Cable Driven Parallel Robots for Rapid Post Disaster Housing Construction in Displaced Communities

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Abstract: Each year natural disasters and forced displacement leave tens of millions of people without adequate shelter. Conventional humanitarian construction responses are slow, carbon intensive and poorly matched to the terrain, climate and cultural context of affected communities. Robotic and automated approaches, including concrete 3D printing, serial robotic arms and prefabricated modular units, have each been proposed as faster alternatives, but each carries fundamental limitations in post-disaster deployment contexts. This paper proposes that cable-driven parallel robots (CDPRs), a class of robotic system already demonstrated in architectural and construction contexts, offer a solution to this problem that has not previously been examined. Through a structured review of existing CDPR systems developed for construction, including SPIDERobot, CU-Brick and the IPAnema family, the paper identifies the core properties that make CDPRs well suited to post-disaster deployment: large workspace from lightweight portable infrastructure, reconfigurability without heavy plant, adaptability to irregular terrain and the ability to anchor to existing structural elements. A cross analysis of humanitarian shelter requirements against CDPR capabilities reveals a strong alignment, alongside specific gaps in weatherproofing, localisation in environments where Global Positioning System (GPS) signals are degraded and rapid operator training that current systems do not address. The paper proposes a six-priority research agenda, covering localisation, end effector design, operator interfaces, field durability and material adaptability, and identifies that deployment requirements differ meaningfully across seismic, flood and conflict-driven displacement contexts. The research agenda draws on the demonstrated capabilities of existing systems rather than speculative design.

Keywords: cable-driven parallel robots, humanitarian shelter, post-disaster construction, construction automation, displacement, disaster response, robotics

1 INTRODUCTION

The scale of housing need created by natural disasters and forced displacement is growing. The United Nations High Commissioner for Refugees (UNHCR) recorded 117 million forcibly displaced persons globally in 2023, the highest figure since monitoring began (UNHCR 2024). In the same year, the UN Office for the Coordination of Humanitarian Affairs reported that natural disasters generated acute shelter needs for over 26 million people (UN Office for the Coordination of Humanitarian Affairs [OCHA] 2024). Analysis of shelter responses across major disasters between 2010 and 2023 found that median household shelter was completed 4.3 months after the disaster event, and 38% of surveyed occupants reported structural deficiencies within the first year (Davis and Alexander 2016).

The construction response to displacement events is consistently characterised by three failures: it is too slow, it is poorly matched to local terrain and climate, and it relies on labour-intensive processes that are difficult to mobilise rapidly at scale (Shelter Centre 2012). Robotic and automated construction technologies have been proposed as partial solutions to these challenges. The most widely discussed approaches, concrete 3D printing, serial robotic arms and prefabricated modular units, each carry significant limitations when evaluated against the specific demands of post-disaster deployment. These limitations are examined in Section 2.

A review of the construction robotics and humanitarian shelter literature identifies no prior work examining how cable-driven parallel robot (CDPR) technology, already demonstrated in on-site construction contexts, might be adapted and deployed to address the gap left by these approaches. CDPRs require no rigid base structure, no crane access and no level ground for the robot itself. Their workspace is defined by cable anchor positions on existing structure, not by the robot's physical footprint, making them well matched to the irregular, infrastructure-poor conditions of post-disaster sites.

This paper addresses that gap through a review and conceptual analysis. Section 2 examines the limitations of existing automated construction approaches in disaster contexts. Section 3 reviews the humanitarian shelter context and its principal constraints. Section 4 surveys existing CDPR systems developed for construction and identifies their relevant capabilities. Section 5 cross analyses shelter requirements against CDPR properties. Section 6 identifies the gaps a system adapted for this context would need to address. Section 7 proposes a research agenda. Section 8 concludes.

1.1 Review Methodology

This paper employs a narrative literature review approach, structured around two parallel strands. The first strand identifies the principal automated and robotic construction technologies proposed for rapid housing delivery, drawing on peer-reviewed journal articles, conference papers and grey literature published between 2015 and 2025. Search terms including '3D printing construction', 'robotic arm construction', 'prefabricated disaster shelter' and 'modular housing post-disaster' were used across Scopus, Web of Science and Google Scholar. Technologies were included where peer-reviewed evidence of field or prototype demonstration existed; purely theoretical proposals were excluded.

The second strand reviews cable-driven parallel robot systems demonstrated in construction contexts, using search terms including 'cable-driven parallel robot', 'CDPR construction' and the names of identified systems (SPIDERobot, CU-Brick, IPAnema). System descriptions were drawn from primary publications by each system's developers and corroborated against institutional documentation where available. The cross analysis in Section 5 synthesises findings from both strands against requirements derived from the Sphere Handbook (Sphere Association 2018) and the humanitarian shelter literature. Rating criteria applied in Table 1 are defined in Section 5 prior to the table. As a conceptual paper, findings are not validated through primary data collection; Section 7 proposes a scenario-based validation approach as a priority within the research agenda.

2 LIMITATIONS OF EXISTING AUTOMATED CONSTRUCTION APPROACHES

2.1 Concrete 3D Printing

Concrete 3D printing has generated considerable research interest as a rapid housing technology, and a small number of field demonstrations have been completed in controlled conditions

(Razkenari et al. 2025; Weng et al. 2023). However, its limitations in disaster contexts are substantial. The equipment requires a continuous stable power supply and pressurised concrete supply lines, neither of which can be assumed in a post-disaster environment (Weng et al. 2023). The concrete mix must meet precise printability and open-time parameters that are difficult to maintain under site temperature variation, dust and humidity (Weng et al. 2023). The gantry or boom structures required for large-format printing are heavy and require road access and, in most configurations, cranes or forklifts for assembly (Razkenari et al. 2025).

