

# A new vision for urban interstices: redesigning forgotten spaces within cities

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**Abstract.** This research investigates the feasibility of inflatable structures as temporary public space interventions for underutilised urban interstitial spaces in Sheffield, UK. It aims to revitalise neglected gap spaces sandwiched between buildings along the corridor stretching from Sheffield Train Station to the Arts Tower. Drawing on an integrated methodology combining site surveys, material testing, digital simulation and physical prototyping, this paper establishes a three-tier site screening framework. Core findings reveal that low-pressure modular inflatable systems can be fully deployed within several hours, with construction costs accounting for merely 10%–20% of conventional building solutions. The study concludes that inflatable technology, paired with intelligent pressure regulation and community-participatory inflation mechanisms, delivers a reversible, low-impact and socially inclusive strategy for the regeneration of vacant post-industrial urban sites.

**Keywords:** inflatable structures, Interstitial spaces, temporary architecture, regeneration of urban gaps, flexibility

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## 1. Introduction

### 1.1. Research background

Continuous urban expansion has generated a vast stock of underused, derelict and vacant urban spaces. Narrow gaps wedged between existing buildings are frequently overlooked by local residents due to their lack of distinctive character. Such spaces harbour untapped spatial potential waiting to be unlocked and upgraded.

This challenge is not unique to Sheffield. According to the *Report on Vacant Urban Spaces* published by the Royal Institute of British Architects (RIBA) in 2021, an average of 12% of central urban land across northern English cities exists in a state of "informal vacancy": these plots are neither sold, actively managed nor incorporated into formal regeneration schemes. Long-term neglect plagues these sites, stemming from their irregular geometry, poor accessibility or positioning beneath viaducts.

Sheffield is a dynamic city boasting a diverse array of shops, restaurants, bars and cultural attractions. Nevertheless, countless disused street gaps fill the spaces between buildings along a key central thoroughfare running east from the railway station to the Arts Tower in the west, remaining largely invisible to public perception.

## 1.2. Research questions and significance

The core research problem centres on the systematic neglect and inefficient utilisation of interstitial vacant urban spaces. These sites often function as "dead zones", exacerbating social alienation and rupturing the continuity of the public realm. Conventional permanent built interventions are frequently economically unviable, spatially constrained or structurally rigid, making them ill-suited for deployment within such narrow, irregularly sized voids. There is therefore an urgent demand for an adaptable, low-impact and temporary structural framework capable of revitalising residual spaces without excessively altering historic built fabric.

This paper addresses the above challenge by proposing a framework of temporary architectural interventions underpinned by pneumatic technology. Its scholarly and practical significance unfolds across three dimensions:

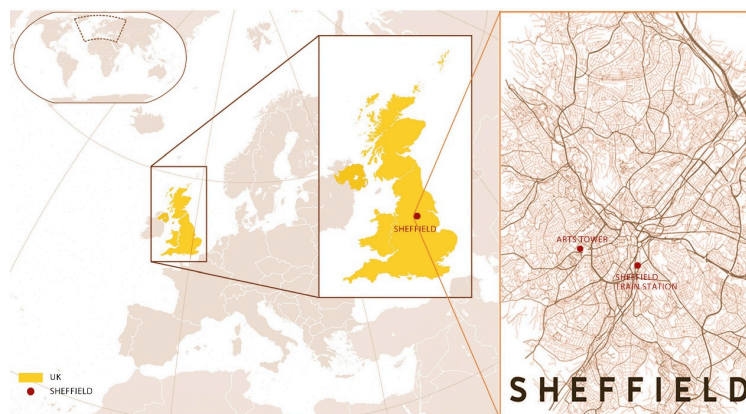
1. **Spatial Revitalisation:** Integrated with automatic inflation systems and advanced biomimetic materials, these lightweight transient structures dynamically reshape urban life and streetscapes, transforming systematically undervalued interstitial voids into vibrant nodes of community interaction.

2. **Social Cohesion:** By inserting flexible spatial typologies into urban gaps, the interventions create a protective architectural "skin" that shortens social distance both physically and psychologically. Micro-spaces conducive to interpersonal engagement are formed, effectively counteracting alienation prevalent in contemporary cities.

3. **Methodological Innovation:** Borrowing principles from traditional origami folding, the paper introduces a highly portable, scalable deployment strategy. It delivers an efficient, cost-effective approach to tactical urbanism transferable to residual vacant spaces worldwide.

