement block masonry remains dominant due to its accessibility and relatively low cost, forming the basis of most residential and commercial developments (Neto et al., 2020; Silva, 2019). Nonetheless, challenges related to material quality, extended construction periods, high waste generation, and limited skilled labour negatively affect efficiency, sustainability, and overall project viability (Duarte, 2022; Jones, 2017; Mendes et al., 2021).

That the adoption of improved construction techniques and higher-quality materials could mitigate these limitations, although such advancements depend on coordinated efforts among public institutions, industry stakeholders, and local communities (Barker &

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Sutherland, 2020).

2.2 LSF CONSTRUCTION SYSTEM WORLDWIDE

The LSF construction system has experienced significant global growth due to its efficiency and versatility. This method uses cold-formed galvanised steel profiles to create lightweight yet strong structures, offering notable advantages such as rapid construction, design flexibility, and reduced waste generation (Harris & Tarefder, 2017). Widely adopted in developed countries, LSF is valued for its energy efficiency and sustainability properties (Smith, 2018).

In the United States and Europe, LSF is frequently used in residential and commercial projects, meeting stringent performance requirements and environmental regulations (McDonald & Williams, 2019). This system enables the construction of large spans and complex designs without compromising structural stability (Jones & Patel, 2020). Furthermore, LSF is recognised for reducing construction time and enhancing the thermal and acoustic insulation of buildings (Lee et al., 2021).

2.2.1 Description of the LSF Construction System

The LSF method originated in the United States in the nineteenth century, driven by westward expansion and rapid urbanisation. Initially, the system was based on sawn timber and the Balloon Framing technique, known as Wood Frame (Campos, 2014). With the development of the steel industry and the growing need for faster and more economical construction methods, LSF was introduced. Its first public demonstration took place at the 1933 Chicago World's Fair, highlighting the use of steel profiles as an alternative to timber and promoting the conservation of environmental resources (Santiago et al., 2012). LSF is distinguished by its rapid, flexible, and environmentally sustainable construction, aligning with the needs of a developing society.

2.2.2 Main Elements of a LSF Building

LSF profiles are manufactured from cold-formed galvanised steel, with thicknesses ranging from 0.8 to 3.2 mm and flange widths between 30 and 90 mm, depending on structural requirements (Freitas & Castro, 2007). Regarding construction methods in LSF, the following are highlighted: i) stick-built method, where elements are assembled on site; ii) panelised method, involving prefabrication of panels in workshops and on-site assembly;

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and iii) modular method, where prefabricated units are delivered complete with internal finishes. Tables 1 and 2 present the main elements of an LSF building, as well as the advantages and disadvantages of the LSF system, respectively.

Table 1

Main Elements of a Light Steel Framing Building

Element	Description
Oriented Strand Board	Structural panel composed of oriented wood strands bonded with resin under high pressure. Environmentally friendly, used in walls, ceilings, and floors.
Galvanised Steel Profiles	Stiffened U-shaped profiles for studs and beams and simple U-shaped profiles for tracks. Assembled with spacing of 400 or 600 mm (Santiago, 2012).
Cement Board	Used for enclosure and finishing, with high thermal and acoustic performance. Applicable to both internal and external walls (Santiago, 2012).
Dry and Wet Slabs	Dry: OSB or cement boards; Wet: corrugated metal sheet and concrete, improving thermal and acoustic insulation (Santiago, 2012).
Steel Deck Slab	For flat roofs. Pitched roofs follow conventional principles, replacing timber with galvanised steel (Souza, 2014).
Thermal–Acoustic Insulation	Glass wool and rock wool, providing sound absorption and thermal resistance (Facco, 2014).
Foundations and Anchorage	Simplified foundation (strip footing and raft). Anchorage ensures stability against uplift and tensile forces (Santiago et al., 2012).
Water-Impermeable/Vapour-Permeable Barrier	Tyvek membrane prevents water penetration while allowing ventilation (Campos, 2014).
LSF Studs and Roofing	Studs in U-shaped profiles spaced 400–600 mm. Roofing designed with lightweight coverings, especially asphalt shingles (Campos, 2014).

Source: Author, 2025.

