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SYNTHESIS ON THE ASSESSMENT OF DESIGN PLATFORMS IN TERMS OF CONSTRUCTION EFFICIENCY

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Abstract: The construction sector is one of the important sectors of the economy, but it also has a significant negative impact on the environment. The global targets for increased economic efficiency and climate neutrality mean that the sector has to meet increasingly complex requirements. As this complexity increases, it becomes increasingly difficult and costly to achieve these economic, energy, and sustainability performance targets using conventional CAD or BIM design methodologies and software. To meet the complex requirements of the construction industry, various design platforms have been developed in recent years with different functionalities that allow the designer to easily create multiple schematic solutions, and analyze and evaluate them to identify the most efficient solution from various points of view. These design platforms complement the functionalities of conventional software and support the design process that takes place afterward. This paper aims to identify these platforms, and their functionalities and to analyze how they can contribute to the construction efficiency in design, execution, and operation. These platforms' evaluation is particularly important as they are newly developed, not sufficiently studied in research works, and will produce a paradigm shift in the design process.

Keywords: efficient constructions, efficient design, design platforms assessment, automation of design processes

1 INTRODUCTION

The construction sector is one of the most important sectors of the global and European economy, producing annually between 5 and 6% of the Gross Domestic Product of the European Union (Eurostat, 2021, 2023). Still, it is not a very efficient sector due to the delay in assimilating technologies or methods that have made other sectors such as aerospace, automotive, or manufacturing more efficient (Abrishami & Martín-Durán, 2021).

The conventional approach to building design and construction is generally complex (Brockmann & Kähkönen, 2012), time-consuming, costly, and inefficient process because it still relies heavily on outdated techniques and methodologies even when advanced technologies are used.

The complexity of the process is driven by the fact that today's buildings have to meet in the most efficient way possible not only the basic requirements like structural strength, operational safety, and fire safety but also more complex requirements regarding energy performance, sustainability, noise protection or user wellbeing (The European Parliament and the Council of the European Union, 2021).

Ensuring these performance criteria using common CAD (Computer Aided Design) or BIM (Building Information Modeling) software has certain limitations because originally they were built only to facilitate the 2D drawing process (Stefano & Francesco, 2010). Even if these software have subsequently been developed with various functionalities for 3D modeling or for automating certain processes, such as extracting drawings or project-related data from the 3D model (Kim et al., 2022), they still lack the functionalities that facilitate the automatic and rapid generation of multiple solutions at a conceptual level and the functionalities that allow these solutions to be evaluated and compared in real time.

In addition to this aspect, these platforms do not allow multi-objective optimization and multi-criteria evaluation of design solutions at an early stage of design, either because they do not have such features, or because the low level of detail of 3D models, which is specific to the initial stages of projects, does not lead to accurate analyzes. In the conventional approach, in the initial stages, the design is empirical, relying heavily on aesthetic principles. Therefore environmental, sustainability, or economic efficiency analyses are carried out at a later stage when the project is more detailed and making changes with a significant impact on the project's efficiency becomes more expensive (Babí Almenar et al., 2022).

Design is a multi-phase process that is iterative because construction has to meet the multiple and often conflicting needs of many internal and external stakeholders involved in or affected by the project at different phases (Mujumdar & Maheswari, 2018). In the traditional approach, a project passes through the following phases: Pre-design, Schematic Design, Design Development, Construction Documentation, Agency Permit/Bidding, Construction, and Closeout (The American Institute of Architects, 2014, p.7). After the handover, the building will enter the operational phase. At the end of its life cycle, the post-use phase, the building can be demolished, relocated, rehabilitated, and modernized to meet current comfort and legal requirements.

In the early stages of a project, the economic feasibility of the investment is assessed across various construction solutions. Consequently, these iterations are more frequent and may anticipate radical changes that significantly impact the project's subsequent performance. To ensure an optimal construction solution at this early stage, it is crucial to use a program that can swiftly generate and evaluate multiple solutions.

These objectives are currently being pursued by multiple online platforms or apps that have been developed in recent years for the construction sector by new tech companies (Fabian et al., 2024). Unlike conventional CAD or BIM software which have wider applicability and can be used at all stages of a project (Eadie et al., 2013), these platforms focus in particular on fast modeling and evaluation functionalities needed in the initial stages of a project to check the economic feasibility and/or for multi-criteria assessment of project performance.