## 2. Research context

Sheffield is located in South Yorkshire, central England, as illustrated in Figure 1. Covering an urban area of 367.94 km<sup>2</sup> with an estimated population of 740,000 (2026), it ranks among England's eight largest cities outside London. A historic industrial settlement, Sheffield originated as an Anglo-Saxon village. From the 19th century onward, it rose to global renown as a steel manufacturing hub, earning the moniker "Steel City". However, the city's spatial configuration did not take its present form organically; its urban morphology underwent repeated dramatic restructuring over a millennium, culminating in the unique dual fabric of historic core districts and fragmented interstitial voids visible today.

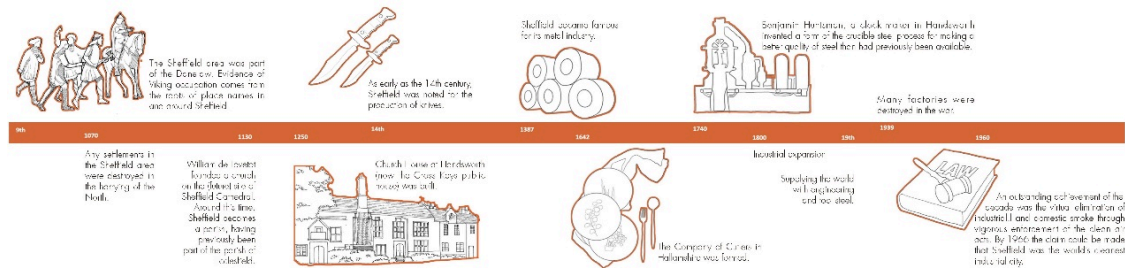


**Figure 1.** Location map of Sheffield

## 2.1. Historical evolution and current condition of Sheffield's urban interstices

### 2.1.1. Temporal development and morphological transformation of Sheffield

The spatial formation of modern Sheffield is intertwined with a thousand-year multi-layered evolutionary timeline. As shown in Figure 2, the region's earliest geopolitical framework dates to the 9th century, when it fell under Danelaw rule, and Viking occupation left enduring imprints on local toponymy [1]. This early settlement pattern suffered severe morphological destruction during the Harrying of the North (c.1070), which laid waste to widespread residential areas. Circa 1130, William de Lovetot founded a church on the site of the future Sheffield Cathedral, triggering institutional and physical reconstruction of the district and establishing it as an independent parish separated from Ecclesfield.



**Figure 2.** Developmental history of Sheffield

### 2.1.2. Institutionalisation of metal trade and industrial specialisation

By the 14th century, the town emerged as a specialised cluster of material production, famed for micro-manufacturing of cutlery and edged tools powered by local watercourses and coal reserves. Major landmark buildings such as the parish hall in Handsworth marked the physical expansion of the town in the late medieval period. Between 1387 and 1642, Sheffield's municipal identity became indelibly linked to metalworking; by the early 1600s, it had grown into Britain's largest cutlery production centre outside London. This flourishing industry later received formal institutional governance through the incorporation of the Company of Cutlers in Hallamshire.

### 2.1.3. Paradigm shift in technology and large-scale industrial expansion

The mid-18th century marked a revolutionary technological turning point: Benjamin Huntsman's invention of the crucible steelmaking process in 1740 yielded high-grade steel previously unavailable on global markets, unlocking unprecedented industrial growth. Throughout the subsequent Industrial Revolution, this technological edge drove exponential expansion of the city's built footprint and population, converting rural landscapes into dense, high-capacity industrial terrain. By the 19th century, this productive capacity fuelled radical industrial scaling, supplying premium engineering and tool steel to international markets. Owing to its systemic socioeconomic weight, Sheffield was incorporated as a municipal borough in 1843 and granted city status in 1893. The unregulated expansion of this era generated a quintessential "young industrial landscape" characterised by extensive underutilised sub-districts within the urban boundary—sites that now represent prime potential for urban regeneration yet carry a legacy of fractured spatial fragments born of rapid industrialization [2].

### 2.1.4. Wartime destruction, post-war modernisation and environmental remediation

Sheffield retained its status as a preeminent industrial metropolis through the first half of the 20th century. Nevertheless, the Second World War (commencing 1939) inflicted catastrophic structural damage across the urban landscape, destroying countless historic factories and central industrial zones and creating immediate spatial rifts and premature urban vacancy. In the post-war era, the city embarked on an aggressive programme

of environmental modernisation. A defining milestone arrived in the 1960s: rigorous enforcement of the Clean Air Act virtually eliminated industrial and domestic smog, allowing Sheffield to claim the title of "the world's cleanest industrial city" in 1966 [3].

