

When Labs Move: Lessons-Learnt from Relocating and Upgrading Human-Façade Interaction Lab

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Abstract

Experimental research on human-façade interaction is essential for advancing user-centered façade and glazing technologies, particularly in relation to serviceability of glass and façade technologies, multi-domain comfort and resilience and acceptance with novel technological approaches. Yet only a limited number of laboratories worldwide provide flexible, reconfigurable, and realistically scaled test environments capable of hosting human participants. The MATELab—originally inaugurated in 2018 in Cambridge (UK)—is one such facility. In 2024, the lab underwent a full relocation and upgrade when the laboratory was disassembled and moved at Delft University of Technology. This paper presents the lessons learned from the relocation process, highlighting both the logistical and scientific challenges of transferring a human-subject testing laboratory across contexts. Beyond documenting the practical constraints of reassembling complex façade test rigs, we discuss how the move enabled significant functional and methodological improvements to better support research on human responses under changing climatic conditions and emerging societal challenges. The insights provided aim to inform future efforts to establish human-façade interaction laboratories and research directions.

Keywords

Human comfort, Glass performance, Façade technologies, Human-façade interaction

Article Information

- Digital Object Identifier (DOI): [10.47982/cgc.10.780](https://doi.org/10.47982/cgc.10.780)
- Published by [Challenging Glass](#), on behalf of the author(s), at [Stichting OpenAccess](#).
- Published as part of the peer-reviewed [Challenging Glass Conference Proceedings](#), Volume 10, June 2026, [10.47982/cgc.10](https://doi.org/10.47982/cgc.10)
- Editors: Christian Louter, Freek Bos & Jan Belis
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Abbreviations

- ABB Asea Brown Boveri
- BACnet Building Automation and Control Networks
- BMS Building Management System
- CO₂ Carbon Dioxide
- HA Home Assistant
- HVAC Heating, Ventilation and Air Conditioning
- IEQ Indoor Environmental Quality
- IP Internet Protocol
- KNX Konnex Building Automation Standard
- MATELab Multi-domain Adaptive Technologies and Environments Laboratory
- Modbus Modicon Communications Bus Protocol
- MQTT Message Queuing Telemetry Transport
- RS485 Recommended Standard 485 Serial Communication Protocol

1. Introduction

The performance of façade and glazing systems is typically characterised through computational simulation and standardised laboratory testing under idealised boundary conditions. While these approaches are essential for material qualification, technology development and regulatory compliance, they should be complemented by empirical data collection in semi-controlled environments and real buildings under real occupancy or weather conditions in the performance validation chain (Babich et al, 2024). This is crucial to capture the full complexity of real-world performance and support market uptake. Empirical evidence on how real occupants perceive, respond to, and interact with building envelope systems under realistic weather conditions is key for advancing façade and glazing technology to support resource-efficient and healthy buildings. For instance, actual energy consumption, indoor environmental quality, and occupant comfort are all strongly influenced by the interaction between the façade system, the dynamic outdoor climate, and the diverse physiological, cognitive, and behavioural responses of real occupants. Beyond comfort, a wide range of scientific challenges can also benefit from such tests, from questioning current serviceability limits (Hassen et al., 2024) to human acceptance of glass design (Bedon & Mattei, 2021, Bedon 2022), dynamic glazing parameters (de la Barra et al, 2024) or overall multi-domain comfort (Luna-Navarro et al., 2022). Field monitoring in operational buildings can capture this complexity but at the cost of experimental control — confounding variables are numerous, boundary conditions cannot be systematically varied, and interventions are constrained by operational requirements, making it structurally difficult to establish causal relationships between design parameters and performance outcomes (de la Barra et al., 2025).

Within this landscape, facilities specifically designed to study multi-domain human interaction with façade and glazing systems remain rare (Luna-Navarro et al. 2022). Standard climate chambers and test rooms provide thermal and visual control but typically do not accommodate full-scale façade assemblies, real outdoor solar and climatic boundary conditions, or the realistic spatial configurations needed to study occupant-façade interaction as an integrated, multi-domain phenomenon. This limitation is particularly important because occupant responses to façade technologies are not solely determined by individual comfort metrics such as glare or temperature. Instead, they emerge from the interaction of physiological, psychological, and behavioural responses across multiple environmental

domains. Conflicts between thermal, visual, acoustic, and air-quality conditions can substantially influence overall perception, satisfaction, adaptation, and decision-making. Capturing these human-building interactions requires experimental environments that are simultaneously realistic—providing real daylight, real weather, and realistic spatial configurations—while maintaining sufficient control to isolate the contribution of specific design parameters.