Table 2

Advantages and Disadvantages of the Light Steel Framing System

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Reduction in construction cost and time.</td><td rowspan="2">Limitation to buildings of up to five storeys.</td></tr>
<tr><td>Lightweight structure, reducing foundation demands.</td></tr>
<tr><td>High resistance to fire and corrosion.</td><td>Potential damage when hanging heavy objects.</td></tr>
<tr><td>Good thermal and acoustic performance.</td><td rowspan="2">Requirement for specialised professionals.</td></tr>
<tr><td>Lower maintenance costs.</td></tr>
</table>

Source: Author, 2025.

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2.2.3 Knowledge, Labour, and Cost Barriers

A significant barrier to the adoption of LSF is the lack of knowledge about the system. This unfamiliarity often leads to insecurity and resistance to the adoption of new technologies, highlighting the need for better understanding and cultural acceptance of lightweight construction systems (Ramos, 2015; Milan et al., 2011).

The primary challenge faced by the LSF system is the shortage of qualified labour and adequate technical knowledge. Professionals must have a comprehensive understanding of the system to ensure efficient execution and problem-solving (Ramos, 2015; Oliveira, 2013). Proper training and capacity-building are crucial for successful LSF implementation. Design and planning errors are common sources of problems and additional costs, making it essential to follow well-established criteria in structural system selection and material specification to avoid recurring failures (Crasto & Freitas, 2006; Sales, 2001).

2.2.4 LSF Construction System in Africa and Particularly in Angola

In Africa, the LSF system is emerging as an innovative solution to address housing and construction challenges (Nair & Dlamini, 2021; Quissanga & Pimentel, 2019). Although still in the early stages of adoption compared to traditional techniques such as masonry, its potential to deliver fast and sustainable construction is increasingly recognised (Kumar et al., 2020).

In Angola, LSF has been introduced as an alternative to conventional cement block construction. The system offers significant advantages, including reduced construction time and lower reliance on highly specialised labour, which is particularly relevant in a context where technical capacity may be limited (Mendes et al., 2021). LSF construction in Angola also provides solutions to challenges related to material waste and the environmental impact of traditional construction practices (Silva et al., 2022).

However, the adoption of LSF in Angola faces barriers such as the need for specialised materials and technologies, as well as resistance to change among professionals accustomed to traditional methods (Neto et al., 2020). Overcoming these barriers requires promoting technical training and increasing awareness of the benefits of LSF (Duarte, 2022). The integration of LSF can therefore contribute significantly to the modernisation of Angola's construction sector, offering more efficient and sustainable solutions (Pereira et al., 2023).

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2.2.5 LSF Construction System in Angola

In Angola, the LSF system remains at an early stage of adoption. Although the use of this technology is increasing, substantial efforts are still required in terms of awareness, investment, and infrastructure to enable large-scale implementation.

Several buildings have already been constructed using this system, including the Catholic University of Benguela, social housing projects in Benguela and Huambo, penthouses atop luxury buildings, steel pavilions, and the rehabilitation of floor slabs in residential buildings through the application of composite slabs, among others. The literature review highlighted the importance of clarifying key concepts related to the topic and underscored the need for studies with significant impact on the construction industry. The next section of this article presents the methodology and case study, addressing the stages and technical issues involved in the design of a building intended for the Faculty of Nursing at ISTM.

3 CASE STUDY

The comparative analysis presented in this research project aims to evaluate the feasibility of the LSF system for the construction of a building located in the municipality of Viana, specifically within the facilities of the Instituto Superior Técnico Militar (ISTM). The project has particular characteristics due to its location within a military area. The Faculty of Nursing covers an area of 1,049 m², according to the proposed architectural design. Both the architectural project and the structural design were developed for the conventional and LSF systems.

3.1 LOCATION AND CHARACTERISATION OF THE STUDY AREA

The plot is situated within ISTM, on road de Catete, in the municipality of Viana, in the capital of Angola, Luanda (see Figure 1). The lot is surrounded by existing buildings and has a perimeter of 148 m with a total area of 1,200 m². The geographical coordinates are as follows: P1 (Lat: 8º 52' 03"S, Long: 13º 18' 21"E), P2 (Lat: 8º 52' 21"S, Long: 13º 18' 24"E), P3 (Lat: 8º 52' 05"S, Long: 13º 18' 19"E), and P4 (Lat: 8º 52' 04.03"S, Long: 13º 18' 23.89"E). The terrain is flat and without depressions.