#### *2.1.5. Macroeconomic restructuring, deindustrialisation and the spatial legacy of interstitial gaps*

This gradual environmental transition was ultimately overshadowed by severe deindustrialisation triggered by economic recession following the 1973 oil crisis. Compound pressures from automation and pan-EEC geopolitical restructuring of steel manufacturing precipitated the systematic closure of Sheffield's historic steelworks. This complex historical cycle—encompassing medieval built destruction, wartime industrial ruin and modern clean-air zoning—has bequeathed a deeply fragmented spatial legacy: a dense historic core rich in architectural vocabulary, interspersed with residual negative geometries and urban interstitial voids ripe for contemporary adaptive reuse. Furthermore, the regeneration of Sheffield's urban gaps cannot be reduced to mere physical infill; it constitutes a systemic ontological transformation integrating heritage conservation, ecological risk management and the reconstruction of social relations [4].

### **2.2. The spatial paradox of urban interstices: systemic problems and regenerative potential**

The structural remnants of deindustrialisation manifest today as "urban interstices": forgotten interstitial voids, redundant corner plots and negative geometric spaces compressed within the existing built environment. Theoretical discourse in modern urban design posits that cities ought not to be understood as static assemblages of isolated building masses; instead, they function as vast, highly complex, interconnected multi-dimensional matrices [5]. Within this framework, unmanaged urban gaps represent substantial negative assets, operating as visual and social dead zones that disrupt urban continuity and deepen social division.

The core vision of this research dismantles the traditional negative framing of interstitial vacant urban spaces, reimagining them as catalysts for continuous urban evolution through micro-architectural intervention. Rather than framing these voids as systemic flaws or spatial errors in urban development, the study seeks to convert them into vibrant localised urban nodes. Strategic functional reorganisation of these negative spaces enables them to deliver highly optimised, context-responsive services tailored to local residents, elevating everyday quality of life. Simultaneously, such interventions foster a distinct sense of place, revitalise local economic and cultural ecosystems, and visually articulate the unique poetic and heterogeneous aesthetic inherent to urban residual spaces.

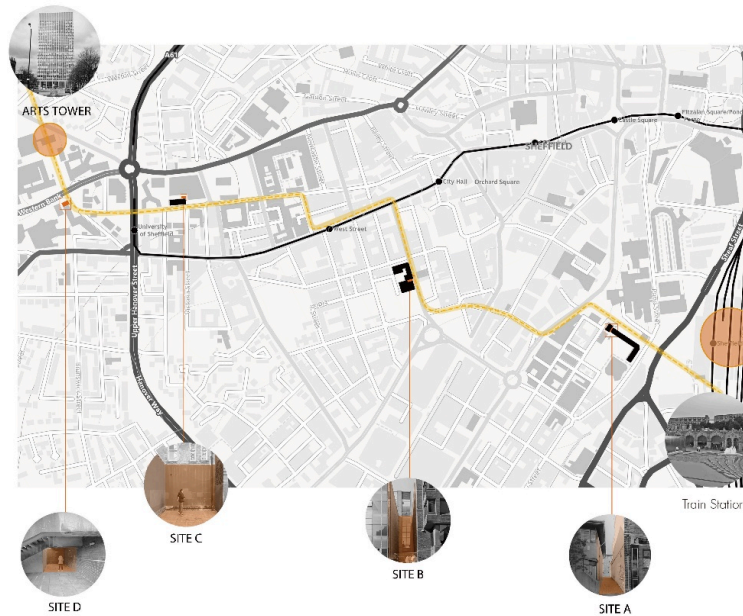
To bridge historic cultural heritage and contemporary tactical urbanism, functional transformation of interstitial voids must actively engage adjacent corner plots and redundant neighbouring sites. This integrated intervention strategy establishes profound material and narrative dialogue between new architectural components, the city's industrial past and the historic facades of surrounding existing buildings. Ultimately, the project moves beyond temporary, isolated site activation to prioritise long-term systemic scalability: it reframes these micro-urban residual units as interconnected, modular, self-propagating micro-ecological networks that incrementally reconstruct and repair the broader urban fabric [6].

