Integrating Computational Design and Space Syntax in Urban Planning and Design Education: A Data-Driven Pedagogical Model

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Abstract. Despite the increasing integration of computational tools in urban planning and design education, the structured application of space syntax as a configuration-based organisational framework within urban design studio pedagogy remains underexamined. While computational technologies are widely used for performance simulation and digital modelling, their role in systematically structuring the urban planning and design studio workflow from spatial diagnosis to validated design intervention has received limited focused investigation. This study addresses this gap by proposing a data-driven computational pedagogical model that embeds space syntax within a sequential and iterative studio framework. The aim is twofold: to formalise a reproducible workflow integrating computational procedures into studio education and to examine how algorithmic spatial evaluation enhances analytical coherence and evidence-informed decision-making. The research adopts a multi-phase methodology combining axial analysis, visibility graph analysis (VGA), agent-based simulation, and empirical observations (gate count and behavioural mapping), followed by post-intervention recalculation and statistical validation. The findings revealed that the strengthened social logic of space following the intervention demonstrates not only enhanced spatial coherence, but also the successful integration of algorithmic reasoning into the educational process.

Keywords: Computational Design · Urban Design Education · Urban Planning Education · Pedagogical Model · Space Syntax · Didactic Approach · Urban Park

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1 Introduction

Computational design is the use of algorithmic procedures, data-driven modelling, and simulation-based techniques to aid analytical rationale and judgment in spatial design [1]. Computational design in urban analysis goes beyond digital representation to include graph-based models of street networks, metric analysis of spatial configuration [2], visibility calculation [3], and agent-based simulations of movement behaviour [4]. Furthermore, computational design allows designers to evaluate accessibility, connectivity, and behavioural potentials using quantifiable metrics [5]. Urban environments can be studied as physical artefacts and as dynamic, rule-based systems [6], as well as through the prism of performance testing, comparison, and refinement [7]. As a result, computational design is important in mediating between hypothetical spatial concepts and empirical urban phenomena, in support of more stringent and empirically well-founded methodologies of urban analysis [8].

A pedagogical model in studio-based education refers to the framework according to which the process of learning, the development of designs, and the acquisition of knowledge are systematically structured and directed [9]. In the context of urban design studios, a pedagogical model outlines the sequential analysis procedures, describes the connection between theoretical abstractions and their practical implementation, and establishes the evaluative standards used in making design decisions [10]. The model controls how students perceive spatial problems, how they transfer observations of empirical data to strategic proposals, and how they support their design solutions [11]. It is no longer limited to instructional methods; rather, the pedagogical model can serve as a formal architecture of learning that coordinates the interactions of analytical tools [12], empirical data [13], and creative synthesis [14]. As a result, the form of the pedagogical model directly influences the level of reasoning, methodological clarity, and analytical consistency which define the studio setting [15].

The pedagogical models that have been widely researched in scholarly studies in design education comprise reflective practice [16], participatory approach [17], experiential learning [18], and problem-based design [19] models. The issue of integrating digital and computational tools into architectural and urban design studios has been investigated many times, namely parametric modelling [20], gamification [21, 22], and simulation environments [23]. These efforts show an increasing concern with integrating computational thinking into design education. Nevertheless, the systematic implementation of space syntax as a configuration-based analytical concept in the studio setting, despite the growing use of computational technologies, is understudied in comparison. While space syntax has been extensively applied in the study of urban spaces in order to explore spatial configuration [24, 25, 26], equitable socio-spatial accessibility [27, 28, 29], and movement dynamics [30], there has been a dearth of focused research on its application as a pedagogical structuring tool that provides a systematic way of guiding the studio process from spatial analysis to design intervention. This gap shows that the graph-based computational approach, which is also referred to as space syntax, should be treated not only as a form of analytical support, but as an organisational logic that can guide the pedagogy of the urban design studio.

To address this gap, the objective of this study is to create and introduce a systematised data-driven pedagogical framework that incorporates the aspect of computational

design into the learning process of the urban design studio. In particular, the research paper aims to reveal how configuration-based computational tools can be utilised as an organisational guide through the sequential phases of spatial diagnosis, analytical appraisal, and design intervention in a studio setting. The objectives of this study are twofold: first, to codify an executable workflow for the integration of computational processes into the studio process; and second, to investigate how embedded computational processes can be utilised to improve the quality of evidence-based decision-making in student projects.

In this study, computational design specifically refers to the use of space syntax analysis tools. Being a graphical method of computation, space syntax converts spatial arrangements into relational data that is subject to algorithmic mathematical computations to produce measurable indices [31]. It measures urban configuration and the topological relationship between spaces and introduces a methodical approach to assessing spatial performance, as opposed to using an intuitive method alone, which offers a coherent structure for evaluating urban structure and behavioural potential [32].