This paper aims to analyze these design platforms in terms of several economic efficiency, environmental, and sustainability indicators to identify and assess how they can contribute to building efficiency at different stages of the construction life cycle.

2 METHODOLOGY

In order to make an objective assessment, it was necessary to define a methodology that could be followed in the analysis process of each design platform. To do so, a process composed of the following 4 steps was used: identification of design platforms, accessing these platforms, identification and classification of functionalities, and evaluation of platforms according to their functionalities. This methodology is illustrated graphically in Figure 1.

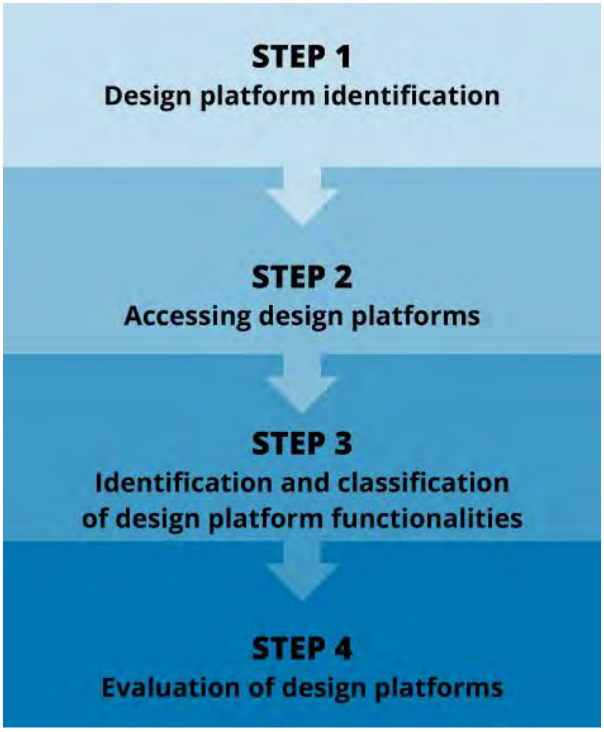

Figure 1. The 4 Steps followed to evaluate design platforms

2.1 The identification of design platforms that can be used to increase building performance

After conducting Internet searches the following 19 design platforms were identified: Archistar, ArchiTECHtures, ARKdesign, Autodesk Forma, Digital Blue Foam, Giraffe, Hektar, Hypar, Kolega Space, Planalogic, Preoptima, Skema, Spacio, StrateGIS 3D CityPlanner, Testfit, Tessa Modulous, XKool Design Cloud, Urban Dashboard, Zenerate Modular.

2.2 Accessing Design Platforms

This phase involved creating test or educational accounts to allow access to the platform and requesting access to these platforms if this could not be done directly from the platform's official website. This phase was very challenging as some of the platforms identified in the previous phase have not yet been commercially launched even though they are in advanced stages of development.

These platforms offer access only to a limited number of users based on registration on a waiting list. Other platforms offer access only to business customers, after scheduling and taking a test to learn about the platform functionalities and purchasing a subscription. Some of these platforms did not respond to the request to organize such a test as a researcher, while some platforms preferred to offer access through an educational account.

Access to some platforms was not possible because they did not offer free access for a trial period or through an educational account, nor did they respond to requests sent by email or contact form and therefore access and information regarding platform features could not be obtained.

The platforms that could not be accessed, those that did not provide sufficient information or materials (brochures, guides, tutorials) to allow evaluation of the functionalities, and those that did not have an English interface were not analyzed. Thus the following software was removed from the analysis: Digital Blue Foam, Hypar, Kolega Space, Planalogic, Tessa Modulous, Xkool Design Cloud, and Urban Dashboard. Some of these programs show promising functionalities in terms of improving building efficiency, which is why it is recommended to follow their evolution. So 12 platforms provided access or could be evaluated based on the presentation materials produced by the platform developers and could be analyzed and evaluated.

2.3 Identification and classification of design platform functionalities

The analysis of the platforms involved the study of 68 parameters of which 10 are general data such as launch date, platform type, and costs. The remaining 58 parameters represent various platform functions that facilitate the process of generating and evaluating building solutions in different ways. Given the large number of parameters considered for the evaluation, it was decided to group them into the following 8 functionality groups that are illustrated in Figure 2: interoperability functionalities, visualization functionalities, manual editing functionalities, automatic solution generation functionalities, environmental analysis functionalities, sustainability analysis functionalities, quantitative analysis functionalities, economic analysis functionalities.