## **3. Site selection and spatial analysis**

### **3.1. Spatial scope**

This research tests the operational efficacy of the proposed deployable architectural network within a real-world urban fabric. A high-density pedestrian corridor is delineated as the core empirical study area, aligned along a major socioeconomically and academically significant urban axis in Sheffield that forms a highly

connected pedestrian route. The corridor is anchored at either end by two of the city's most vital regional landmarks, as visualised in Figure 3.



**Figure 3.** Spatial scope diagram

### 3.1.1. Starting point: Sheffield Midland Train Station

The design corridor originates at Sheffield Train Station, historically named Pond Street Station before being rebranded Sheffield Midland Station. A critical rail and light rail interchange hub, it serves as South Yorkshire's busiest transport terminal, with an adjacent Sheffield Hallam University tram stop reinforcing its function as a key multimodal gateway. At a national infrastructure scale, the station ranked the 43rd busiest in the UK for the 2017–2018 fiscal year, and 15th busiest outside the Greater London metropolitan area. Its strategic national transport importance is further underscored by planned HS2 high-speed rail spur connections, cementing its role as a vital portal for regional population movement.

### 3.1.2. Termination point: Arts Tower, University of Sheffield

The corridor terminates at the Arts Tower of the University of Sheffield, situated at 12 Bolsover Street. Completed in 1966 in a modernist architectural idiom, the building is described by Historic England as "the most elegant university tower of its era in Britain". Standing 78 metres tall, it is Sheffield's second-highest building and retains the record for the tallest academic structure in the United Kingdom, functioning as an iconic visual city landmark. It boasts exceptional walkable accessibility adjacent to the central commercial district and features an on-site University of Sheffield tram stop.

## 3.2. Site selection criteria

Sheffield is actively advancing an urban regeneration masterplan targeting the transformation of its post-industrial landscape into an international hub for innovation and knowledge production. Within the delineated study corridor, four distinct intervention nodes are selected according to three systematic morphological criteria:

(1) Typology of Urban Interstice: All selected target sites consist of narrow structural gaps—residual urban voids compressed between the envelopes of pre-existing buildings. Long overlooked by conventional urban

planning, these negative spaces are functionally and visually stagnant. The intentional selection of such interstitial vacant sites demonstrates how low-impact, deployable architectural inserts can revitalise forgotten land parcels and endow them with optimised community functionality.

(2) Socio-Technical Ecosystem Alignment: Each site lies within a robust university-industry infrastructure ecosystem dedicated to industrial research and development, with a deep-rooted culture of material innovation and world-class technical education resources, guaranteeing high public engagement with deployable construction technologies.

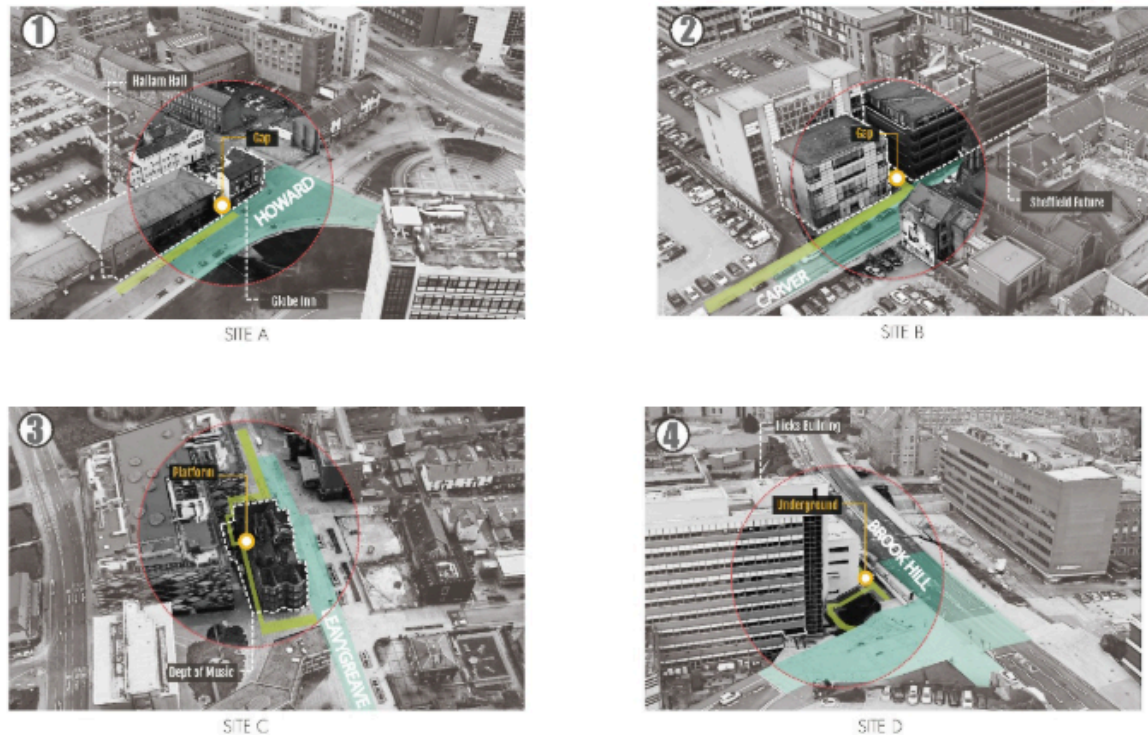
(3) Geographic and Topographic Advantages: All selected sites front public city streets, offering ideal conditions for harnessing natural energy flows, passive ventilation and microclimate optimisation.