2 Material and Methods

This study adopts a multi-phase methodology: in Phase 1, students conducted an analytical diagnosis through axial analysis (macro-scale configurational assessment using integration and connectivity metrics), micro-scale visibility evaluation using VGA, and empirical observation techniques, including gate counts and static snapshot behavioural mapping. These analytical outputs formed the basis of the students' initial assignments. In Phase 2, students translated the findings into spatial interventions (rearrangement proposals), followed by a reanalysis of both axial and VGA models to assess the impact of proposed modifications. Phase 3 introduced evaluation and feedback, where pre–post comparisons and performance verification were conducted. Building upon these stages, Phase 4 synthesised the structured workflow into the formulation of the computational pedagogical model as a reproducible framework. Finally, Phase 5 positioned the model within a broader academic context through comparison with traditional studio pedagogy and a strategic SWOT analysis. This phased methodology integrates analysis, intervention, validation, and critical reflection into a coherent, iterative research and pedagogical process. These methodological phases are presented in Fig. 1.

1.1. *Case Study and Analytical Sub-units*

The case study is the city of Cagliari in Italy and it serves as a testbed in practice by which the computational pedagogical model is put into application and tested. In particular, the case of 'Giardini Pubblici' is chosen as the representative analytical subunit of the projects that were developed in one of the studios because of the completeness of the computational workflow, the consistency of the empirical observations, and the fact that configurational metrics were turned into spatial design proposals, which were clear. The 'Giardini Pubblici' is an old public garden in Cagliari and is a transitional green corridor between the medieval fortified core of the city and subsequent urban extensions of the city. It combines landscaped promenades, axial, terraced, and panoramic visual access routes to the Gulf of Cagliari.

It is architecturally and culturally enclosed and has important civic and heritage attributes, including the *Civic Art Gallery*, and it is also near the *Roman Amphitheatre* and *Buoncammino promenade.* All these characteristics contribute to the twofold nature of the park as a recreational and a cultural intersection in the urban texture. The significance of such green corridors and greenery landscapes within the historic core of Castello neighbourhood has been substantiated in prior studies [33].

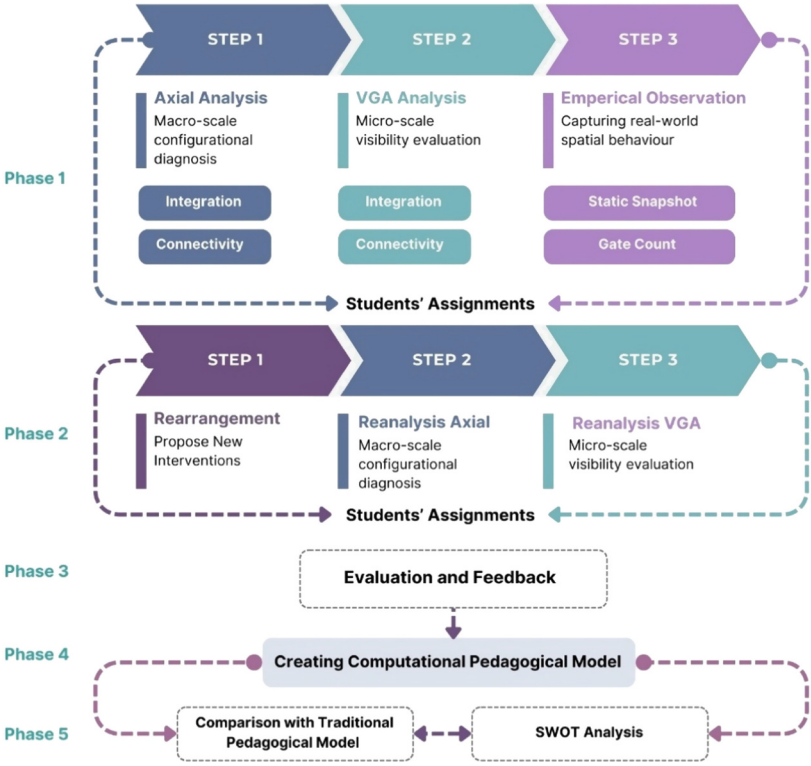

Fig. 1. Research method framework illustrating the sequential phases of the study

1.2. *Analytical Tools*

This analytical framework of the work is organised into two toolsets that are complementary to each other: (1) space syntax configuration analysis and (2) empirical observation. Although the computational component represents spatial structure and the possibility of movement by algorithmic processes of graphical processes, the empirical component records the observed patterns of use and activity in urban space. Together these tools allow a multi-layered evaluation of the performance of the space to combine the configurational measurements that may be quantified with the field-based mobility data. This two-fold analytical framework constitutes the main methodological premise that the computational pedagogical model is brought to bear in the studio setting.

Space syntax computational processes, which view urban space as a type of relational graph, produce quantitative measures of spatial organisation. Three major analytical tools were used in the workflow of the studio: axial analysis, VGA, and agent-based simulation. DepthmapX was used to implement these tools so as to adhere to consistency in spatial modelling and metric extraction. A combination of these calculation processes formed a range of analytical processes that interrelated macro-scale accessibility, micro-scale visibility, and dynamic movement modelling. The implementation of these tools into the studio allowed testing spatial configurations in measurable indicators before design intervention, which formed the basis of the computational framework of the suggested pedagogical model.

In order to supplement the computational analysis based on configuration, tools of empirical observation were used to record actual movement pattern and spatial utilisation in the sample public space which were chosen. Whereas space syntax represents possibility of behaviour using algorithmic processes, observational techniques describe behavioural manifestations in the same space. The observational part was a combination of quantitative pedestrian flow measurement with qualitative-spatial mapping of activities that made it possible to validate behaviour and put computational results in context.