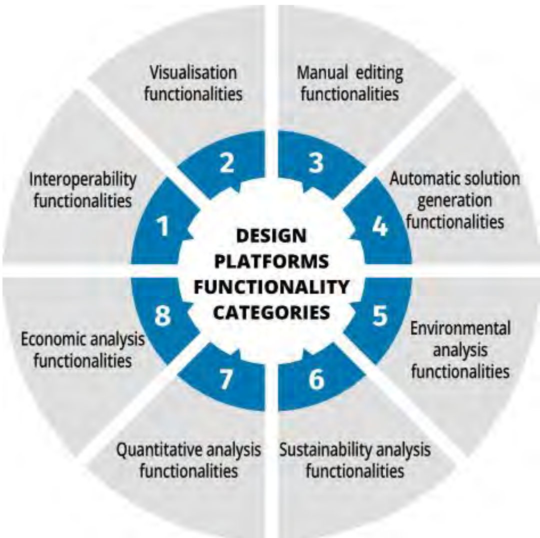

Figure 2. The 8 categories of design platform functionalities

2.4 Evaluation of design platforms according to their functionalities

The evaluation of the platforms involved assigning one point for each functionality the platform had. These scores were then organized by functionality group to identify the platform with the highest score in each category. Additionally, scores were centralized by platform to determine which one has the highest overall score and the most functionalities.

3 OVERVIEW OF THE DESIGN PLATFORM FUNCTIONALITIES

Unlike traditional CAD/BIM software which is designed to be used for all phases of the project and by all specialists involved in the project, the design platforms used to assess the economic feasibility of the projects studied in this paper have a narrower applicability and some are also addressed to users without design experience such as developers or real estate agents. So these platforms have a simple interface that makes it easy to access important functions, but also easy and quick to configure the settings needed to automatically generate solutions even for inexperienced users. Another important difference is that traditional CAD/BIM software is installed on the user's computer while the design platforms presented in this paper are generally hosted in the cloud on the platform developer's server and accessed via the internet through the browser. Of all the platforms reviewed in this paper, the only one that installs on the user's computer is TestFit. Thus these platforms can be accessed from anywhere, from any equipment with internet access, but also by multiple users who can collaborate in real-time to the project. Another advantage of this type of software is that it automatically receives real-time updates from the software developers, so the user no longer has to install these updates or buy newer versions.

These platforms are classified as Software as a Service (SaaS), and they can be used on a subscription basis rather than a perpetual license as is most commonly the case with CAD/BIM software.

These characteristics also result in the main disadvantages of this type of software, namely that in the absence of an internet connection or if technical problems occur on the servers where the design platform is installed, it will be impossible to use it. At the same time, the high cost of subscriptions for accessing the platforms, which cannot be amortized over time as in the case of perpetual licenses, means that these platforms can be used mainly by offices with a constant flow of projects that exploit the functionalities of these platforms.

3.1 Interoperability functionalities

This category includes functionalities that improve the efficiency of the design process by offering multiple ways of communication with other software such as exporting the project in different open standard formats (.pdf, .xls, .dwg, .ifc), by having direct connections with different B.I.M. software or by offering the possibility to extend the functionalities of the software by integrating extensions or software made by other software developers.

Using these functions the data, 2D model, and 3D model of the construction can be exported and imported into other software easily, without losing data and a lot of time remodeling the project or parts of it when it becomes necessary to use another software (Idrissi Gartoumi et al., 2023). These functions are very important because the design platforms studied in this paper are intended to be used in the initial stages of the project for multi-criteria analysis of multiple schematic design solutions and cannot be used for the entire design process.

Therefore, after validating the conceptual solution, the project must be continued in CAD/BIM software, which allows for detailing the project to the level required for the construction phase.

In addition to export and import possibilities, it was also analyzed whether other applications, extensions, or plugins could be installed inside the platforms. These features allow the designer to customize the platform, extending its functionality by installing applications provided by other software developers. At the moment these functionalities are available on only 3 platforms, the number of applications that can be installed is very limited and the use of certain applications involves other paid subscriptions and therefore additional costs.