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Figure 1

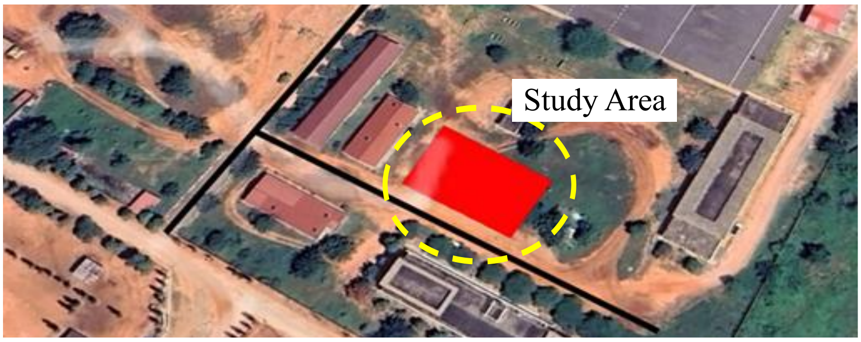
Location of the study area plot

Source: Author, 2025.

Figure 2 schematically illustrates the location of the surrounding buildings, with geographical positions obtained using Google Earth Pro, highlighting a maximum elevation of 70 m. Figure 4 shows the plot in a microlocation to facilitate the identification of the study area, its typology, and the region of the geometric layout.

Figure 2

Macrolocation of the plot



Source: Author, 2025.

3.1.1 Climatic Aspects of the Study Area

According to the 2023 report by the National Institute of Meteorology and Geophysics (INAMET), the study area generally experiences above-average temperatures, with a warm climate and satisfactory rainfall and ventilation. The hot season occurs from January to April, with average daily maximum temperatures above 29ºC. March is the hottest month in Luanda, with average temperatures of 30ºC (maximum) and 26ºC (minimum). The cool season occurs from July to September, with average daily maximum temperatures below 27 ºC. August is the coldest month, with average temperatures of 20ºC (minimum) and 26ºC (maximum). The climate is predominantly tropical, with dry characteristics and a low

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aggressiveness index.

3.1.2 Geotechnical Characterisation of the Study Area

Given the characteristics of the building under design, for the geological characterisation and determination of parameters for geotechnical analysis and design, existing reports were used, many of which were conducted by the ISTM Department of Civil Engineering laboratory in adjacent areas. The studies indicate a predominance of low-plasticity silty sand, with a specific weight of 18 kN/m³, a deformation modulus of 8 MPa, and an allowable stress of 0.3 MPa.

3.2 ARCHITECTURAL CHARACTERISATION AND DESIGN OF THE BUILDING

The project concerns a building intended for the Nursing course, with a footprint area of 1,200 m², composed of two floors. The architectural design was developed with a focus on modern architecture, aiming to integrate the construction with the surrounding landscape. Defined lines and geometric shapes were used to create a clean, economical, and functional building. Figures 3 to 7 illustrate the architectural plan and characteristics, following the Brazilian standard ABNT NBR 16970/2022 for LSF structural design.

Figure 3 shows that the building has an irregular configuration, with a built area of 1,049 m² and a perimeter of 146.60 m. Figures 4 to 7 present vertical sections, highlighting variations in ceiling heights and a roof with a 2% slope for the conventional system. All sections enabled the quantification of costs and detailed scheduling of activities. Tables 3 and 4 present the building's compartments.

Figure 3

Architectural plan of the building – Ground floor and First floor

Source: Author, 2025.

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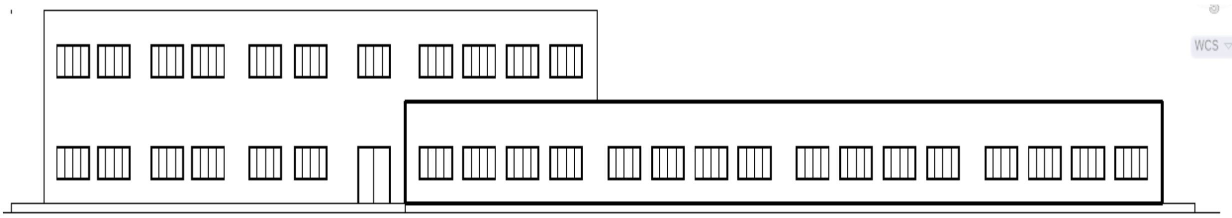
Figure 4