The intensity of pedestrian flow was quantified by means of a structured gate count method. Each of the public urban spaces had 3–5 the observation gates at their main points of entry within a diameter of 500 m. The choice of the location of gates was guided by street network structure and movement corridors that were expected to be formed as a result of the axial analysis. People who crossed a given observation line at the gates were counted by hand after a predetermined period at every gate. Directional recording of movements was to be used to record inbound and outbound movements. The obtained data produced quantitative flow measures that allowed comparing them with spatial integration and connectivity measures obtained through the network analysis.

1.3. *Integration of Computational and Observational Analysis*

The multidirectional nature of computational and observational analysis is built in a progressively and mutually reliant workflow as opposed to separated processes and forms a configuration-behaviour correlation model. On a macro level, the axial integration and connectivity measures have been compared to the data on the number of gates to study the correspondence of the spatial centrality and the observed pedestrian flow. VGA findings at the micro level were superimposed to behavioural mapping outputs to determine the level of correlation between visual integration and movement activity patterns. The agent-based simulations also brought about dynamic modelling which helped to compare simulation movement distribution with empirical data. This cross-validation of spatial potential and actual behaviour was made possible through this multi-layered analytical synthesis, which served as a feedback mechanism in the studio. The combination of configurational measures, behavioural evidence, and simulation results enabled achievement of the process of establishing the design interventions using integrated, performance-grounded analytical foundation, which is the operational centre of the computational pedagogical model.

1.4. *Feedback and Evaluation*

This stage was aimed at verifying the spatial effect of the suggested interventions by the students in terms of their systematic reanalysis and feedback. Having prepared rearrangement proposals, which were made by initial configurational and empirical results, the students rebuilt the axial and VGA models in the constant computer parameters. The value of integration and connectivity was re-calculated and compared with the pre-intervention results to evaluate the changes in spatial accessibility, permeability, and structural coherence. This phase served as a performance verification tool, in that, the design choices were not merely justified conceptually they were quantitatively evaluated as well. The repeated comparison between the current and suggested settings formed a feedback-based refinement cycle, ensuring analytic responsibility and, therefore, completing the diagnosis-intervention cycle.

1.5. *Creation of the Computational Pedagogical Model*

This phase formalised the structured studio practice into a coherent computational pedagogical model. The model was abstracted into a reproducible methodological framework based on the sequential and iterative processes followed during the studio, the macro scale analysis, micro scale evaluation, empirical observation, synthesis and validation. This stage passed beyond the output of students and formalised the logic of the procedures that the studio was based on and made it a transferable pedagogical model. This study conceptualises computational analysis as the organisational foundation of the design process, integrating algorithmic rigour, empirical grounding, and model validation into a cohesive educational framework.

1.6. *Model Effectiveness through Comparative and Strategic Assessment*

This phase tested the usefulness of the computational pedagogical model on two levels, the comparative analysis with the traditional studio pedagogy and the systematic SWOT evaluation. The comparison demonstrated the change to intuitively based, critique-based, and performance-proven workflows to a sequential, data-based and performance-validated workflow. The SWOT analysis also analysed internal strengths and weaknesses as well as external opportunities and threats to implementation and scalability. Combined, these evaluations resulted in a critical analysis of the pedagogical worth of the model, its operational viability and strategic applicability in the modern teaching of urban design. This step was used to make sure that the proposed framework did not only exist as the theoretically articulated one, but it was also systematically reviewed with regard to its scholar strength and practical flexibility.

3 Results

3.1 Macro-Scale Configurational Diagnosis

The axial line analysis of the 500 m diameter around ‘Giardini Pubblici’ is shown in Fig. 2 depicting three configurational indicators, i.e. Integration, Connectivity and Entropy. All these measures indicate the macro-scale spatial organisation of the surrounding street network and its possible impact on the accessibility patterns.

The Integration map (Fig. 2–01) shows the accessibility of the street portions in the given 500 m diameter. Warmer colours (yellow to red) denote streets which are more

integrated and hence more readily accessible by all the other routes within the network whereas cooler colours (blue to green) denote routes which are more segregated or marginal. The findings show that the major street pathways near the study area have a greater value of integration, and they constitute the principal movement routes in the region. Conversely, secondary and inner residential streets lessen the amount of integration, meaning that they lose configurational centrality. The same trends indicate that the park is placed along structurally important routes, which supports its possible accessibility on the wider urban scale.

The number of directly connected axial lines per street segment (Fig. 2–02) is taken as the Connectivity map, which indicates the level of local-level linkage intensity. Warmer-coloured streets have more immediate connections, which means that they are more permeable locally and have more intersections. The analysis exposes that the intersections which are situated along the main streets surrounding the park have a high degree of connectivity and serve as local nodal points to the network. On the other hand, less curvy or cul-de-sac-like segments depict low values of connectivity. With the high connectivity and high integration along specific axes, there are spatial corridors that have a local and global significance in the network structure.

The Entropy graph (Fig. 2–03) shows the level of structural predictability and hierarchy of the street network. A smaller value of entropy (cooler colours) suggests more distinct spatial hierarchy and more differentiation of central and peripheral routes, whereas a large value of entropy (warmer colours) suggests more intricacy and less hierarchical structure of the network. The findings show moderate entropy throughout the 500 m diameter, implying a partially structured network characterised by highly integrated paths alongside more localised segments. The fact that distinctly detectable high-integration corridors are available suggests that the surrounding urban fabric has a readable spatial hierarchy as opposed to an equally complex arrangement.