3.3. Comparative analysis of selected intervention sites

Four distinct interstitial voids along the transit corridor linking Sheffield Midland Station and the University of Sheffield Arts Tower undergo comprehensive site evaluation to facilitate systematic rollout of the proposed architectural network, summarised in Table 1 and Figure 4. Each site represents a unique morphological variant of post-industrial urban interstices formed under divergent historical and institutional contexts. Though currently marked by functional stagnation and severe environmental neglect, they offer highly differentiated opportunities for local structural renewal and public programming.

Table 1. Morphological and functional matrix of Selected interstitial sites

| Site                              | Location                                                                                                                              | Spatial Morphology                                                                             | Spatial Deficiencies                                                                                                                 | Regeneration Potential                                                                                                      |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Site A:<br>Howard<br>Street       | Between The Globe<br>Inn and Hallam Hall                                                                                              | Narrow ribbon<br>structural gap running<br>parallel to a primary<br>commercial<br>thoroughfare | High pedestrian footfall<br>paired with severe visual<br>obstruction; heavy passenger<br>volume yet a total lack of<br>resting nodes | Gateway micro-rest<br>zones, high-capacity<br>pedestrian circulation<br>hubs, interactive<br>information display<br>facades |
| Site B:<br>Carver<br>Street       | Between Sheffield<br>Future and an under-<br>construction building                                                                    | Linear structural void<br>alongside a secondary<br>residential road                            | Low foot traffic, enclosed<br>spatial conditions and<br>pronounced social isolation                                                  | Community-scale<br>modular pavilions,<br>neighbourhood pocket<br>parks                                                      |
| Site C:<br>Department<br>of Music | Raised platform to the<br>rear of the Department<br>of Music building on<br>Leavygreave Road                                          | Elevated platform<br>space embedded<br>within the university<br>campus core                    | Chronic noise disturbance<br>from arterial roads and<br>physical segregation;<br>consistently overlooked by<br>staff and students    | Semi-open micro-<br>performance venues,<br>student social micro-units                                                       |
| Site D:<br>Hicks<br>Building      | Adjacent to the main<br>university block,<br>beneath an<br>infrastructure viaduct<br>alongside an<br>underground pedestrian<br>tunnel | Covered subterranean<br>space located under a<br>bridge structure                              | High passing pedestrian<br>volume yet zero public<br>attention; persistently vacant<br>negative space                                | Student gathering zones,<br>round-the-clock<br>collaborative workspaces,<br>digital fabrication self-<br>service hubs       |



**Figure 4.** Spatial schematic of Selected sites

## 4. Material properties and technical infrastructure

### 4.1. Overview of inflatable structure development

Pneumatic architecture has been integrated into architectural discourse for over half a century. While the concept of compressed air as a load-bearing structural mechanism is longstanding, its sustainable real-world deployment hinges on modern breakthroughs in textile engineering, advanced polymer lamination, specialised construction methodologies and automated pressure regulation systems. Early pioneering collectives of the 1960s such as Jersey Devil delivered civilian pneumatic architectural prototypes (Figure 5), while Michael Rakowitz (1988) showcased tactical urban interventions utilising waste HVAC exhaust air (Figure 6). More recently, Kengo Kuma's Tea House (2005) (Figure 7) embodies the philosophy of "weak architecture", employing low-pressure air circulation to transform high-tech textiles into organic, blooming volumetric forms.