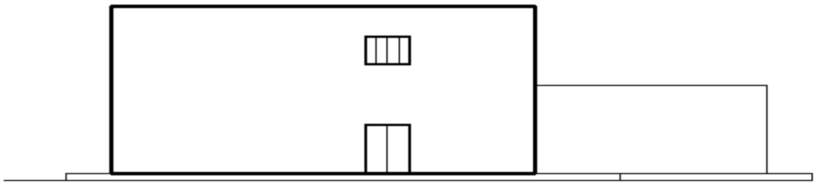
Main Elevation



Source: Author, 2025.

Figure 5

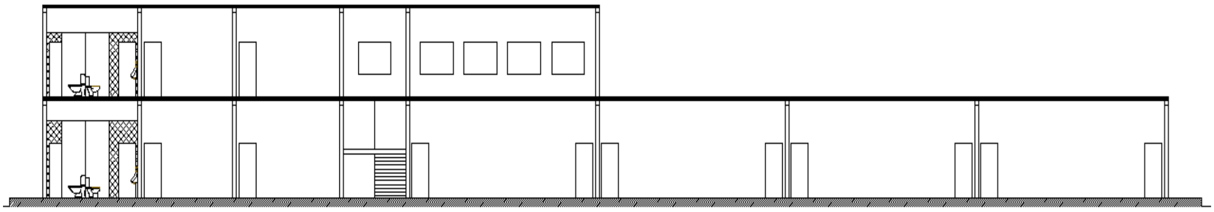
Left side elevation



Source: Author, 2025.

Figure 6

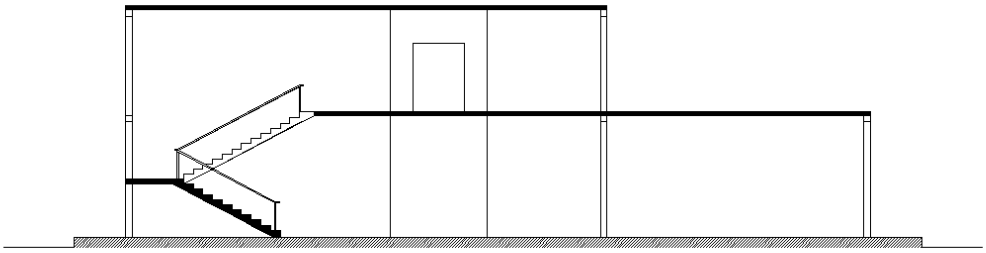
Longitudinal section of the building



Source: Author, 2025.

Figure 7

Cross-section of the building



Source: Author, 2025.

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Table 3

Section Dimensions

Description	Dimensions
First Floor ceiling height	3.80 m
Second Floor ceiling height	3.45 m
Slab thickness	12.00 cm
Beam section	20 × 20 cm
Door height	2.10 m
Window	1.6 × 1.2 m
Riser	16.00 cm
Floor thickness	30.00 cm
Plinth	30.00 cm
Total height (left side)	8.19 m

Source: Author, 2025.

Table 4

Building Room Layout

Upper Floor – Administrative Area	Dimensions (m)	Area (m²)	Ground Floor – Study Area	Dimensions (m)	Area (m²)	Ground Floor – Laboratory	Dimensions (m)	Area (m²)
Head of Nursing Department Office	9 × 7.8	70.2	Teachers' Room	9 × 6	54	Medical Inspection	7.84 × 5	39.2
Secretary	7.8 × 5	39	Library	9 × 6	54	Microbiology Lab	9 × 7.84	70.56
Meeting Room	14.6 × 9	131.4	Amphitheatre	9 × 7.84	70.56	Storage 1	5 × 3.2	16
Archive 1	4.4 × 3.2	14.08	4 Classrooms	4 × (11.5 × 9)	414	Storage 2	4.4 × 3.2	14.08
Archive 2	5 × 3.2	16	Circulation	36.8 × 3	110.4	Male WC	3.32 × 2.54	8.43
Circulation	17.62 × 3	52.86	Staircase to upper floor	8.04 × 3	24.12	Female WC	3.32 × 1.85	6.14
Male WC	3.32 × 2.54	8.43	Male WC	6 × 4.40	26.4	Circulation	17.62 × 3	52.86
Female WC	3.32 × 1.85	6.14	Female WC	6 × 4.40	26.4	—	—	—

Source: Author, 2025.

