# The Optimized Social Distance Lab:

## A Methodology for Automated Building Layout Redesign for Social Distancing

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**Abstract.** The research considers buildings as a test case for the development and implementation of multi-objective optimized social distance layout redesign. This research aims to develop and test a unique methodology using software Wallacei and the NSGA-II algorithm to automate the redesign of an interior layout to automatically provide compliant social distancing using fitness functions of social distance, net useable space and total number of users. The process is evaluated in a live lab scenario, with results demonstrating that the methodology provides an agile, accurate, efficient and visually clear outcome for automating a compliant layout for social distancing.

**Keywords:** Social Distancing, Architecture, Optimization, Signage, Wayfinding.

## 1 Introduction

COVID-19 has had an unprecedented impact on the day-to-day use of buildings [1]. These effects are likely to have an enduring medium- and long- term impact on the arrangement of building layouts to comply with social distancing, posing immediate and ongoing risks to both the personal health of users through non-compliance and to the financial viability of building operation due to increased circulation and distancing requirements [2]. The cost in person-hours to the global economy represented by the millions of concurrent and disparate exercises in building layout replanning during the pandemic has been truly significant [3]. To ameliorate against further substantial cost to the economy through both abortive space planning and non-compliant layouts [4], we propose a unique automated methodology for building operators to redesign their layouts to comply with social distancing. This will reduce timescales for reopening and adaptation in the event of revised government advice, local lockdown, or further variant outbreaks [5]; benefitting user health through verification of distances, whilst improving the efficiency of building operation through optimization of capacity. Our key research question is: can social distancing guidance be effectively automated for building layout plans?

## 2 Related Work

Our approach was to build a multi-criteria optimization definition using parametric software Grasshopper and Wallacei [6] to generate a redesigned floor layout with minimal human design input. A review of existing research reveals that no existing study provides practical development, testing and evaluation of optimized floor layout design in relation to social distancing; an expected consequence of the short time since the start of the pandemic. Of the papers that explore spatial layouts in the context of COVID-19, most refer to speculative or theoretical guidance as opposed to means-tested outcomes: Fischetti et al [7] considers a mathematics-based approach to social distancing, exploring the effect of aerosol spread on spatial layouts. Banon et al [8] investigate shape grammar optimization by mathematical formula. Yet no existing research evaluates the complexity of practical application considering real-world influences including multiple paths, wayfinding and unpredictable user behavior.

Of the significant research completed on multi-criteria optimization of design for spatial layout studies pre-pandemic, Guo et al [9] explore a multi-agent evolutionary optimization process to define office and housing layouts. The introduction of pedestrian flow for multi-objective optimization presented by Huang et al [10] provides insight into the potential of agent-based modelling on wayfinding cognition. Recent research by Dubey et al [11] proposes a new system for the automated positioning of signage based on a multi-criteria optimization approach; referencing theories of Space Syntax and behavioral and cognitive science. Yet, as a consequence of the rapid onset of the pandemic, none have investigated automated optimization of layouts in the setting of social distancing restrictions. In the context of this gap of knowledge, the work proposes a new methodology to bridge between theory and practical evaluation in the new context of the pandemic.

## 3 Research Methodology

To evaluate the methodology, the project tested a 'live' site, automating the design of the interior layout and wayfinding signage of the ground floor of a public building complex owned by Lancaster City Council (LCC) - the Storey Building in Lancaster City center. The *Social Distance Lab* opened to key stakeholders for three weeks in May 2020, providing opportunity for local business owners to explore a building altered to comply with social distance restrictions, with the dual purpose of collecting evaluation data from users active in the space.

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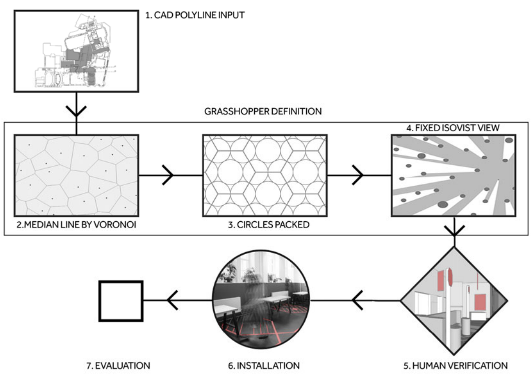


**Fig. 1.** Generative social distance framework overview

To generate the redesigned and optimized building layout incorporating a) user routes b) user destinations (e.g seating / toilets) and c) signage locations, a simplified AutoCAD 2D building plan of the building was used as input. The workflow method is summarized in Fig.1. Three fitness functions were defined: (i) Social distance (in meters) (ii) Net useable space (m2) (iii) Total number of users. Using the Wallacei plugin, fitness functions were tested using the NSGA-II algorithm. The analysis tools contained within Wallacei, including the Parallel Coordinate Plot, were used to identify preferred outputs on the basis of fitness.

### 3.1 User Route Generation

A Voronoi offset was applied to the 2D DWG building plan, generating a median line to establish a user route centered between adjacent fixed structures. An *exclusion zone* representing the social distance offset *(fitness function 1)* either side of the median line was tracked onto plans, and areas highlighted at risk of non-compliance were identified using attractor points checking collision on an analysis surface. This provided an early visual risk analysis through color codification of existing non-compliant spaces and routes. Using an Isovist definition [12] a visibility graph analysis was generated to indicate the visibility of walled surfaces using a restricted field of view Isovist in the direction of the path of movement. (Fig.2). This subsequently defined the physical location of wayfinding signage.