**Figure 5.** Schematic of early pneumatic architectural practice by Jersey Devil



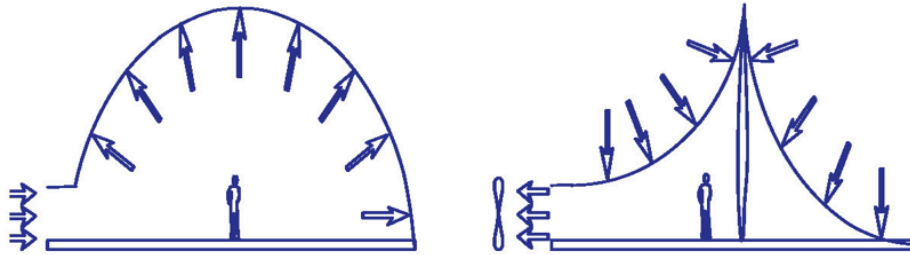
**Figure 6.** Schematic of ParaSITE urban intervention



**Figure 7.** Kengo Kuma's Tea House – schematic of low-pressure pneumatic structure

## 4.2. Structural classification of inflatable architecture

Pneumatic building systems are structurally categorised by their internal pressure mechanics, illustrated in Figure 8.



**Figure 8.** Schematic of low-pressure and high-pressure systems

(1) Low-Pressure Systems: Comprise single-layer or double-layer membrane enclosures operating under slight positive or negative internal pressure relative to atmospheric levels. Cable networks or local ground anchors are commonly deployed to reduce curvature radii, substantially mitigating local tensile stress within textile substrates.

(2) High-Pressure Systems: Defined by discrete tubular inflatable structural components (arches, beams or columns). Elevated internal pressure delivers significant structural rigidity, enabling the system to withstand substantial external static and live loads.

The two primary membrane materials deployed are PVC and ETFE:

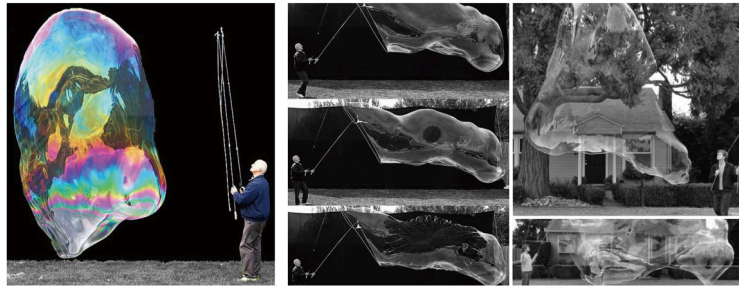
(1) Polyvinyl Chloride (PVC): Formulated with anti-ageing and thermal modifiers, PVC delivers lightweight, moisture-proof and flame-retardant enclosure solutions. Its superior machinability and flexibility render it ideal for highly sculptural, short-term deployable installations.

(2) Ethylene Tetrafluoroethylene (ETFE): A premium alternative to conventional glass, weighing only 0.15–0.35 kg/m<sup>2</sup> while maintaining up to 95% light transmittance. ETFE features high ultraviolet permeability, top-tier fire resistance, self-cleaning surface properties activated by rainwater runoff, and a service lifespan of 25–35 years, establishing it as the material of choice for long-term, semi-permanent adaptive reuse schemes.

## 5. Design strategy and system integration

### 5.1. Conceptual origin: the ephemeral aesthetic of soap bubbles

The physical deformation mechanics and fluid volumetric geometry of soap bubbles provide direct morphological inspiration for the formal evolution and spatial conception of this design research, visualised in Figure 9. This ephemeral aesthetic, paired with cutting-edge advances in polymer thin-film chemistry and lightweight structural joint technology, enables the scaling of microscale bubble phenomena into habitable architectural enclosures. This unique immersive spatial experience forms the core creative foundation of the design proposal.



**Figure 9.** Schematic of floating soap bubble spaces

## 5.2. Structural systems and spatial responsive strategies

Inflatable structures represent a category of lightweight building systems whose load-bearing capacity is primarily derived from compressed air, a technical principle introduced to architectural practice decades ago. Their most widely recognised engineering applications include balloons and airships, historically deployed for military operations. Within architecture, membrane structures constitute one of the most cost-effective solutions for long-span construction. Characterised by simple assembly, rapid disassembly and low upfront cost, pneumatic structures stand out as the preferred system for temporary architecture—qualities rendering them perfectly suited to placemaking within urban interstitial voids in the context of this research.