3.2 Visualisation functionalities

The evaluation of these functionalities involved identifying how solutions generated in the design platforms can be visualized. This included whether the generated solutions can be visualized in 2D, or 3D, whether the platforms allow the generation of realistic static images, and whether the 3D model can be visualized through augmented or virtual reality technologies. These functions contribute to a better understanding of the project, improve communication between the stakeholders involved, and thus facilitate the decision-making process (Whyte et al., 1999). At the same time, it has been investigated whether the studied platforms have 4D visualization functions that allow the programming and visualization of the construction stages to optimize this process and also identify possible conflicts (Farnood Ahmadi & Arashpour, 2020).

3.3 Automatic solution generation functionalities

The automatic solution generation functions are the most important because they can automatically and almost instantly generate multiple project solutions based on criteria defined by the designer in the platform interface.

In the first phase, it was analyzed whether the design platforms could be used for the automatic generation of a single building or assemblies composed of several buildings. Subsequently, it was checked for which functions solutions can be automatically generated and the elements that are automatically generated and their level of detail were identified. In this regard, it was checked whether the programs generate models with plot layouts, which contain, in addition to buildings, landscape elements such as roads or vegetation, whether buildings are generated only as simple volumes or are divided into spaces of different sizes and functions, or whether the plan of these buildings is automatically generated. In addition to these aspects, it was also checked whether the platform automatically generates a single solution or multiple solutions for each project. The design platform must be able to automatically generate multiple solutions at each stage of the project because this allows the designer to choose the right solution by comparing and analyzing multiple solutions. This function is very important at this time because these platforms are still under development and therefore the generated solutions are often not usable, requiring manual editing by the designer.

A higher level of detail in automatically generated solutions improves the accuracy of economic analysis, making it possible to evaluate the solutions correctly. Platforms that automatically generate solutions with a high level of detail and also communicate with BIM software contribute to a significant reduction in design time because some of the elements that are usually designed manually in BIM programs can be generated automatically by these platforms.

3.4 Manual editing functionalities

In this phase, it was analyzed whether the platforms studied allow manual editing of the topography of the terrain, functional zones, circulations (roads, alleys, parking lots, accesses), or the constructions.

Platforms that automatically generate solutions for construction projects are still in the early stages of development and therefore some of the generated solutions contain various anomalies that can be corrected by manual editing by the designer. At the same time, some programs can only automatically generate certain elements of the project and therefore the designer has to add manually elements that are not automatically generated. On the other hand for some platforms before the automatic generation of solutions, the designer has to manually define accesses, roads, or functional zones. However, not all the platforms analyzed offer the possibility to manually model the project or at least parts of it. The lack of these manual editing functions is a major disadvantage as the designer may have very limited control over the generated solutions.

3.5 Environmental analysis functionalities

Environmental analysis functionalities facilitate the assessment of how a project influences and is influenced by various environmental factors. These analyses allow the assessment of sunlight levels on facades or interior spaces, potential solar energy production, noise levels, wind conditions, microclimate, and visibility to the sky or significant landmarks. Although these functionalities and analyses do not directly contribute to construction efficiency in the construction phase, they contribute significantly to construction efficiency in the operational phase. These features make it easier to design optimized solutions in terms of daylight, wind, and noise levels to ensure the well-being and a higher level of comfort for both indoor and outdoor users (Zhou & Guo, 2023).

In addition to these analyses, some platforms also contain data regarding various natural hazards (flood zones, bushfire risk zones, protected areas, etc.). These data inform the designer at an early stage of the project that a site is exposed to certain natural hazards and that the construction must therefore be designed considering these hazards, their limitations, and the additional costs they may generate.

3.6 Sustainability analysis functionalities

Sustainability analyses enable the evaluation of a project's environmental impact and facilitate testing and comparing various architectural and construction solutions to determine the option with the lowest environmental impact. Carrying out these analyses at an early stage is particularly important in developed countries where building permits and taxes depend on these aspects.

Environmental impact assessment is a very important component in the certification of green buildings by international bodies such as BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), or national bodies such as ROGBC (Romanian Green Building Council). In addition to certifying the reduced impact of a building on the environment, obtaining these certifications has other advantages such as reducing operational costs, improving the image of the company operating the building, increasing its attractiveness to tenants or buyers, and reducing credit costs by applying preferential interest rates (Grzegorzewska & Kirschke, 2021; Jang et al., 2018; Leskinen et al., 2020).

3.7 Quantitative analysis functionalities

This function allows the automatic extraction from the designed solutions of different statistics, lists, or reports on project areas, bills of quantities, number of apartments or terrain systematization. If the platform does not contain economic analysis functions, these data can be used to generate economic reports in other software like Microsoft Excel or Google Sheets.