3.2 Micro-Scale Visibility Evaluation

The visibility graph of ‘Giardini Pubblici’ (Fig. 3) is a micro-scale analysis, which demonstrates the visual integration, visual connectivity, and distributes agent-based movement within the park boundary. In contrast to the axial analysis, focusing on macro-scale street network structure VGA analyses internal relationships between spatial permeability and co-visibility and indicates the ways in which the internal organisation of the park forms a visual representation of accessibility and movement opportunities. The visual Integration graph (Fig. 3–01) quantifies the visual accessibility of every point in the park with regard to all the rest of the visible points. Warm colours (yellow to red) signify locations of high visual integration, which convey spatial locations that are centrally located visually and more prone to undergo elevated degrees of co-presence and encounter. Darker colours (blue to green) signify visually segregated or marginalised areas. The findings indicate that the primary longitudinal axis of the park has the greatest value of visual integration, which is its main internal route. The secondary pathways and peripheral green regions have lower value of integration implying lower visual exposure. This measure is especially helpful in determining what may potentially be the objects of social interaction and place of greater visibility, which can determine gathering and passive surveillance patterns. Visual connectivity graph (Fig. 3–02) provides the number of

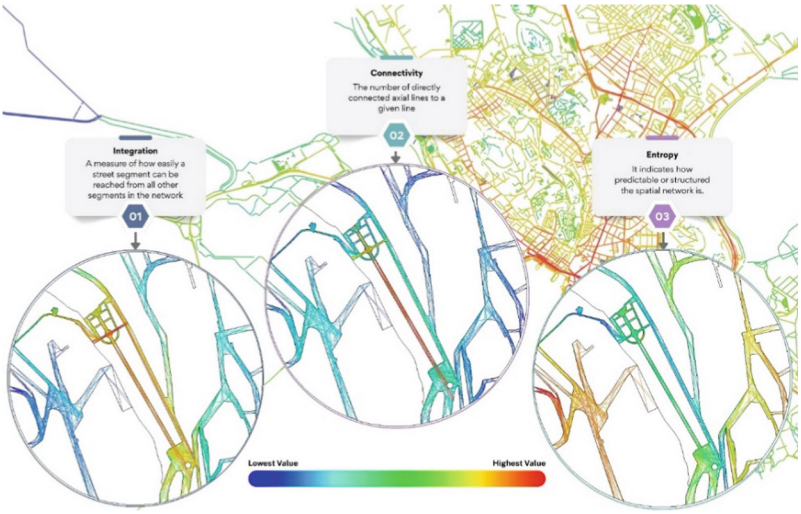

Fig. 2. Axial line analysis within a 500 m diameter surrounding 'Giardini Pubblici': (1) Integration, (2) Connectivity, and (3) Entropy. Source: Authors elaboration.

immediately visible points at every point in the park. It is a local permeability of visuals as opposed to universal accessibility. The regions that are better connected depict more visual fields and highly aware of immediate space. It can be analysed that open linear corridors and central intersections will have high connectivity values, whereas enclosed and vegetated areas have low visual connectivity values. This measure is applicable in assessing spatial openness, legibility, and safety perception because the more visual the connection between areas, the more conducive it becomes to succinct orientation and tracing spatial control.

The agent-based simulation (Fig. 3–03) is a model that has probabilistic movement of pedestrians using the underlying VGA structure. The gradient of colour shows spots where there are more agents and less agents throughout the simulation, which approximates the possible distribution of pedestrian density. The findings indicate that the simulated movement is focused along high-integration central axis, and there is moderate accumulation of the agents in the intersection nodes and few in the periphery areas. This dynamic output gives a behavioural projection based on spatial configuration. Notably, the agent distribution graph is a strategic tool that is used to ascertain where the potential areas for walkability will be positioned. In this way, the position of gates may be identified to capture varying degrees of movement by examining high, medium and low simulated agent concentrations. As an illustration, one of the gates can be situated along the transitional area of high agent concentration (high agent density), another in a moderate-density area, and the other in a low-density peripheral region. This makes sure that the empirical flow data reflect different spatial conditions as opposed to dwelling on dominant routes only.

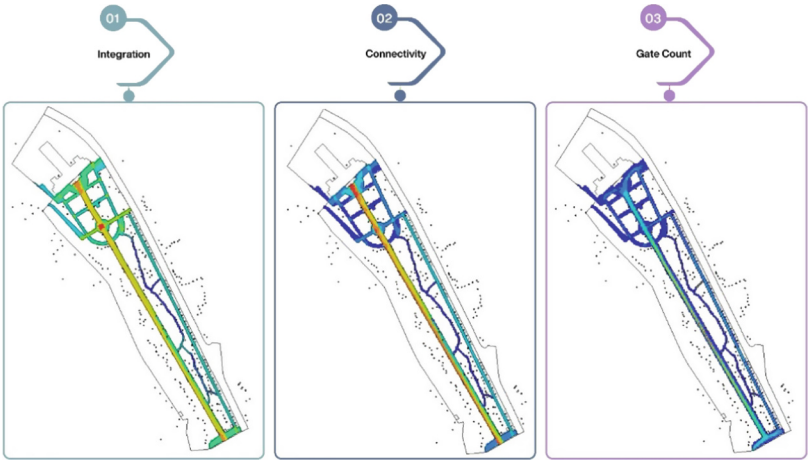

Fig. 3. VGA of 'Giardini Pubblici': (1) visual integration, (2) visual connectivity, and (3) Pre-processing of agent-based movement distribution. Source: Authors elaboration.