Outdoor test cells and specialised façade laboratories have been developed to address this need (Luna-Navarro et al. 2022). MATELab — Mobile Adaptive Technology Experimental Lab — extends this approach to include the human dimension: designed as a flexible, reconfigurable outdoor test chamber capable of hosting human participants under real climatic boundary conditions while housing full-scale façade specimens. This laboratory was first inaugurated at the University of Cambridge in 2018 and validated as a research platform for occupant-façade interaction studies (Luna-Navarro and Overend, 2021). Since its commissioning, the facility has supported experimental campaigns establishing that multi-domain assessment frameworks are essential when evaluating smart façade technologies (Luna-Navarro et al., 2022). In 2024, the MATELab underwent a full relocation and upgrade: the facility was disassembled at University of Cambridge and reassembled at Delft University of Technology, with significant functional improvements to address emerging research challenges including heat resilience under extreme climatic conditions, the evaluation of novel radiant and convective heating technologies, and expanded multi-domain sensing capabilities. This relocation was both a logistical and a scientific challenge. Transferring a human-subject testing laboratory across institutional and national contexts with contained budget, requires decisions that have no established methodology in the literature: how to sequence disassembly and reassembly while preserving components integrity; how to select a new location based on climatic, spatial, and research context criteria; how to exploit the disruption as an opportunity to upgrade rather than merely replicate; and how to ensure that experimental protocols developed in one context remain valid in another. The literature on test room design and living lab methodology provides guidance on facility construction and experimental design (Pisello et al., 2021; Vittori et al., 2022; Cureau et al., 2022) but does not address the specific challenges of relocating and upgrading an existing human-subject façade testing facility.

This paper documents the lessons learned from this process. It describes the original MATELab design rationale and research contributions at Cambridge; the criteria and methodology used to plan and execute the relocation to Delft; the functional and methodological improvements introduced during reassembly; and the challenges encountered at each stage that carry lessons for other research groups developing, relocating, or upgrading similar facilities. The contribution is practical and methodological: in a field where experimental infrastructure is scarce, expensive to construct, and difficult to transfer, documented experience of this kind constitutes a scientific resource that the community currently lacks.

2. MATELab and human-façade interaction research

Human-façade interaction research places specific requirements on experimental facilities that extend beyond the capabilities of conventional climate chambers and test rooms. Occupant responses to façade technologies emerge from the interaction of multiple environmental domains, including thermal, visual, acoustic, and air-quality conditions, as well as from physiological, psychological, and behavioural processes. These responses are strongly influenced by contextual factors such as outdoor weather conditions, daylight availability, spatial configuration, and opportunities for occupant control.

MATELab was specifically developed to address these requirements and provide a platform for studying human-façade interaction under realistic yet controllable conditions. Located at The Green Village, the facility combines full-scale façade mock-ups with exposure to real outdoor weather, solar radiation, and daylight conditions, enabling the investigation of façade technologies within the environmental complexity in which they are ultimately deployed. At the same time, the facility provides extensive environmental sensing, integrated building control systems, and configurable experimental setups that allow specific design variables to be manipulated while maintaining continuous monitoring of both building and occupant responses.

Unlike conventional façade test facilities, MATELab was designed around the human-building interaction paradigm. The facility enables the simultaneous assessment of thermal, visual, acoustic, and air-quality conditions together with occupant perception, behaviour, and physiological responses. This integrated approach makes it possible to investigate not only how façade technologies affect environmental performance, but also how occupants perceive, interact with, adapt to, and ultimately accept these technologies under realistic operating conditions.

3. Disassembly and moving a lab

This section summarised the main challenges encountered in the disassembly and relocation of the lab, summarised in Figure 1 .

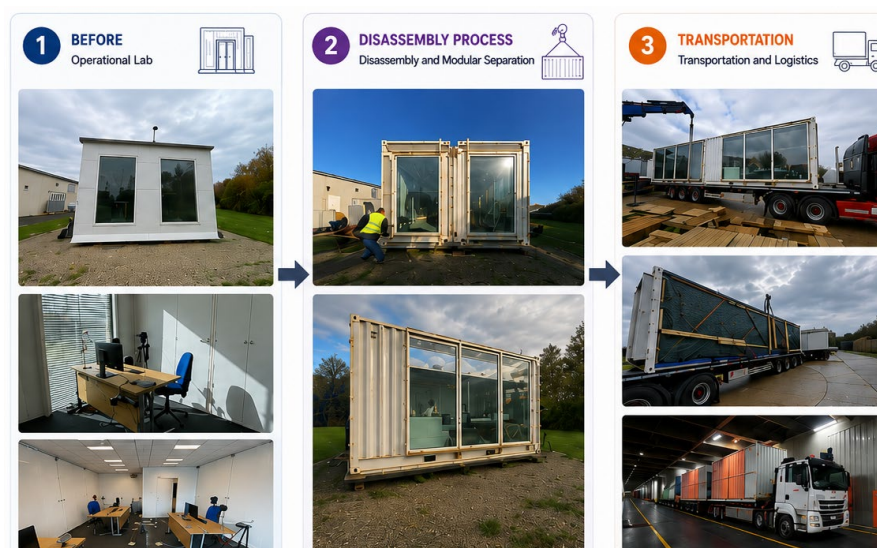


Fig. 1: The disassembly and relocation process of the MATELab. The workflow highlights key stages including baseline operation, façade and component removal enabling modular separation, and subsequent transport of the units for redeployment.

3.1. Funding and regulatory framework

The relocation from Cambridge to Delft required crossing an international customs boundary following the UK's exit from the EU customs union, necessitating formal export and import declarations for all components, including commodity codes, values, and origin. The heterogeneous inventory—spanning structural, façade, and electronic systems—complicated classification and required engagement with a specialist freight forwarder. Import duties and VAT were avoided by classifying MATELab as a temporary installation, remaining under the ownership of Permasteelisa Scheldebouw and declared as a temporary export/import. This required early coordination with customs authorities and careful documentation. Transport and reassembly were funded through a joint research proposal and the in-kind donation of the facility, avoiding direct capital expenditure while enabling system upgrades.