3.8 Economic analysis functionalities

The economic analysis functions use data from quantitative analyses and other relevant economic data configured by the designer such as land cost, hard costs, soft costs, sales or rental prices to generate certain reports on the construction or operational cost, as well as other relevant economic data that contribute to verifying the economic feasibility of the project or the most economically efficient solution from the early stages of the project.

The performance of most construction projects is affected by time and cost overruns (Ashtari et al., 2022). These can be avoided through project management practices that aim to accurately estimate and budget costs at each stage of the project (Shah et al., 2023).

By utilizing these new design tools, a preliminary economic evaluation of the project can be conducted. Given the low level of detail at this stage, the evaluation may have lower accuracy, which is typical for early project phases. This margin of error must be considered to minimize its impact on the project budget.

4 ASSESSMENT OF THE FUNCTIONALITIES OF THE TESTFIT PLATFORM

This chapter will present the functionalities of the Testfit platform which obtained the highest score (38 points) and could be tested using the educational license provided by the application developer. The purpose of this presentation is to demonstrate the methodology used for assessing the platforms and to enhance understanding of how these functionalities are integrated into each platform.

4.1 Interoperability functionalities

This software offers the possibility to export the project in .pdf, .dxf, .skp, .csv and .gltf format. The functionalities of the platform can also be extended by linking the project to Revit, the most used BIM software globally, or using integrated programs such as Zoneomics (maps with urban regulations), Enscape (photorealistic 3D visualization), TT Core Studio (automatic generation of parking structures), Cove Tools (environmental and sustainability analysis) or Esri (thematic maps with different risk areas).

For this category of functionalities, Testfit received 11 points.

4.2 Visualisation functionalities

Testfit allows the project to be viewed in 2D (see Figure 3), and 3D (see Figure 4), and by using the Enscape plug-in that is integrated into the program, photorealistic 3D renderings can be created. Automatic solution generation functionalities. However, the platform does not have 4D visualization functions that allow the visualization of the construction sequences, or visualization using VR technology.

For this category of functionalities, Testfit received 3 points.

Figure 3. 2D view of an apartment building generated automatically in TestFit

Figure 4. 3D view of an apartment building generated automatically in TestFit

4.3 Automatic solution generation functionalities

Concerning these functionalities, it should be noted that TestFit is one of the most versatile programs studied, as it allows both single-building projects and projects containing groups of buildings with different functions (single-family housing, multi-family housing, mixed-function buildings, hotels, retail, offices, industrial, ground level parking, road parking or garage parking). At the same time, the platform automatically generates a complete design of the plot, which contains not only buildings but also roads, parking lots, and vegetation. The generated buildings are automatically subdivided into units detailed to the furnished floor plan level.

Although the program automatically updates the plan, the division into units, and the volumetry of the buildings as a result of changes to the project, it automatically generates multiple solutions only for the way the buildings are placed on the plot, not for the division into units or the plan. Another functionality that streamlines the design process is the automatic import of terrain and buildings from the studied area.

For this category of functionalities, Testfit received 18 points.

4.4 Manual editing functionalities

The program allows manual editing of functional zones, roads, and constructions, but does not allow manual editing of terrain topography. This is an important disadvantage for this platform because even terrain with small slopes requires certain systematization works that can significantly influence the cost of the project and therefore it is important to be able to assess these costs at an early stage of the project. The topography of the terrain can also have important implications on the architecture of the building. At the moment Tesfit does not automatically generate solutions adapted to the topography of sloping terrain. Therefore at this moment it cannot be considered the best design software solution for projects on sloping terrain.

For this category of functionalities, Testfit received 3 points.

4.5 Environmental and Sustainability analysis functionalities

The main disadvantage of TestFit is that it does not provide functionalities for environmental and sustainability analyses. However, some of the analyses in this category can be carried out using Cove. Tools, a program that can be used for various environmental and sustainability analyses and can be linked with TesFit. However, the use of Cove Tools involves the purchase of a separate subscription, and therefore these functionalities cannot be scored.

TestFit did not receive any points for environmental and sustainability analysis functionalities.

4.6 Quantitative analysis functionalities

The program automatically generates various data that facilitate the quantitative evaluation of the project such as different areas, zoning regulation data, and number of units. This data can be saved as a report, but its design, layout, or content cannot be customized. The program does not generate data about cuts & fills required for land systematization or bills of quantities.