3.3 Empirical Observation

The gate count analysis was performed to measure the level of pedestrian flows at the main access points of 'Giardini Pubblici' in Cagliari. This scheme evaluates the amount of people entering and leaving the park via specific entry points to allow movement distribution and any access route that is mostly used to access the park. There are three main entrances of 'Giardini Pubblici', which were considered as the main gates in this study. These entrances are distributed for space connecting the park with the urban flows of various directions around it. Two planned observation sessions were held so as to give variability of data collection in time. The initial observation was carried out on a weekday (Thursday) at around 11: 00 a.m. on sunny conditions and the other one on Sunday at about 2: 00 p.m. on partially sunny conditions. The duration of stay in each gate was maintained at 15 min where both the inbound and out bound pedestrian movements were recorded. The observations carried out in various times and in diverse environmental conditions made possible comparative analysis with intensity of flowing and offered an understanding of how the temporal and contextual factors can affect movement patterns of pedestrians in the park. Figure 4 shows the outcomes of the observations of the number of gates made at the three main entrances of the park (a) Observation 1 (Thursday, 11:00 a.m.), (b) spatial location of the gates, and (c) Observation 2 (Sunday, 2:00 p.m.). The graphs are used to display the number of pedestrians that come in and out through each gate in 10 min intervals.

The Gate 3 had the highest pedestrian flow during the weekday observation, then Gate 1, and finally, Gate 2 had a relatively low intensity of movement. The inbound and outbound movements were largely equal at Gates 1 and 3, implying a consistent bi-directional circulation. The increased flow at Gate 3 may be attributed to its connection with the *Buoncammino* recreational and historical area, whereas Gate 1 benefits from its proximity to the city centre and the historic core. The gate 2 which is situated on the

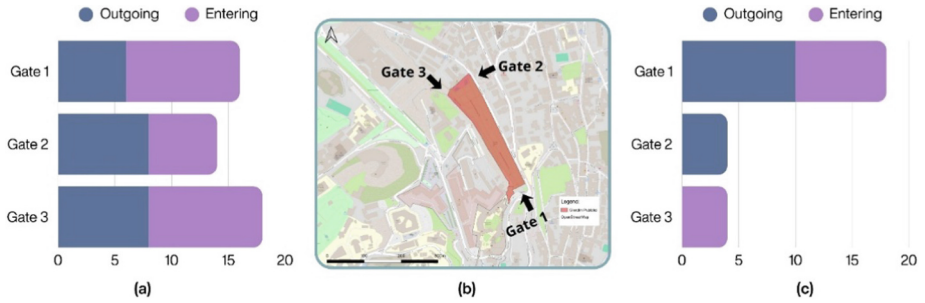

Fig. 4. Gate count observation results at the three main entrances of the park: (a) Observation 1 (Thursday, 11:00 a.m.), (b) spatial location of Gates 1, 2, and 3, and (c) Observation 2 (Sunday, 2:00 p.m.). Source: Authors elaboration.

Viale San Vincenzo showed average level of activity meaning that it plays a second role in overall park accessibility during the weekdays (Fig. 4a).

The fact that the situation on the weekend is different also shows a clear redistribution of pedestrian flows. The amount of entering movements at Gate 1 is very high than on the weekday session; this is a sign that the movements were more attracted towards the city-centre direction during leisure time. Gates 2 and 3, on the other hand, exhibit a significantly lower intensity of movement, indicating that weekend leisure visits can be better directed towards the southern entrance. The directional imbalance at the gate 1 shown by the larger number of incoming counts than outgoing counts could be the peak arrival times instead of the constant circulation records. The lower flows at the other gates show that there is a time change in the most stable access paths when the circumstances are of the weekend (Fig. 4c).

3.4 Synthesis and Design Translation

In the synthesis and design translation phase, the analytical outputs of the computational pedagogical workflow were converted into spatial design strategies systematically. Instead of considering configurational measures and behavioural observations as distinct analytical task, this step meant that they be explicitly incorporated into the design interventions formulation. The students were advised to consider the values of the axial integration, visibility, agent-based move, and the number of gates altogether and use them as their rationale to support the spatial changes, programmatic redistribution, and circulation restructuring. This step was aimed at creating an explicit traceable connection between proposed design solutions and data-driven diagnosis with the purpose of securing that any intervention can be analytically based. By synthesising the above in this structured way, space syntax functioned not just as a form of evaluation, but as an organisational logic through which the transition of spatial analysis to design decision-making is carried out.