De-installation at Cambridge posed atypical health and safety challenges, as the temporary installation status placed the project outside standard construction and laboratory frameworks. Conventional contractors proposed demolition rather than disassembly for reuse. A tailored approach was therefore required, involving specialist façade contractors, a bespoke method statement developed with the university safety office, and direct supervision by the research team. This resource-intensive process highlights the need to explicitly budget for controlled disassembly in future relocations of similar facilities.

3.2. Disassembly challenges

The original MATELab at University of Cambridge was not designed with future relocation in mind (Luna-Navarro & Overend, 2021). The structural chassis comprised two standard ISO steel shipping containers arranged to form a reconfigurable outdoor test chamber, a configuration chosen for its low-cost, speed of assembly, structural robustness, modularity, and the practical advantages of a temporary installation permit at the Cambridge site. The overarching disassembly strategy was to return the MATELab to its original base configuration — two separate ISO shipping containers — which could then be transported independently as standard freight units. This approach was both logistically practical and structurally sound: the container chassis had been the starting point for the original construction, and reversing the assembly sequence to recover two transportable units was conceptually straightforward. In practice, however, the degree to which individual building elements could be cleanly separated into two independent systems varied substantially depending on how they had been designed and installed. The relocation therefore presented a de-installation challenge rather than a straightforward reversal of the assembly sequence, requiring the team to develop a disassembly strategy for a structure that had no corresponding disassembly documentation. For the disassembly, a building contractor was appointed in England, UK.

The facility had been conceived with research partitioning in mind: the two container bays could be operated as independent experimental chambers during studies, and the HVAC, electrical control, and lighting systems had accordingly been designed as two parallel systems that could be independently operated or combined. This partitioned design philosophy proved highly advantageous during disassembly — these service systems could be isolated, disconnected, and removed with relatively limited intervention and without damage, and their components were retained for reinstallation at Delft.

Other elements had not been designed with the same partitioning logic. The upper floor boarding, for instance, had been installed as a single continuous deck spanning both container bays, with no designed break at the container junction. Separating the floor into two independent units therefore

required stripping the boarding entirely rather than splitting it cleanly at the interface. Once removed, the timber boarding could not be reused in the reassembly: dimensional changes resulting from weathering and the mechanical damage sustained during removal meant that the panels no longer met the fit tolerances required for reinstallation. The floor boarding was therefore written off as a material loss and replaced with new material at Delft — an avoidable outcome had the original design incorporated a designed discontinuity at the container junction consistent with the partitioned operational logic applied to the service systems.

A similar situation arose with the external facade cladding panels, which sustained damage during de-installation that rendered them unsuitable for reuse. The panels had been fixed in a manner that prioritised weathertightness and structural performance during operation rather than reversible installation, and the force required to remove them without damaging the underlying structure resulted in panel deformation that could not be remediated. These panels were replaced at Delft with new units of equivalent specification.

By contrast, a substantial proportion of the facility's components were successfully recovered and reused. The roof structure and the substructure supporting the additional insulation layer were removed intact and reinstalled at Delft without modification. The carpet floor elements, the furniture, the facade test rigs, and the glazing specimen collection — which together represent the highest-value and most scientifically irreplaceable elements of the facility — were recovered without significant damage and reinstalled at Delft. The glass specimens in particular, which had required the most careful packing and handling, arrived in good condition and were immediately available for research use following reassembly. For the transportation, the open container face, resulting from decoupling the two steel portion, was covered by a waterproof layer to ensure protection to rain during transportation for the interior components.

3.3. Transit challenges

An unanticipated material loss during relocation arose from moisture exposure during transit. The period between removal of the weathertight envelope at Cambridge and re-establishment at Delft was extended due to logistical and customs delays, increasing the duration of environmental exposure. Although container openings were protected with waterproof membranes following decoupling, this measure only mitigated direct ingress. Some components—most notably sections of carpet flooring previously deemed reusable—experienced moisture damage not detected until unpacking, requiring replacement. This highlights a frequently overlooked risk: materials suitable under operational, weathertight conditions may be vulnerable during transit. A more conservative packing strategy, treating all soft and floor elements as moisture-sensitive, would likely have prevented this loss at limited additional cost.

More broadly, the transit phase should be treated as an environmental exposure event, requiring risk assessment beyond mechanical handling to include moisture, temperature variation, and exposure duration relative to packing performance. For international relocations, this assessment should account for potential customs delays and adopt conservative assumptions on transit duration.

The transport of glazing specimens presented the most technically demanding challenge. The MATELab includes bespoke and often irreplaceable units—such as switchable glazing, electrochromic samples, and custom assemblies—unsuited to standard freight methods. Each specimen was individually assessed, packed using custom timber framing and foam isolation, and transported in an orientation aligned with its structural behaviour. Movable internal components were either secured or removed

and packed separately to prevent damage. The packing specification, developed with a specialist glazing transport contractor, was documented to support correct unpacking without requiring on-site specialist supervision.

4. Reconstruction of MATELab at TU Delft

4.1. Selection of site within TU Delft campus

Site selection was a key determinant of the MATELab's research potential and operational viability at TU Delft. An initial preference for a location within or adjacent to the Faculty of Architecture and the Built Environment—due to disciplinary alignment and proximity to the research team—proved unfeasible because of space constraints.