3.2.1 Comparison Between Structural Designs

The structural designs compared include the conventional system and the LSF system. Both designs are based on the previously presented architectural projects. The soil study was carried out and provided by the ISTM Construction Engineering Laboratory, ensuring that both designs use the same parameters for a balanced comparison.

- Partially Reinforced Conventional Structure (Masonry)

On the first floor, with a ceiling height of 3.8 m, the walls will be masonry with a mortar mix of water, sand, and cement. External walls will be made of blocks with a thickness of 15 cm and a finishing layer of 20 cm, while internal walls will have blocks 15 cm thick with a 20 cm finish. Columns will be distributed along the perimeter of the floor with spacings ranging from 3 to 6.2 metres. Beams will span between 3 and 6.2 metres, and the slab will be solid with a thickness of 12 cm. Foundations will be shallow and isolated, with 80 cm footings and 20 cm columns, without pedestals.

On the second floor, with a ceiling height of 3.45 m, walls will be constructed with hollow bricks. External walls will have blocks 15 cm thick with a 20 cm finish, while internal walls will have blocks 11 cm thick with a 15 cm finish. Access to the upper floor will be via a U-shaped staircase located inside the building at the rear of the main entrance on the first floor. For small-scale projects, standards and tables are used to determine wall thicknesses, number of reinforcement bars, spacings, and beam sections to budget costs and prepare the activity schedule (Gantt chart).

The foundation plan (isolated footing) and ground beam consider a column section of 20×20 cm, with a footing cover of 50 mm. The characteristic compressive strength of concrete is f_{ck} = 25 MPa, and the characteristic yield strength of steel is f_{yk} = 500 MPa. The partial safety factors are g_c = 1.4 for concrete, g_y = 1.15 for steel, and C_C = 1.40. The soil is a low-plasticity silty sand, with a unit weight of 18 kN/m³, a deformation modulus of 8 MPa, and an allowable bearing stress of 0.3 MPa.

4 RESULTS AND DISCUSSION

This study presents a comparative analysis between the conventional construction system and the LSF system for a building intended for the Faculty of Nursing at the Instituto Superior Técnico Militar (ISTM) in Angola. The research addresses the applied loads, construction times, and associated costs, highlighting the advantages of LSF in terms of energy efficiency and cost reduction.

4.1 APPLIED LOADS

The collected data show that the LSF system has a significantly lower total load

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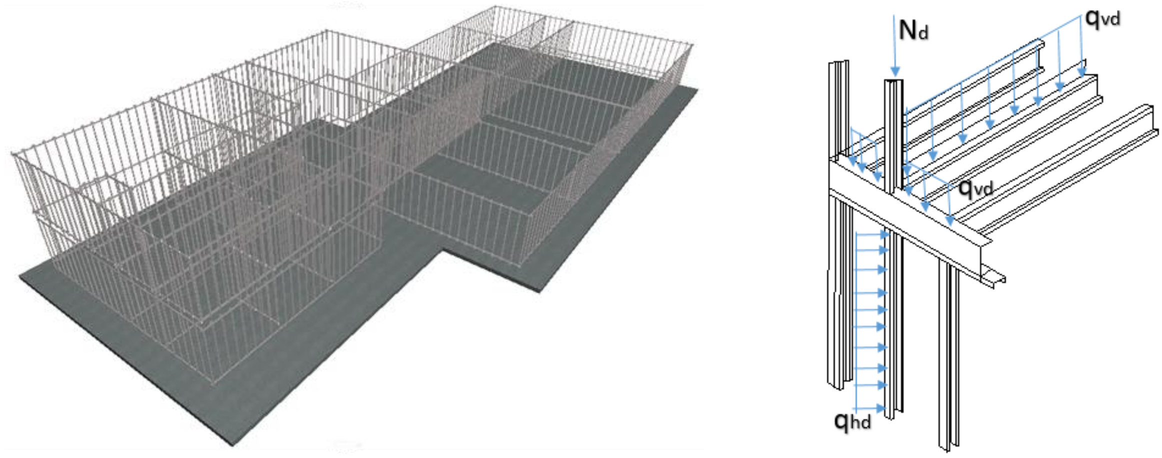
compared to the conventional system. Table 5, which presents the calculated loads, indicates that the design load for the conventional system is 174.54 kN, whereas for the LSF system it is only 23.04 kN. Additionally, foundation stresses are lower in the LSF system, with s_{rafter} = 12.37 kN/m² compared to $s_{footing}$ = 123.58 kN/m² for the conventional system. This structural lightness of LSF not only contributes to less costly foundations but also improves the building's energy efficiency by reducing the need for heavy materials.