Figure 5 demonstrates the results of configurations of the proposed design interventions based on recalculated simulations of integration, connectivity, and agent-based movement. According to the post-intervention integration graph, the central longitudinal axis is reinforced and, at the same time, the accessibility in the secondary pathways

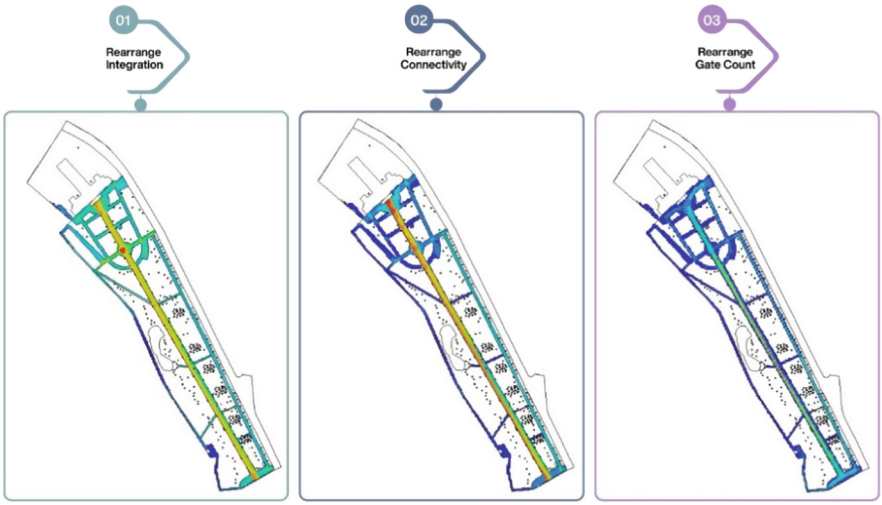

Fig. 5. VGA of 'Giardini Pubblici' with new interventions: (1) visual integration, (2) visual connectivity, and (3) agent-based movement. Source: Authors elaboration.

is enhanced. The values of integration are more evenly distributed in comparison with the original condition, and it may indicate improved spatial coherence and a decreased segregation of peripheral areas. The connectivity graph also shows more local connection between the internal paths that had been broken in the past, especially around the recently added landscape elements like the pond and the reorganised circulation paths. These changes enhance transversal interconnections and enhance inter-permeability in the park. The revised agent-based simulation demonstrates a less biased flow of people on the site. Although the central corridor consistently remains as the main pathway, the movement intensity is now stretched out to newly activated space such as ecological corridors and gathering nodes. The redistribution shows that the interventions are effective in reducing the over-concentration along one axis and promoting spatial diversification of use.

The scatterplots of visual connectivity and visual integration of the 'Giardini Pubblici' configuration in the form of (01) existing condition (pre-intervention) and (02) proposed design (post-intervention) are shown in Fig. 6. The points on it are the spatial nodes of the VGA, that is, the visual permeability of the area (connectivity) and the visual accessibility of the entire area (integration). Under the current state (01), the correlation between connectivity and integration will yield strong positive relationship, with the value of R^2 of 0.816. This means that the difference in connectivity can be attributed to integration by about 81.6%, indicating a comparatively intelligible spatial structure whereby locally observable regions would be more likely to coincide with accessibly global locations. Nevertheless, the local/global spatial performance is not entirely consistent according to the scatter of the values of the mid-range.

After the suggested interventions (02), the correlation is even better, and the R^2 value goes to 0.829. This growth is the sign of a better correspondence between local connectivity and global integration of the internal configuration of the park. The closer

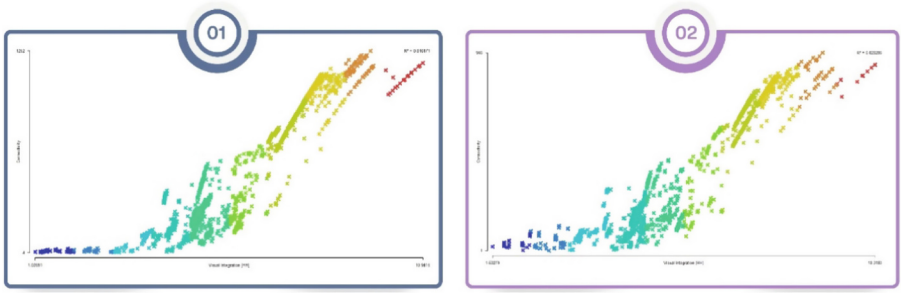

Fig. 6. VGA scatterplots, illustrating the correlation between visual connectivity and visual integration: (01) existing configuration (pre-intervention) and (02) proposed configuration (post-intervention). Source: Authors elaboration.

the points are to the regression trend, the greater the spatial legibility; this suggests that high local permeability is accompanied by enhanced visual accessibility throughout these areas. This, in configurational terms, is a more intelligible structurally consistent spatial system. The growth of R^2 within the intervention model indicates that the proposed design improves internal logic of the spatial network, which minimises fragmentation and supports the connection between centrality of global networks and visibility at the local level. This statistical upgrade supports the fact that the interventions do not only bring ecological and programmatic improvements, but they also statistically reinforce configurational performance.