Selection criteria were defined across four priorities: (i) solar access and orientation, (ii) logistics and future expansion capacity, (iii) infrastructure availability, and (iv) regulatory flexibility. Unobstructed solar exposure in at least two orientations was essential to support multi-façade experimental configurations and realistic boundary conditions, including outdoor view. Sufficient surrounding space was required for crane access, material handling, and future reconfiguration, addressing logistical limitations experienced at the Cambridge site.

The selected site—The Green Village, TU Delft's innovation test field—met all criteria and provided additional advantages. As a purpose-built experimental campus with dedicated technical support, it offers shared infrastructure including data connectivity, three-phase power, water supply, and mechanical handling equipment, significantly reducing setup requirements. Crucially, its regulatory framework—tailored to experimental installations—ensures compliance with safety standards while exempting the facility from conventional building permit procedures. This enables rapid modification and expansion without planning constraints, a key advantage for a facility intended for iterative reconfiguration.

4.2. Re-assembly on site

The re-assembly and construction procedure is summarised in Figure 2. The reassembly of the MATELab at The Green Village was carried out by a combination of specialist contractors and the research team, following the component inventory and photographic documentation produced during the Cambridge de-installation. The total duration from the arrival of the first container units on site to completion of a fully operational facility was eighteen months, though this figure includes a significant interruption caused by a gap in funding availability that temporarily halted construction activity. The active construction period was substantially shorter, and the extended overall timeline should not be taken as indicative of the intrinsic complexity of reassembly but rather of the funding sequencing challenges that are common in research infrastructure projects of this type.

The foundation design at Delft differed from the original Cambridge installation in a manner that reflects both the lessons of the original build and the specific requirements of The Green Village site. At Cambridge, the containers had been placed on shallow foundations of timber beams bearing directly on the ground — a simple and low-cost solution appropriate for a temporary installation on a stable substrate but one that required ground preparation and left some residual disturbance on removal. At Delft, steel beams bearing on prefabricated concrete plates were used instead, providing a level, stable, and durable base that can be fully dismantled without ground disturbance and without any wet trades — a fully dry assembly that is consistent with the temporary installation classification,

The Green Village's requirement that experimental facilities leave no permanent alterations to the site, and the broader design-for-disassembly principle that the Cambridge experience had made apparent. The insulation panels from the Cambridge foundation assembly were recovered and reused at Delft, representing a further instance of material continuity across the relocation and reducing the material cost of the foundation upgrade.

The primary challenge during reassembly was the precision placement of the two container halves relative to each other. The MATELab's operational configuration requires the two containers to be aligned to tight tolerances at their junction — both for the structural connection and for the continuity of the floor, envelope, and service systems that span the junction. Achieving this alignment with standard crane and rigging equipment, on a site with limited maneuvering space, required careful planning of the lifting sequence and multiple positioning adjustments before the final placement was accepted. This challenge is inherent to any reassembly of a multi-unit container structure and should be anticipated as a time and resource demand in the planning of comparable relocations.



Fig. 2: The process of re-assembly: 1. Preparation of the foundation; 2. Module placement; 3. Assembly completion and start of re-construction and upgrading work; 4. Reconstruction according to the new design and capabilities.

5. New capabilities of MATELab at TU Delft

5.1. New Building envelope construction

The reassembly at Delft was used as an opportunity to substantially upgrade the building envelope relative to the Cambridge configuration. The original external cladding comprised aluminium sandwich panels — a system chosen for speed and cost of construction — which were replaced at Delft with a fully ventilated facade incorporating timber cladding over a highly insulated substrate, maintaining the low U-value achieved at Cambridge while improving aesthetics, weathertightness and extending the functional role of the external surface. The timber cladding was selected deliberately to serve a dual purpose: in addition to providing the primary weather barrier, it functions as a test rig substrate to which new cladding materials, surface treatments, and facade components can be directly fixed by screwing into the timber structure, enabling weathering and performance testing of novel envelope materials alongside the primary human-subject research programme. The ventilated roof configuration from the Cambridge installation was retained, providing a continuous ventilated cavity

at roof level that reduces solar heat gain in summer and contributes to the overheating resilience of the test chambers. The final building envelope configuration is shown in Figure 3.a-b.

As in the Cambridge configuration the laboratory cannot be physically rotated, so orientations not under investigation are closed off using heavily insulated panels to enable flexible configurations Figure 3.c.. The key upgrade relative to Cambridge is that closure panels are now deployed on both the indoor and outdoor faces simultaneously, whereas the Cambridge configuration used insulating closure panels on the outdoor face only. The closure panels themselves were sourced as bespoke manufactured units adapted from the insulated panel systems used in refrigerated lorry bodywork — a construction type that provides high thermal resistance, structural rigidity, and precise dimensional tolerances in a thin and lightweight assembly. Panels are held in place on the interior face by a simple hinge system that allows rapid installation and removal without tools, while the exterior panels are secured using an elastic rubber anchoring system analogous to those used on sailing boats, providing a weathertight and vibration-tolerant fixing that can be released and repositioned quickly as the experimental configuration changes. View of the outdoor panels anchoring systems are shown in Figure 3.d,e. View of the internal panels are shown in Figure 3.b,g,f and h.