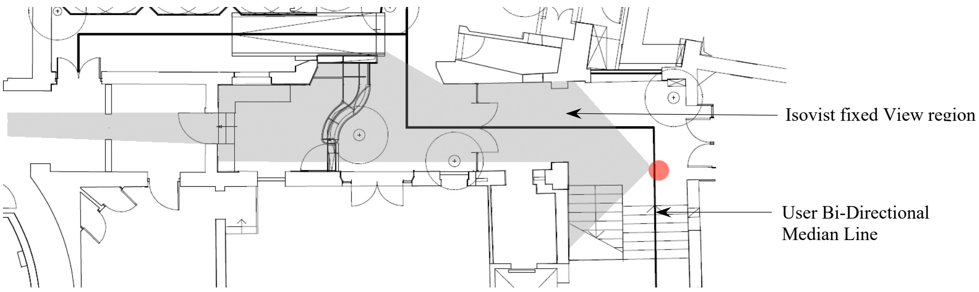


**Fig. 2** Visibility graph analysis indicating fixed view projected onto surfaces

### 3.2 Layout Optimization

The seating region was defined by subtracting the established *exclusion zone* from the net building outline *(fitness function 2).* To provide optimal seating capacity within this region, circles offset from a point (representing each user) were packed to fit wholly within each region *(fitness function 3).* Signage typologies and layouts were developed concurrently in collaboration with the client, LCC. Directed by both the optimized layout outcomes from Wallacei and associated isovist visibility graphs, the design team verified the final signage design and location with clients for fabrication and installation.

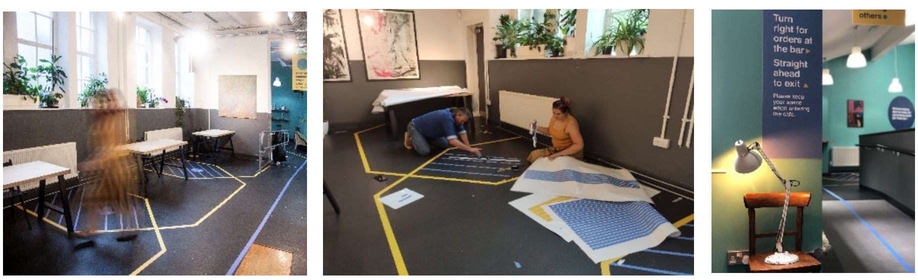


**Fig. 3.** Installation of the signage in the Storey building, Lancaster, UK. Installation took 18 hours, and 24 local businesses visited the space.

# 4 Results

In order to quantify the differences between human designed and automated layouts, five store designers were asked to draw a plan with identical parameters of input *prior* to viewing the automated outcome [Fig 4]. Human-designed plans included, on average, 32 seated locations compared with 40 of Plan B, a 25% increase in total capacity using the automated methodology. The percentage of useable space defined as the seating region is improved by 12% in the generated layout. On verifying accuracy, the human-designed plans (e.g *Plan A, Fig 4)* include an average of three locations that infringed upon the 2m social distance.

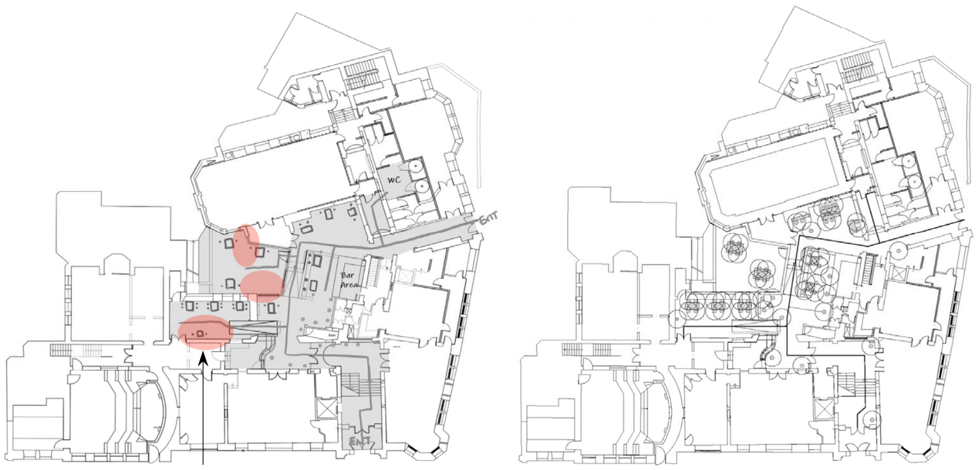


**Fig. 4.** Comparison of human-designed plan (A) and automated Grasshopper definition (B)

**TABLE 1.** Results of plan comparisons and survey of designer and key stakeholders

| | Human Designed | Generative Designed | Diff |
|---|---|---|---|
| Useable Net Seating Area (m2) | 210 | 224 | 14 |
| Length of Path (m) | 52 | 48 | -4 |
| Number of Seats | 32 | 40 | 8 |
| Instances of sub 2m compliance | 3 | 0 | -3 |

Key stakeholder evaluation by invited businesses showed that 92% (n.22/24) of visitors to the Social Distance Lab thought the social distance measures installed were effective, and 92% (22/24) thought they were visually clear.

# 5 Conclusion

The research has provided a methodology that successfully automates social distancing guidance using optimization software in the context of the case study building. The method provides automated socially complaint plan designs, delivering improved capacity and net useable area in comparison with human designed layouts. Subsequent user evaluation in the live lab proves the method presents visually clear and effective social distancing measures. As the definition retains variable fitness functions, crucially social distance, the layout may be redesigned instantly to comply with any value of distance, providing an agile and responsive means to comply with changing social distance advice, providing an essential resource for resilience against future viral variants.

**Acknowledgement**

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