From a technical classification perspective, pneumatic architecture divides into air-supported structures (single membrane reliant on internal positive pressure) and air-inflated structures (composed of discrete pressurised components). Their geometry typically favours rounded forms, which maximise internal volumetric capacity while minimising material consumption. These structures can operate as standalone load-bearing envelopes or integrate into composite building assemblies, suitable for both permanent and temporary applications. Streamlined construction logic and highly prefabricated components drive drastically lower capital investment and maintenance overheads compared to conventional construction, alongside vastly accelerated on-site assembly timelines.

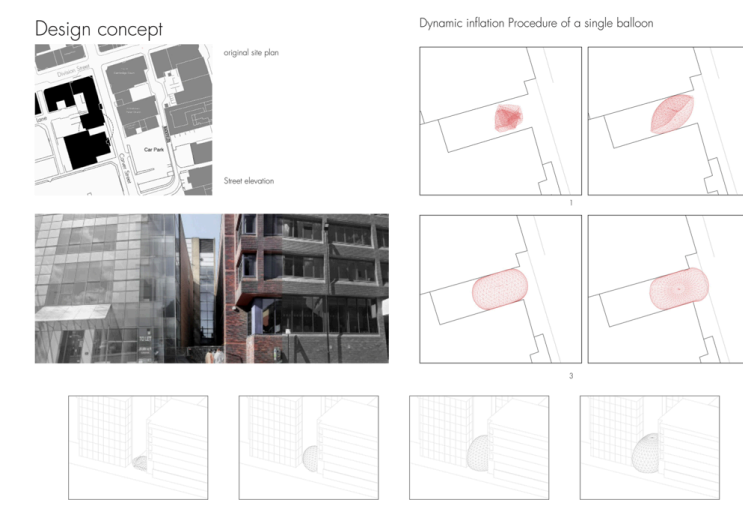
Inflatable bladders are selected as the intervention medium for urban gaps due to four core performance strengths: Ultra-low self-weight and exceptional portability for streamlined transport and rapid on-site deployment; Sustained load-bearing capacity once pressurised, delivering robust structural rigidity to the overall system; Low membrane manufacturing and on-site fabrication costs, delivering strong economic viability; Unparalleled formal flexibility, accommodating curved, symmetrical or fully irregular geometric configurations—a critical advantage given the highly differentiated spatial contours of urban interstitial voids.

## 5.3. Site strategy validation: case study of site B (Carver Street)

Site B (Carver Street) is selected as a representative demonstration site to validate the feasibility of the proposed design strategy within real urban gap conditions. The space forms a linear structural void alongside a secondary residential arterial road, defined by low pedestrian footfall, enclosed spatial conditions and marked social alienation—an archetypal urban interstice precisely targeted by temporary inflatable intervention logic.

Figure 10 illustrates the sequential inflation cycle of a single bladder unit and the spatial effects of synchronised multi-bladder deployment. Read left to right, the membrane expands gradually from a folded compact state into an inhabitable spatial unit upon inflation. When multiple bladders activate simultaneously, they conform to the irregular boundary geometry of the narrow interstitial gap while generating interconnected sequential spaces between adjacent units. The sectional diagrams at the bottom of the figure further articulate the spatial relationship of inflatable bladders wedged between building facades: encased within the protective

structural "skin", physical and psychological social distance between users is compressed. By introducing bladder units of variable scale, occupants engage in small-scale interpersonal behaviours such as rest, conversation and shared activity within these micro-spaces, partially mitigating social alienation endemic to contemporary cities.

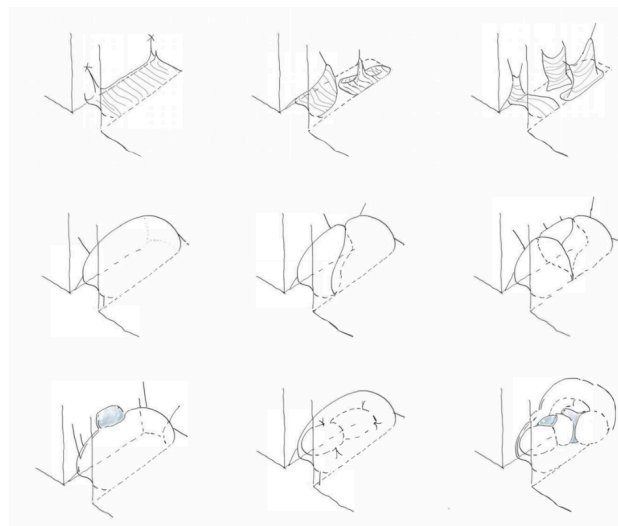


**Figure 10.** Spatial simulation of inflatable bladder expansion within interstitial space

#### 5.4. System scalability and deployment mechanisms

##### 5.4.1. Multi-unit coordination and spatial morphology regulation

While single-bladder deployment verifies the spatial adaptability of inflatable structures within discrete interstitial voids, activating urban gaps demands complex multi-functional spatial configurations catering to diverse needs ranging from individual rest to group assembly, static lingering and interactive activity. Accordingly, this research further explores spatial regulation strategies enabled by coordinated multi-bladder assemblies.