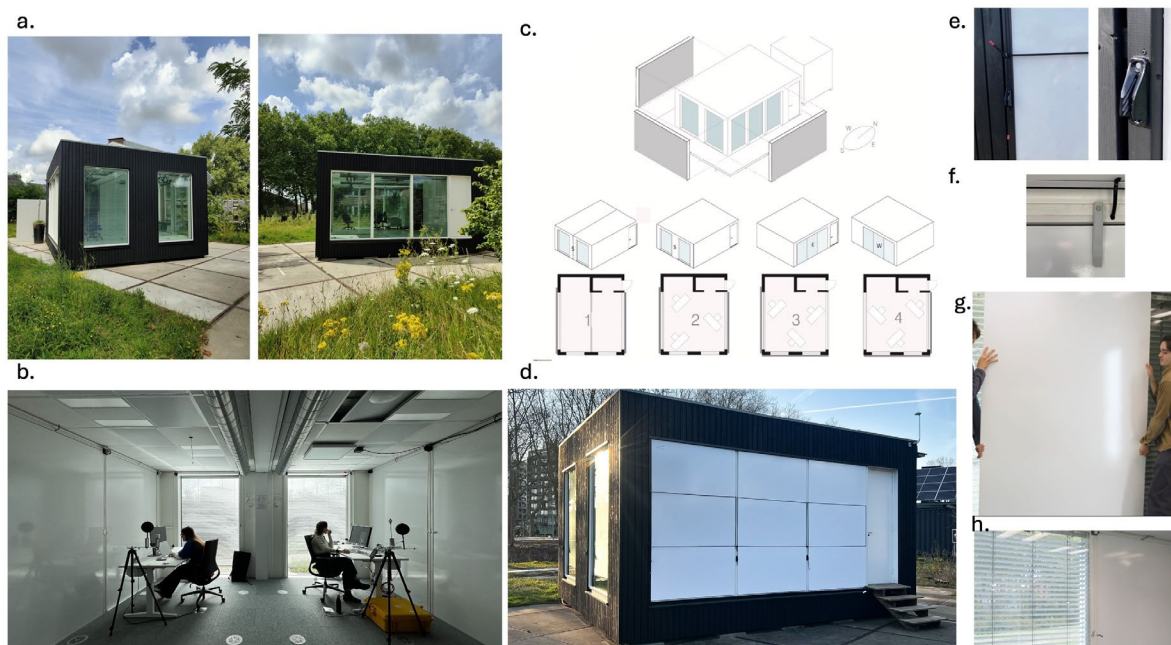


Fig. 3: The new envelope design at MATELab: a. The new MATELab with a ventilated timber façade and highly insulated panels; b. a view of the newly configured lab during experimental testing with human participants; c. the overall diagram of functioning of the lab, where different orientation can be studied by positioning the internal and external insulating panel; d. the external placement of outer insulating panels to cover the east orientation when not in use; e. a detail of the anchoring systems of the movable outer insulating panels used to cover up the test rigs not in use; f. a detail of the anchoring system used internally for the internal insulating panels used to cover the orientation or façade bay not under testing; h. a view of the internal setup where one facade bay is under testing and the other one is covered by the insulated panels.

The facade test rigs — the structural frames into which glazing specimens and facade assemblies are installed for experimental campaigns — were carried over from Cambridge and retain the same fundamental design principle: a timber pressure frame system in which the specimen is held in place by a screwed timber surround that applies clamping pressure around the perimeter, allowing specimens of varying thickness and construction to be installed and replaced without specialist tools

or bespoke fixings. The timber frame construction makes the system straightforward to modify or extend as new research requirements arise — new aperture sizes, additional instrumentation mounts, or alternative clamping configurations can be implemented by cutting and screwing standard timber sections on site. This approach prioritises flexibility and low cost of reconfiguration over the precision tolerances achievable with metal framing systems, a deliberate design choice consistent with the facility's purpose as an experimental rather than a production testing environment. An example of façade installation within a test rig is shown in Figure 4.