For this category of functionalities, TestFit received 2 points.

4.7 Economic analysis functionalities

After the user defines multiple economic parameters like: land costs, soft costs, hard costs, rental income, parking income, operating expenses, and the capitalization rate, the program automatically calculates various economic indicators such as total costs and revenues, net operating income (NOI), yield on cost, and capitalization rate.

For a correct economic assessment of the project, the investor and the designer must have experience regarding the average costs and revenues specific to the area in which the investment will be realized and the type of investment that will be realized. Otherwise, the project's economic performance might be misjudged, potentially steering it in an economically unfeasible direction.

An important disadvantage of TestFit is that these economic data cannot be exported as an economic report and therefore the designer must spend additional time elaborating it manually.

For this category of functionalities, TestFit received 1 point.

5 RESULTS

All platforms were evaluated using the methodology outlined in Chapter 3 and demonstrated with TestFit in Chapter 4. The results obtained after the evaluation have been centralized in Table 1 below. These results were then interpreted and discussed.

The highest-scoring platforms are TestFit (38 points), Autodesk Forma (35 points), and Archistar (35 points).

Table 1. The Matrix of design platforms vs features centralizes the scores awarded to each platform for each functionality. Cells with a green background highlight the functionalities for which a platform scores highest, and cells with a red background highlight the functionalities for which a platform scores lowest. A red-to-green gradient background was used for the total score and price to highlight the hierarchy between the maximum and minimum values.

FUNCTIONALITY \ PLATFORM	Archi TECHures	Spacio	Giraffe	Autodesk Forma	TestFit	Zenerate Modular	Preoptima	Skema	Archistar	ArkDesign	3D Cityplann	HEKTAR
Interoperability	5	7	5	12	11	3	3	3	5	4	2	4
Visualisation	2	2	2	3	3	2	2	2	2	2	4	2
Manual editing	1	2	4	2	3	1	0	3	4	1	3	0
Automatic solution generation	7	12	10	10	18	8	2	7	18	5	12	8
Environmental analysis	0	4	2	4	0	0	0	3	1	0	1	0
Sustainability analysis	0	0	0	3	0	0	2	0	0	0	0	0
Quantitative analysis	3	2	3	1	2	2	1	1	3	2	2	1
Economic analysis.	2	0	2	0	1	1	0	0	2	0	1	0
TOTAL SCORE	20	29	28	35	38	17	10	19	35	14	25	15
PRICE	468 €	3588 €	3000 $	1500 $	15000 $	1800 $	1188 $	2171 $	950 $	0 $	540 €	1790 €

The platform with the lowest score is Preoptima (10 points). This score is a consequence of the fact that Preoptima focuses on the functionalities of assessing the carbon footprint of buildings and less on the functionalities of modeling, automatic generation of solutions, or quantitative and economic analysis. Therefore this program scored the lowest for 6 of the 8 categories.

The highest-scoring platforms for interoperability functionalities are Autodesk Forma (12 points) and Testfit (11 points).

The platforms that scored highest for the visualization functionalities are 3D City Planner (4 points), Autodesk Forma (3 points) and Testfit (3 points).

Giraffe and Archistar received the highest scores for manual editing functionalities, each earning 4 points.

The platforms with the highest score for automatic solution generation functions are Testfit (18 points) and Archistar (18 points). As these functionalities contribute significantly to the efficiency of the project from the early stages of design, it was considered necessary to present the scores of all the programs in a radar chart with a scale from 1 to 20 (see Figure 5).

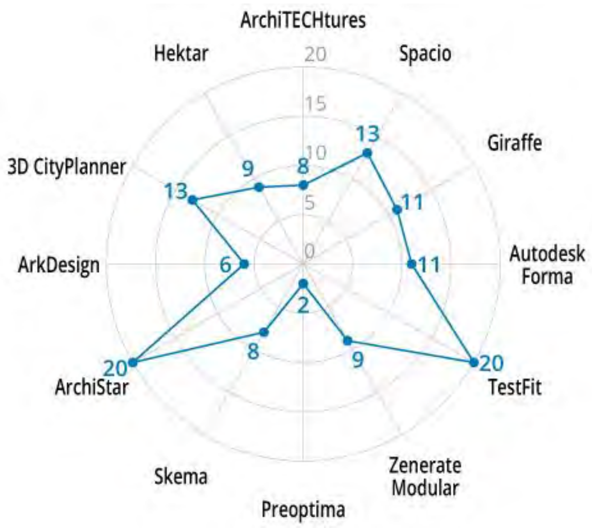

Figure 5. Radar chart with the scores obtained by each platform studied for the automatic solution generation functionalities

The highest-scoring platforms for environmental analysis functionalities were Autodesk Forma (4 points) and Spacio (4 points).