For load calculations, the Ue profile 90 × 40 × 12 × 0.8 was selected, as specified in the ABNT NBR 16970/2022 standard. This choice was essential to ensure the structural adequacy and efficiency of the LSF system compared to the conventional system. Figure 8 shows the Ue profiles (studs) spaced at 60 cm and a detailed LSF view. Table 5 presents a comparison of the loads between the conventional system and the LSF system, highlighting the following observations:

Figure 8

Representation of Ue profiles spaced at 60 cm and LSF detail



Source: Author, 2025.

Table 5

Comparison of Loads Between the Conventional System and LSF

Conventional System	Load Values	LSF System	Load Values
Design load	N_K = 174.54 kN	Design load	N_d = 23.04 kN
Wind action	F = 33.81 N	Wind action	F = 33.81 N
Stresses	$s_{footing}$ = 123.58 kN/m²	Stresses	s_{rafter} = 12.37 kN/m²
Landing weight	Q_1 = 7.5 kN/m²	Landing weight	Q_1 = 7.5 kN/m²
Slab and steps weight	Q_1 = 10) kN/m²	Slab and steps weight	Q_1 = 10 kN/m²

Source: Author, 2025.

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These data demonstrate that the LSF system exhibits superior structural performance compared to the conventional system, with lower loads and reduced stresses. This efficiency is one of the main factors supporting the adoption of LSF in civil construction projects in Angola.

4.2 CONSTRUCTION TIME

4.2.1 Analysis of Project Duration

A comparative analysis of construction duration using conventional and Steel Framing (LSF) systems was carried out for the Faculty of Nursing building at ISTM. The data were organized into Gantt charts, which allow visualization of activity distribution and resource allocation.

- Conventional System

As shown in Figure 9, the estimated total duration for the conventional system is 73 days. The calculations were based on the number of resources, productivity rates, and the teams involved in each activity. Activities ranged from preliminary services, such as topographic surveys and site clearing, to more complex processes, including masonry and installation of fixtures. The Gantt charts (Figure 9) illustrate the overlap of activities and their dependencies, highlighting the need for effective resource management.

Figure 9

Gantt chart for the conventional system

Source: Author, 2025.

- Light Steel Framing System

In contrast, construction using the LSF system showed a total duration of 47 days.

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The calculations were based on the number of resources and teams required for each stage. The Gantt chart (Figure 10) demonstrates a more agile execution of activities, with reduced time allocated to tasks such as excavation and assembly. This efficiency can be attributed to the modular and lightweight nature of LSF, which allows for faster construction.

Figure 10

Gantt chart for the LSF system

Source: Author, 2025.

- Comparison Between Systems and Their Implications

The comparison between the two systems demonstrates a significant reduction in construction time with the use of LSF, resulting in savings of 25 days compared to the conventional system. This efficiency is mainly due to the lower structural weight, easier material handling, and the possibility of executing activities simultaneously.

The findings show that LSF not only accelerates construction but also enables operational cost reductions through optimized schedules and resource use. Additionally, its potential for improved energy efficiency supports more sustainable construction practices in Angola. Overall, the results confirm LSF as a viable and efficient alternative, especially in projects where speed and energy performance are key priorities.

4.3 COST ANALYSIS BETWEEN SYSTEMS

The cost analysis of construction between the conventional system and the LSF system was conducted using the CYPE Price Generator software and data collected directly from the construction context in Angola. Tables 6, 7, and 8 present the costs for the LSF system and the conventional system, enabling a clear and direct comparison.