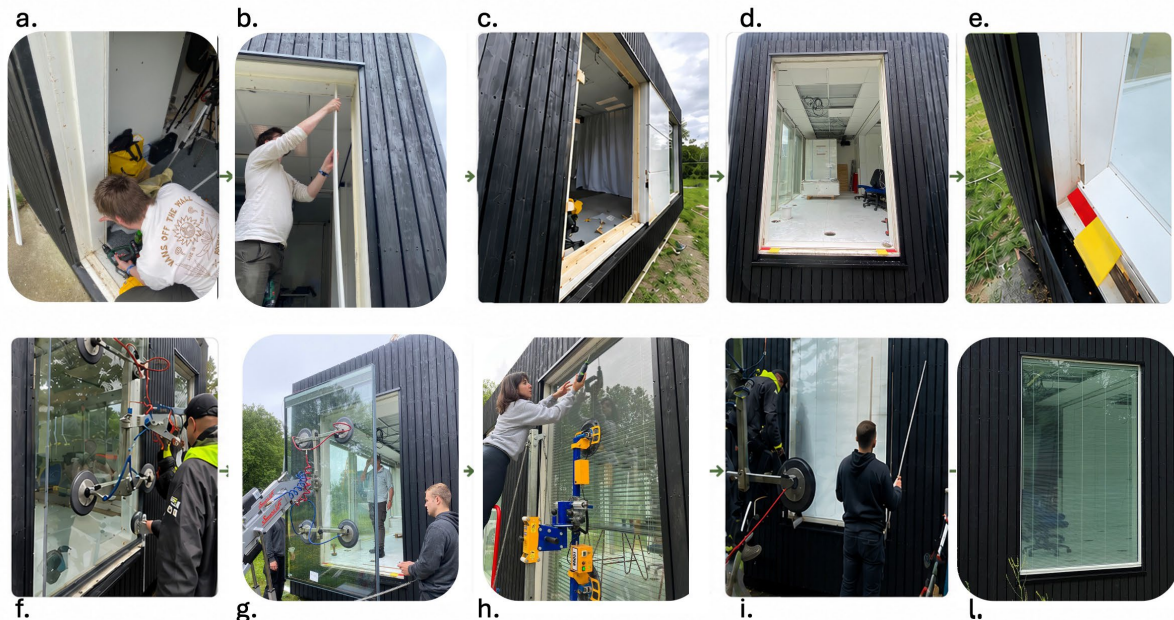


Fig. 4: Images of the step-by-step installation of façade specimen and the reconfigurable test rig and timber frames: a-b-c. positioning of tailored timber frames to host new façade components to be tested; d-e. preparation of spacer and packers to allow tolerance during the installation; f.-g. the positioning of new façade specimen, in this case glazings, by mean of manual or automated glass lifter; h-i. re-positioning of the timber frame to conclude the installation; l. example of the finalized installation.

5.2. MATELab upgrade and building services

The MATELab was upgraded to facilitate the evaluation of human-façade interaction in a multi-domain integrated manner (Figure 5.a). The MATELab chamber at TU Delft maintains a similar flexible floor plan distribution as in the precedent version in Cambridge, shown in Figure 5.c. As explained in section 4.1, MATELab is also designed to be divided into two independent halves along its north-south axis when needed, with the primary research purpose of enabling parallel comparative experiments between two facade configurations facing the same southern orientation simultaneously — for example comparing two different glazing types, shading strategies, or control logics under identical solar and climatic boundary conditions within the same experimental session. The building services follow the same partitioned logic: lighting circuits, HVAC supply and extract, and power metering are each independently served per bay so that the contribution of each half can be isolated.

The relocation to Delft also provided the opportunity to upgrade the electrical supply from single-phase to three-phase power, a change that was necessary to support the higher-capacity HVAC equipment and that enables experimental campaigns involving three-phase electrical loads including novel heating technologies and demand response scenarios. The artificial lighting system uses dynamic luminaires with continuous dimming and tunable white colour temperature (shown in Figure 5.e),

divided into independently controllable circuits per bay, supporting experimental protocols that require precise control of illuminance level and spectral quality. The HVAC system underwent a fundamental redesign relative to the Cambridge installation. At Cambridge, the mechanical plant consisted of two independent heat pumps with heat flow recovery. These were located outside the container structure to minimise acoustic disturbance inside the test chambers, but this configuration created persistent challenges: routing small-diameter supply and extract ducts across the steel container envelope proved difficult to weathertight and acoustically seal, especially during the re-building phase. At Delft, the system was replaced with a compact, low-noise unit developed by Orange Climate under the Verfris product range, shown in Figure 5.f. (Orange Climate, n.d.) — a system designed specifically for retrofit applications in space-constrained environments, prioritising minimal acoustic footprint and compact volume. The overall system is shown in Figure 5. The unit was installed in the existing technical space within the laboratory, eliminating the external plant room and the associated duct penetration problems entirely. The installed capacity was specified to accommodate a wider range of heating and cooling loads than the Cambridge system, supporting experimental campaigns with high internal heat gains or demanding thermal boundary conditions while maintaining adequate ventilation and air quality control. The air distribution strategy was also revised: the Cambridge configuration supplied conditioned air through the raised floor plenum and used the ceiling void as the return air path, an approach that proved thermally inefficient due to uncontrolled leakage and poor stratification control. At Delft, dedicated exhaust air ducts are positioned at ceiling level to improve collection efficiency and eliminate reliance on the ceiling void as a plenum. Supply air is delivered through floor-level vents that can be individually opened or closed to adjust the distribution pattern between bays. To enable finer control of supply air temperature independently of the main conditioning unit, the system incorporates a dual-duct post-heating arrangement — consistent in concept with the Cambridge design but refined in implementation — allowing different thermal conditions to be maintained in the two bays simultaneously, a capability that is essential for studies comparing thermal comfort responses across different heating and cooling strategies in the same experimental session.