3.5 Computational Pedagogical Model

The computational pedagogical model in Fig. 7 is a structured, sequential, and iterative workflow of the incorporation of computational spatial analysis into the urban design studio process. The framework starts by configurational diagnosis at the macro-scale level where axial maps are built and integration and connectivity measures are computed to help set up baseline spatial hierarchy and accessibility patterns. These are then followed by micro scale visual analysis through VGA which allows them to determine the internal spatial permeability and configuration in detail. To be able to link computation findings to actual movement and activity patterns, empirical observations such as gate count and statically snapshot behaviour mapping are then added. The synthesis and design translation phase superimposes both computational and empirical outcomes to create spatial interventions that are directly based on analytical evidence. Most importantly, the model ends in an evaluation and iterative validation step where post-intervention measures are recalculated and statistically compared to pre-intervention states which provides a feedback mechanism that allows refinement and performance checks. The two iterative cycles, analysis and feedback, make the studio a closed-loop performance-driven system instead of a linear design process in which diagnosis, intervention, and validation are interdependent computation phases (Fig. 7).

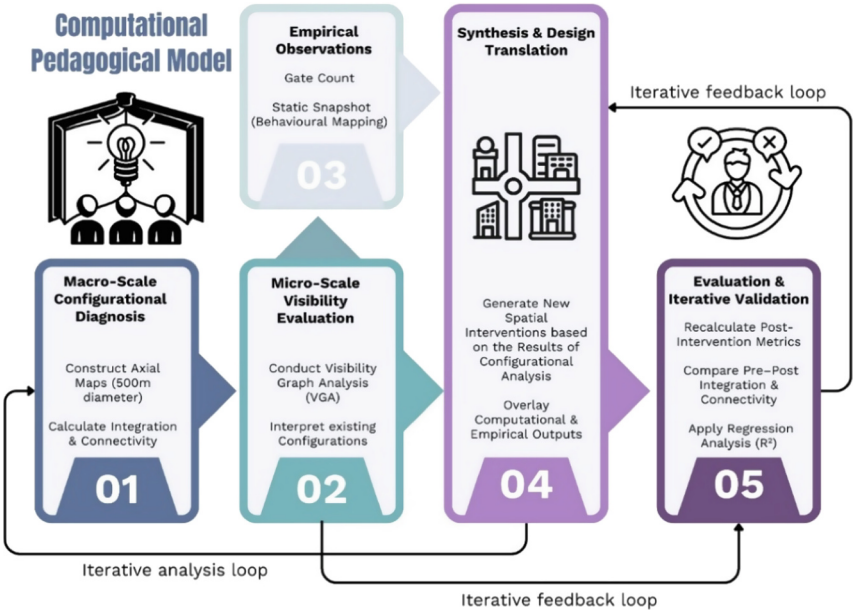

Fig. 7. The Computational pedagogical model. Source: Authors elaboration.

4 Discussion

The findings described in the current paper prove not just that there are quantifiable changes in spatial organisation and distributions of movements, but, more crucially, that there is a pedagogical significance to framing an urban design studio through the lens of a computational analysis. The gradual reduction in scope (from the macro-scale axial analysis to micro-scale visibility modelling, empirical observation, and statistically validated testing carried out after the intervention) made the workflow between the diagnosis and the design decision-making transparent and traceable. Instead of using intuition and being guided solely by aesthetic arguments, students had to base their proposals on quantifiable spatial signs and behavioural facts. This organised procedure helped to turn computational analysis into a secondary technical practice as well as an organisational rationale for the whole studio. The amplified relationship between connectivity and integration after the intervention demonstrates not only enhanced spatial coherence, but also the success of the integration of algorithmic reasoning into the educational process. In this regard, the pedagogical model transforms the studio from a critique-based format into a data-driven, methodologically explicit learning structure.

A comparison of the computational pedagogical model and the conventional urban design studio indicates a paradigm change in the design education structure and rationale (Fig. 8). The traditional forms of studio are usually based on exploration via intuition, successive critique, and informal decision-making where analytical reasoning is usually tacit as opposed to structured. The development of the design is rather linear, and reviewing is done mainly through qualitative feedback at the stages of the development.

The SWOT analysis reveals that the efficiency of the computational pedagogical model is based mostly on its systematic analysis structure and incorporation of quantifiable validation systems into the studio processes. Even though one has to take weaknesses (such as time constraints, cognitive overload, and the potential for excessive emphasis on quantitative indicators) into consideration, the proposed pedagogical model is operational rather than merely conceptual, and its limitations can be mitigated through systematic guidance and a more balanced incorporation of qualitative factors. These outlined opportunities also enhance the applicability of the model, especially the transferability of the model to studio settings, its ability to complement the new computational technologies and its ability to build stronger research-grounded design education. Although threats like institutional rigidity, lack of computer resources and methodological change resistance are likely to impair implementation, they do not weaken internal coherence of the model. Rather, they emphasise the systemic change that is needed to synchronise the modern design education knowledge with information-driven urban analysis. In sum, the SWOT analysis shows that the pedagogical model is effective, as it methodically aligns analytical rigour, computational validation, and design translation in an iterative process that increases the transparency, accountability, and methodological depth in urban design studios (Fig. 9).