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Table 6

Budget for the conventional construction system

Description		Unit	Quantity	Unit Price (Kz)	Total (Kz)
Structure	Structural concrete	m³	22.22	390,000	7,885,800
	Formwork and removal of boards	m²	101.58	38,840	3,945,370
	Reinforcement CA 50A	kg	246.36	7,000	1,724,520
	Solid slab	m²	67.12	60,740	4,076,870
Closure	Ceramic brick masonry e = 16 cm	m²	186.00	29,870	5,555,820
Finishing	Bonding scratch coat	m²	420.25	5,570	2,340,790
	Plaster with cement-lime-sand mortar 1:2:8	m²	420.25	21,600	9,977,400
Total					35,506,570

Source: Author, 2025.

Table 7

Presentation of LSF Prices in Kwanza

Description		Code	Quantity	Unit Price (Kz)	Total (Kz)
Structure	Structural guide 90 mm #0.80 L/6.00 m	PC	30.00	38,190	1,145,700
	Structural stud 90 mm #0.80 L/3.00 m	PC	210.00	21,890	4,596,900
	Acoustic strip roll 10 m × 90 mm	ROLL	7.00	18,230	127,610
	Structural stud 140 mm #0.80 L/6.00 m	PC	35.00	40,100	1,403,500
Closure	OSB sheet for dry slab 1200×2400 mm	un	25.00	58,000	1,450,000
	OSB sheet for external closure 1200×2400 mm	un	53.00	31,950	1,693,350
	Cementitious sheet for external closure 1200×2400 mm	un	53.00	68,000	3,604,000
	Plasterboard for external ceiling 1200×2400 mm	un	21.00	17,010	357,210
	Plasterboard for internal closure 1200×2400 mm	un	69.00	17,010	1,173,690
	Glass wool 12×12.5×50 mm	un	14.00	580	8,120
	Tyvek membrane 0.91×30.5 m	roll	8.00	96,050	768,400
Total					15,065,330

Source: Author, 2025.

Table 8

Labour Cost for LSF Roof

Item Code	Unit	Description	Productivity	Unit Cost (Kz)	Total (Kz)
mt07ali005a	kg	Steel NP EN 10162 S235JRC, cold-formed profiles (L, U or C), galvanised finish, including accessories, screws and anchorage elements	5.000	938.27	4,691.35
mo047	h	Skilled metal structure assembler (1st class)	0.485	1,070.79	519.33
mo094	h	Assistant metal structure assembler	0.485	629.14	305.13
—	%	Additional direct costs	2.0	5,515.81	110.32
Decennial maintenance cost (first 10 years)					281.31
Total Labour Cost					5,626.13

Source: Author, 2025.

4.3.1 Costs of the Conventional System

On the other hand, Table 6 indicates that the total cost of the conventional construction system amounts to 35,506,570 Kz. This value encompasses all construction elements, including concrete, formwork and masonry, resulting in a unit cost of 33,850 Kz/m².

4.3.2 Costs of the LSF System

As presented in Table 7, the total cost for implementing the LSF system is 15,065,330 Kz. This amount includes all structural components, such as tracks, studs and boards, as well as the labour required for assembly. The unit cost of the LSF system per square metre was calculated at 14,360 Kz/m², clearly demonstrating a more economical construction approach.

4.3.3 Cost Comparison and Energy Efficiency Implications

The cost comparison reveals a significant difference between the two systems. The LSF system presents a cost reduction of approximately 58% when compared to the conventional system. This difference not only confirms the economic feasibility of LSF but also highlights it as an attractive alternative for the construction sector in Angola, particularly in projects where cost control is a priority.

Beyond financial aspects, the choice of construction system has direct implications for the energy efficiency of buildings. Due to its composition and construction techniques, LSF provides improved thermal performance, which can lead to substantial energy savings throughout the building's life cycle. This energy efficiency, combined with lower initial costs, makes LSF an increasingly relevant option in the civil construction market.

4.4 DISCUSSION OF RESULTS

This study compared the energy efficiency and costs of two construction systems applied to a building project intended for the Faculty of Nursing at ISTM. The results clearly demonstrate the advantages of LSF in terms of cost reduction and execution time, while also offering insights into its feasibility within the Angolan context.