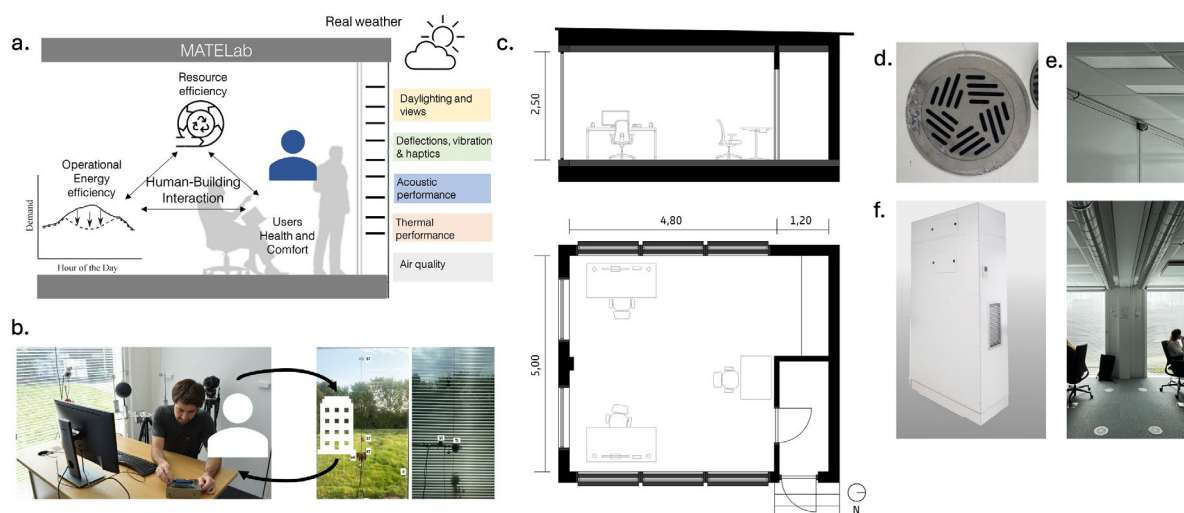


Fig. 5: a. the new overall concept of MATElab for the evaluation of human-building interaction in relation of façade technologies in a multi-domain approach; b. examples of human-building interaction data collection; c. the new floorplan distribution at the MATElab; d. example of the adjustable floor vents; e. the lighting system; f. the Verfris unit from Orange Climate and view of the internal duct system to extract exhaust air.

5.3. Shared sensing platform and BMS

The building management and sensing platform was built around Home Assistant (Home Assistant, n.d), an open-source automation hub, with the aim of supporting multiple communication protocols and providing a unified interface for monitoring, control, and data logging across all connected systems. The overall scheme is shown in Figure 6. Building service control systems connect to Home Assistant through protocol-native integrations: the KNX bus — carrying control signals for motorised shading, artificial lighting, and the KNX-connected weather station — connects via a KNX/IP interface using the platform's built-in KNX integration, which supports bidirectional read and write communication with the bus. The HVAC system, the Verfris unit supplied by Orange Climate [xx] and equipped with a Siemens building controller, communicates with Home Assistant via BACnet/IP. Environmental sensor data from the distributed IEQ sensor network — measuring temperature, relative humidity, CO2 concentration, illuminance, and air velocity — is transmitted to Home Assistant by a scientific-grade datalogger using the MQTT protocol to send the data. This architecture decouples sensor hardware from the central platform and allows any MQTT-capable sensor to be integrated without hub modification, providing the reconfigurability and flexibility desired for MATElab. Electrical energy monitoring is provided by ABB power meters communicating via Modbus, either over RS485 or over IP.

The facility operates two parallel weather monitoring systems that together support both research-grade meteorological measurement and comparison with data quality typical of commercial building management systems. The primary instrument is a Kipp and Zonen sun tracker connected to the MATElab platform through The Green Village shared data-platform infrastructure — the site-level network operated by The Green Village test field that provides shared connectivity and data services to all experimental installations on campus, avoiding the need for a dedicated data connection and representing a further advantage of The Green Village site selection described in Section 3.1. The second weather station is KNX-connected and integrated directly into Home Assistant via the KNX bus, providing meteorological data at the resolution and quality typical of a standard commercial BMS installation; the parallel operation of both systems enables direct comparison between research-grade and BMS-grade weather measurement, a methodologically relevant capability for studies examining how meteorological data quality affects smart building control performance. All data streams — KNX control states, MQTT sensor readings, Modbus energy measurements, and weather data from both stations — are logged centrally within Home Assistant and exported to a time-series database, sharing a common timestamp reference that is a prerequisite for the temporal alignment across heterogeneous data streams.