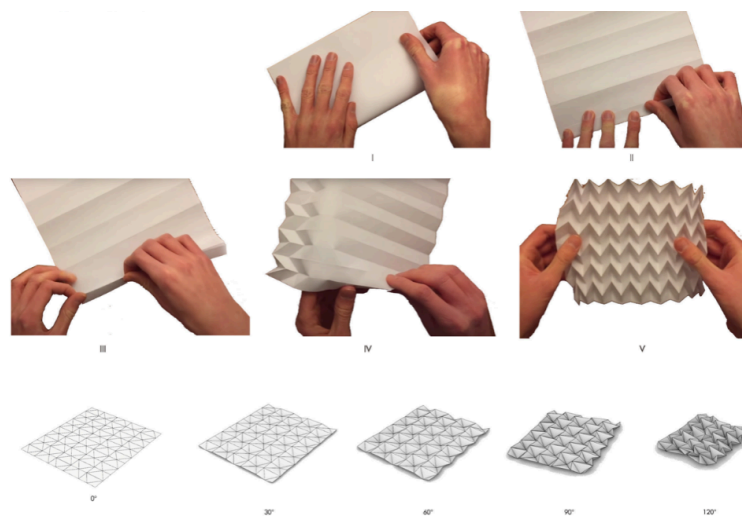


**Figure 11.** Schematic of the relationship between bladder quantity and spatial morphology

The quantity and planar arrangement of inflatable bladders directly shape the overall volumetric geometry of occupied space, as illustrated in Figure 11: single bladders form isolated micro-spaces ideal for individual relaxation; paired or tripled bladders create continuous sequential volumes accommodating small-group interaction; clustered multi-bladder layouts generate compartmentalised composite spaces capable of hosting simultaneous mixed-use activities.

#### 5.4.2. Folded storage system

The deployable merit of inflatable structures stems not only from fast inflation and deflation cycles but also from efficient compact storage and transit when deactivated. Drawing on folding principles from traditional Chinese origami, this research develops an integrated foldable storage system for inflatable bladder membranes. Its core mechanism embeds prefabricated crease lines directly into the membrane during fabrication, enabling ordered compact folding along engineered fold lines post-deflation and drastically minimising storage footprint. As demonstrated in Figure 12, the complete folded system fits within a standard suitcase-sized container for maximum transport portability.



**Figure 12.** Schematic of foldable storage system

This folding system completes a full operational lifecycle for the inflatable intervention strategy: folded transit, on-site unfurling, automated inflation, post-use deflation and compact folded removal. The entire workflow delivers exceptional operational efficiency and universal spatial adaptability, enabling scalable replication across numerous urban interstitial voids worldwide.

## 6. Conclusion

Responding to the demand for remediation of fragmented post-industrial urban spaces, this research systematically examines the feasibility and practical value of inflatable structures as lightweight, temporary micro-architectural interventions, taking the urban interstices along the corridor between Sheffield Train Station and the Arts Tower as a case study.

Through field investigation and a three-tier screening protocol, adaptable target site typologies are established. At the material and structural scale, comparative analysis verifies the superior performance of high-transmittance, self-cleaning, weather-resistant ETFE membrane for temperate maritime climate contexts.

Drawing on traditional folding geometry, a portable, rapidly deployable, fully reversible modular inflatable prototype and integrated folded storage system are engineered.

Core research findings confirm that low-pressure modular inflatable intervention strategies deliver low construction costs, ultra-fast on-site deployment and minimal disruption to pre-existing historic built fabric. Supported by intelligent pressure regulation and community participatory activation frameworks, inflatable structures effectively upgrade the environmental quality and social cohesion of overlooked negative voids. The study offers a highly flexible, low-load and sustainable spatial regeneration paradigm applicable to interstitial renewal and tactical urbanism practice across post-industrial cities globally.

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