As discussed previously, the analysis of acting loads in both systems showed that LSF has a significantly lower structural weight compared to the conventional system. As illustrated in Table 9, the design loads reveal a clear distinction: the conventional system

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presents a load of 174.54 kN, whereas the LSF system exhibits only 23.04 kN. This indicates that adopting LSF can facilitate site logistics and construction handling, while also reducing the demand on foundations.

Table 9

Comparison of Design Loads for the Two Systems

System	Design Load (kN)	Wind Action (N)	Stress (kN/m²)	Landing Load (kN/m²)	Slab and Stair Load (kN/m²)
Conventional	174.54	33.81	123.58	7.50	10.0
LSF	23.04	33.81	12.37	7.50	10.0

Source: Author, 2025.

The estimated construction time using the LSF system was 47 days, whereas the conventional system required 73 days. This reduction in execution time highlights the efficiency of LSF, enabling faster project delivery, which is crucial for meeting the growing demands of the educational and construction sectors in Angola.

Total construction costs also revealed a marked disparity between the systems. As previously discussed, the total cost of the conventional system was 35,506,570 Kz, while the LSF system amounted to 15,065,330 Kz, as shown in Table 10. The unit cost per square metre was 33,850 Kz for the conventional system and 14,360 Kz for LSF.

Table 10

Cost Difference Between the Construction Systems

System	Total Cost (Kz)	Unit Cost (Kz/m²)
Conventional	35,506,570	33,850
Light Steel Framing	15,065,330	14,360

Source: Author, 2025.

The analysis of direct costs by construction stage revealed that wall components accounted for the largest share of expenses. In the LSF system, this stage cost 5,870,210 Kz, corresponding to 51.5% of the total direct cost. In contrast, the conventional reinforced concrete system presented costs 28.4% higher than LSF for the same construction phase.

4.5 PARTIAL FINAL CONSIDERATIONS

This study concludes that the LSF system offers clear advantages in terms of cost efficiency and construction performance when compared to the conventional system. Despite existing challenges, there is significant potential for the adoption of LSF in Angola's civil construction sector, which may foster innovation and sectoral development.

Raising awareness and strengthening technical expertise are crucial for the successful implementation of this construction system in the country. From a future perspective, an increase in the acceptance and application of LSF is expected, promoting a transformative shift in the Angolan civil construction landscape.

5 CONCLUSIONS AND RECOMMENDATIONS

The comparative analysis between the conventional construction system and the LSF system, within the context of constructing the Faculty of Nursing at ISTM in Angola, demonstrates the technical and economic feasibility of adopting LSF. The results indicate significant advantages, including cost reduction, shorter construction time, lower environmental impacts, and an estimated service life of 50 years, subject to periodic maintenance during the first 10 years, as well as enhanced seismic safety.

The collected data show a substantial reduction in labour demand, with decreases of up to 73%, in addition to improvements in water resource management and waste generation reduction. The operational efficiency of LSF; particularly when combined with prefabrication techniques; suggests improved site organisation, optimised logistics, and reduced operational costs. The shortened construction schedule emerges as a strategic benefit, enabling earlier project delivery and more effective financial management. Despite limitations related to data collection and the diversity of analysed projects, the results reinforce the need for further investigations that explore more homogeneous variables and building typologies.

Overall, the adoption of LSF in civil construction in Angola not only promotes energy efficiency and cost reduction but also aligns with contemporary trends in sustainability and modernisation of construction practices. Based on the identified benefits, the following recommendations are proposed: i) Conduct detailed studies on the thermal and acoustic insulation performance of the building; ii) Develop technical services design projects in accordance with LSF standards; and iii) Prepare a comprehensive executive design for the implementation of the project.

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The findings indicate that constructing the Faculty of Nursing at ISTM using the LSF system is feasible and advantageous, offering multiple benefits in terms of economics, construction time, site cleanliness, maintenance, and sustainability. This research may serve as a valuable reference for civil construction professionals when selecting the most appropriate construction system.

Additionally, the description of the main characteristics of LSF, aligned with the reviewed literature, highlighted its advantages and disadvantages in comparison with the conventional system, as well as the associated cost outcomes. The architectural design met the objectives of the study and was developed in compliance with the indicators derived from the proposed hypotheses, using computational tools and relevant technical standards. Therefore, special attention is recommended for the implementation of the proposed next steps to ensure the effectiveness and quality of the future building intended for the Faculty of Nursing at ISTM.

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