The platform with the highest score for sustainability analysis functionalities is Autodesk Forma (3 points). However, it should be noted that although Autodesk Forma offers multiple types of sustainability analysis, Preoptima can generate much more detailed and accurate sustainability reports because the designer can configure considerably more data regarding the environmental impact of the construction. Preoptima also allows the export of generated data as a very complex sustainability report.

The platforms that scored the highest in terms of quantitative analysis functionalities were ArchiTECHtures, Giraffe, and Archistar, each scoring 3 points.

Regarding the price of the platforms, it should be noted that there are currently platforms that are available free of charge because they are still in a test version and therefore are not commercially launched. These applications generally have fewer functionalities and may have some bugs or errors. Platforms that have been commercially released are priced between €468/year and $15,000. Except for Testfit, whose license costs $15,000, the other commercially released programs have a price below $3,600/year.

6 CONCLUSIONS

The fact that none of the programs analyzed managed to score more than 38 points out of the more than 58 functionalities analyzed shows that none of them currently manages to cover the full range of functionalities because some programs are focused on the 3D automatic design generation function, others on environmental or sustainability analysis, others on economic analysis.

Analyzing the results from the previous chapter makes it possible to identify platforms that meet the specific requirements of each designer or project. However, due to the large number of criteria to be taken into account when choosing the optimal platform, further research is needed to develop a fuzzy decision model that uses a smaller number of criteria and simplifies the decision-making process.

Because these platforms receive updates that add new functionalities at much shorter intervals than conventional CAD/BIM software, it is necessary to periodically re-evaluate the programs to update these scores.

Assessing the economic feasibility of a project involves processing a huge amount of information that is beyond human capabilities (Miljkovic et al., 2023). These platforms facilitate the automation of certain processes, making the right decisions faster in the early stages of the project, reducing human errors, and optimizing resource consumption (Nabizadeh Rafsanjani & Nabizadeh, 2023). Making the right decisions in the early stages of the project is of significant importance because substantial changes can be made to the project at this stage, with a significant impact on its performance and at much lower costs than when the project is in advanced stages, in the construction or operational stage.

The development of the platforms analyzed in this paper should continue to enhance interoperability with the BIM software most commonly used by designers. Currently, only four platforms provide this kind of functionalities that significantly reduce design times.

Regarding visualization capabilities, none of the platforms provide the option to visualize designs in VR, and only one platform allows for 4D design visualization. These functionalities would contribute to easing the decision-making process by facilitating the understanding and evaluation of solutions.

Most platforms have limitations or problems regarding automatic solution generation functionalities. These problems include incorrectly generated solutions, a small number of building types or functions for which solutions can be generated, and a low level of detail in generated models. Also, some platforms do not give designers enough control over the solution generation process or the possibility to refine solutions using manual modeling.

There are substantial deficiencies in the functionalities for conducting environmental and sustainability analyses, as only 4 out of the 12 platforms studied possess these capabilities. Considering the importance of these analyses in enhancing construction efficiency throughout its lifecycle, it is crucial to expand these functionalities to other platforms.

While most of the platforms provide sufficient data for project evaluation in terms of quantitative analysis functions, there are many limitations in terms of economic analysis functions because most platforms do not generate economic reports based on certain parameters configured by the designer. Additionally, these platforms should enable designers to integrate this data into configurable and customizable reports, which are crucial for investors to evaluate the project effectively.

All the platforms analyzed have certain functionalities that contribute in different ways to streamlining the design process, but the environmental and sustainability analysis functions of the platforms can also make construction more efficient during the operational phase. At the same time, the quantitative and economic analysis functionalities that are associated with the 3D models support the decision-making process by facilitating the identification of economically efficient solutions.

Generating very easily, in a very short time, a large number of solutions containing in addition to 3D models and data allowing multi-criteria evaluation of solutions makes these platforms produce a paradigm shift because they make possible the transition from empirical design based on aesthetic principles to data-driven design.

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