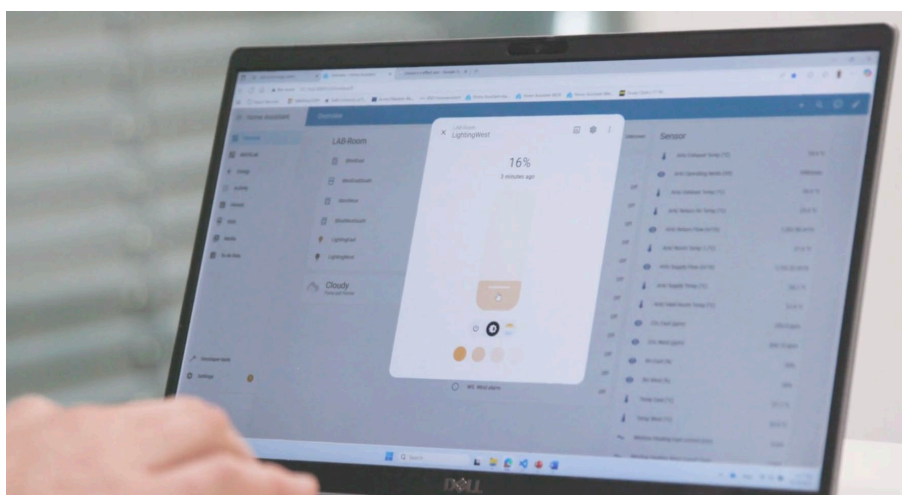
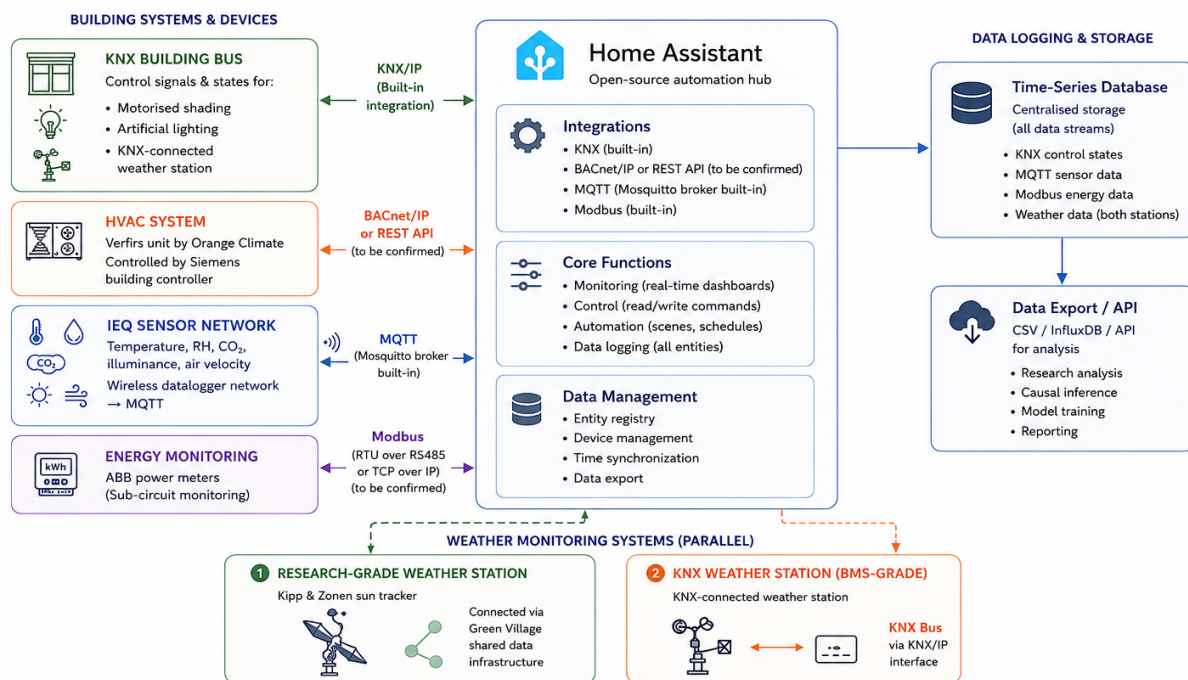


Fig. 6: The BMS platform of MATELab for integration of data collection and control system in a unified platform for interoperability.

6. Conclusion

This paper documents the relocation and upgrade of the MATELab — a human-subject façade interaction laboratory — from the University of Cambridge to TU Delft, providing the first systematic account of the challenges and decisions involved in transferring a specialised experimental facility of this type across institutional and national contexts. The experience generates a set of lessons that are directly applicable to other research groups developing, relocating, or upgrading human-subject façade and building performance laboratories.

Three overarching lessons emerge from the relocation process. First, design for disassembly should be treated as an explicit performance requirement from the outset of any experimental facility intended to be reconfigured or relocated. The MATELab was not originally designed with relocation in mind, and the distinction between elements designed with a partitioned logic — service systems, test rigs, glazing

collection — and those designed as continuous assemblies — floor boarding, external cladding — determined which components could be recovered and reused and which had to be written off. Future facilities should apply the same partitioned logic to all building elements, not only to service systems, and should document as-built conditions systematically from the first day of operation rather than retrospectively at the point of disassembly.

Second, the transit phase should be treated as a distinct environmental exposure event with its own risk assessment. Basic weatherproofing of open container faces is necessary but not sufficient: moisture accumulation, temperature variation, and — particularly for international relocations — unpredictable customs delays can extend transit conditions beyond what standard packing assumptions accommodate. Conservative packing specifications that treat all soft, floor, and absorbent materials as moisture-sensitive, and that assume maximum rather than nominal transit durations, would have prevented the carpet losses experienced during this relocation at modest additional cost.

Third, relocation presents a genuine opportunity for scientific and infrastructural upgrading that should be planned for rather than treated as an incidental benefit. The move to Delft enabled a series of improvements — the ventilated timber facade with dual-face insulating closure panels, the replacement of the external HVAC plant with a compact internal unit, the upgrade to three-phase electrical supply, the revised air distribution system, and the multi-protocol BMS — none of which would have been feasible without the disruption of the relocation. The scientific capabilities of the rebuilt facility substantially exceed those of the original, and the upgrade investment was made possible precisely because the relocation required a full disassembly in any case. Research groups planning relocations should approach the process as a scheduled upgrade opportunity with an explicit scope of improvements, rather than as a pure logistics exercise aimed at minimising change.

The rebuilt MATELab at TU Delft is now operational as a research platform for human-façade interaction studies, with expanded capabilities for multi-domain comfort assessment, heat resilience research, novel heating technology evaluation, and smart building control studies under real climatic boundary conditions. The facility, its sensing infrastructure, and the experimental protocols developed at Cambridge and extended at Delft are available to the research community as a shared resource, and the present paper is intended to contribute to the emerging documentation of experimental infrastructure for human-building interaction research that the field currently lacks.

Acknowledgements

The authors thank the support of the TKI Field Lab and the TKI Heat Face TKI2321 funding program. In addition, we thank Orange Climate, Pilkington NSG and Scheldebouw Permasteelisa for the support during the re-construction of the laboratory. Finally, we thank Victoria Rieger for the support with the images and drawing as well as the Health and Comfort students from TU Delft. Finally, we thank Nando Versteeg and Marijn Leeuwenberg for the support during the realisation of the lab.

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