In contrast to recent research in the field of computational and performance-oriented design education, the current study broadens and redefines the function of computational approaches within the urban design studio. Dogan and Yang [34] refer to performance-based urban design education based on climate mitigation, energy efficiency, and mobility modelling, whereas Van Ameijde and colleagues [35] refer to data-driven analytics to connect the gap between research and schematic design to achieve socially sustainable results. In the same manner, Hensel & Srensen [36] and Brown [37] also anticipate performance-oriented and interactive computational environments, which integrate environmental simulation and optimisation in the architectural design procedures. Zhang [38] focused on structured computational tools based on the web, which reduce the barriers to learning and systematise the workflow integration.

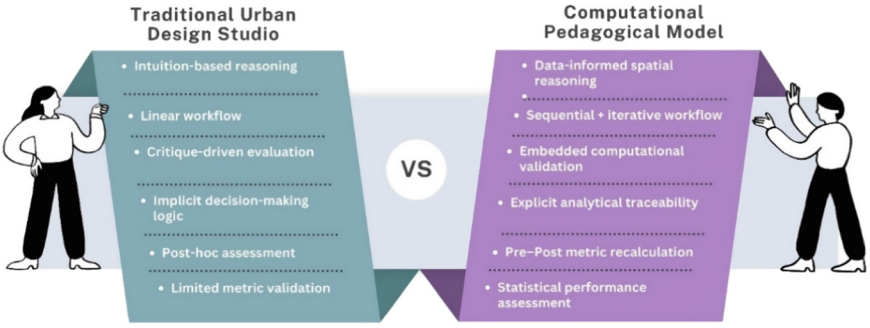

Fig. 8. Qualitative comparative analysis between the computational pedagogical model and the traditional urban design studio. Source: Authors elaboration.

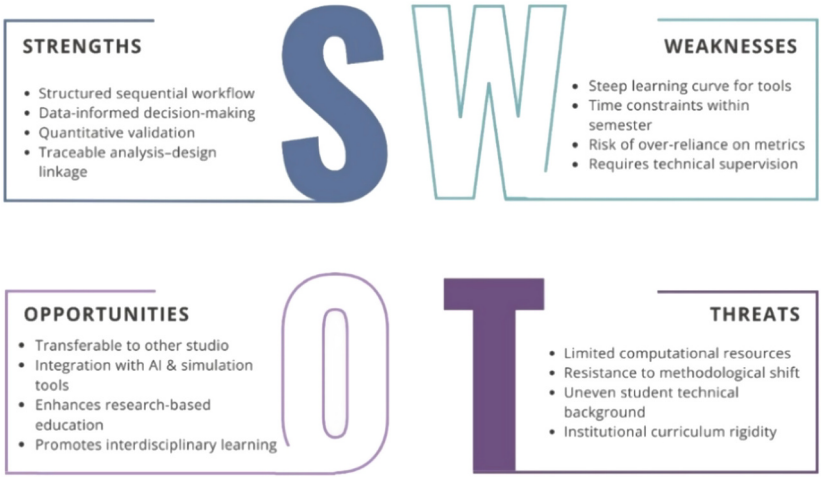

Fig. 9. SWOT analysis of the computational pedagogical model, illustrating its internal strengths and weaknesses, as well as external opportunities and threats. Source: Authors elaboration.

Unlike these works, which are mostly focused on performance simulation, integration of tools, ecological awareness, or building technical skills, the current research establishes space syntax as a performance assessment tool but rather as a logic that organises the whole pedagogical process of an organisation. Instead of considering solely the building-scale simulation or generative optimisation, this paper incorporates configurational analysis, empirical observation, and statistical validation in a sequential and iterative studio model at the urban scale. The important contribution here is then the formalisation of computational analysis as a methodological system of closed loop where diagnosis and intervention are to be conducted and validation is to be made, thus making studio pedagogy a temporisation to become a performance-validated and analytically traceable process of urban design.

The main limitation of this study lies in the generalizability of the pedagogical model, as it was tested within a single case study. The next step in research might be to increase the application of the model to a variety of universities and model studio typology to determine scalability and adaptability. The differences in learning outcomes, quality of design and methodological transparency could be further measured by comparative studies using traditional and computationally structured studios. Furthermore, the incorporation of new technologies, i.e., artificial intelligence, real-time city data feed, or parametric optimisation software, could contribute to the increased analytical power and the pedagogical significance of the model. The longitudinal studies of the effect of exposure to computational workflows on professional practice would also be an interesting source of information on the long-term effects of this educational methodology.

5 Conclusion

This paper introduced a computational pedagogical framework that reframed space syntax from a supporting analysis instrument into a structuring rationale intertwined with the curriculum of the urban design studio. The originality of the study lies in the formalised configuration-based spatial analysis as a closed-loop methodological system, reproducible as a macro-scale diagnosis, micro-scale visibility assessment, empirical observation, synthesis, and iterative validation through one structured workflow. The first objective of the study was fulfilled by creating and operationalising an analytical sequence which could be clearly defined and was transferable, and which made the procedures transparent and the methods consistent. The second objective was fulfilled by demonstrating how algorithmic spatial assessment, regression analysis, and post-intervention recalculation enhanced the coherence of the analysis and based the design decision-making on quantifiable metrics. Along with its concrete spatial discoveries, this paper also serves as a contribution to the reinvention of urban design pedagogy, proposing a shift from an intuitively based studio culture towards a more performance-and-data-driven and iteratively validated pedagogical paradigm, which would re-focus academic training on the analytical requirements of modern urban practice.

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