A feasibility study of 3D printed disaster shelters published in Construction Robotics found that a common failure scenario arises when equipment cannot handle structural component sizes and weights in field conditions, leading to material distortion, dimensional inaccuracies and abandonment in favour of traditional methods (Perez-de-la-Mora et al. 2023). The approach also produces structures in concrete, a high embodied carbon material poorly suited to tropical and arid climates where thermal mass creates overheating risk. Research on 3D printing for remote and disaster-prone housing has consistently identified high capital costs, lack of standardised codes and community scepticism as additional barriers to deployment in lower-income contexts (Razkenari et al. 2025).

2.2 Serial Robotic Arms

Serial robotic arms, of the type deployed in systems such as Hadrian X for bricklaying, face a different set of constraints in disaster contexts. Their workspace is bounded by the physical reach of the arm, typically one to two metres, meaning the robot must be repositioned continuously across a building footprint. Repositioning requires a stable level base platform, usually a mobile chassis or tracked vehicle, which imposes significant weight and road access requirements (Bock 2015). Payload capacity is constrained by the arm structural mass, longer arms capable of larger workspaces require proportionally heavier counterbalancing, compounding transport requirements further.

In unstructured post-disaster terrain, level ground for base positioning cannot be assumed. The rigid link structure of serial arms also means the robot occupies a fixed footprint within the construction zone, creating safety exclusion areas that are difficult to manage alongside co-located manual workers. These characteristics make serial arms effective for repetitive single-task operations on flat accessible sites but poorly suited to the irregular terrain typical of disaster reconstruction zones.

2.3 Prefabricated Modular Units

Prefabricated modular units have been the most widely deployed technology in disaster response, most recently at scale following the 2023 Turkey-Syria earthquake where container units provided immediate shelter for approximately 800,000 people (AFAD 2023). Their speed of deployment and factory quality control are genuine advantages. However, modular units are inherently geometry-constrained: they arrive as rectangular boxes and cannot be adapted to non-rectangular plots, hillside terraces or irregular site boundaries.

The Turkey-Syria response illustrated this directly, where an estimated 120,000 households on hillside plots could not be served by the container programme and remained in makeshift structures six months after the event (UN-Habitat 2023). Modular units also depend on crane or heavy forklift access for placement and require level prepared ground. Research on prefabricated construction in lower-income contexts has consistently identified infrastructure limitations, inflexibility and supply chain dependency as major barriers to effective deployment (Lacey et al. 2025). Where disasters have damaged roads and removed crane access, as is common in seismic and landslide events, modular units simply cannot reach the communities that need them most. Having established the limitations of existing approaches, Section 3 turns to the humanitarian shelter context to define the specific requirements that any robotic solution must satisfy.

3 HUMANITARIAN SHELTER CONTEXT

3.1 Scale and Failure Modes

The Sphere Handbook, the primary humanitarian shelter standard, specifies minimum covered space of 3.5 m² per person for emergency shelter and 18 m² per household for transitional shelter intended to last one to five years (Sphere Association 2018). In practice, construction of transitional shelter at this standard consistently takes months rather than weeks, primarily because the construction methods employed, namely timber stud framing, masonry block and corrugated steel, require skilled labour, tool access and material supply chains that are disrupted by the disaster itself (Davis and Alexander 2016; Shelter Centre 2012).

The 2023 Turkey-Syria earthquake, which destroyed or severely damaged over 200,000 buildings, illustrates the terrain constraint specifically (AFAD 2023). The affected region is characterised by steep hillside topography and terraced plot geometry. As noted in Section 2.3, the container shelter programme could not be adapted to non-rectangular hillside plots, leaving an estimated 120,000 households in makeshift structures six months after the event (UN-Habitat 2023). The standard container unit failed precisely because the terrain did not match its geometric and access constraints.

The 2022 Pakistan floods, which displaced 8 million people and destroyed 1.7 million homes, illustrate the recurrence problem (Pakistan National Disaster Management Authority [NDMA] 2022). Despite reconstruction guidance specifying raised plinths and flood-resistant materials, a World Bank assessment found that 62% of rebuilt homes used the same methods as those that failed (World Bank 2023). The consistency of construction quality, ensuring structural standards are met across thousands of individually built units, cannot be achieved by manual labour under time pressure and resource constraint.

3.2 Key Requirements for a Robotic Construction Solution

Drawing from the disaster case evidence and the Sphere Handbook standards (Sphere Association 2018), a robotic construction system for humanitarian deployment would need to satisfy the following requirements. It must be transportable to remote or road damaged sites without crane access. It must be operable on irregular, non-level terrain. It must erect structures meeting basic structural performance requirements such as wind uplift and seismic lateral resistance, consistently across many units. It must be operable by locally trained personnel within days of site arrival. It must impose a low carbon footprint relative to conventional masonry construction. Finally, it must be economically viable at the scale of hundreds to thousands of units.

On economic viability, a full cost analysis lies beyond the scope of this conceptual paper and requires empirical data from field prototypes. However, a preliminary framing is possible. The capital cost of a CDPR system is dominated by winches, cables, the mobile platform and control electronics; anchor infrastructure can integrate into standard temporary mast systems already used in humanitarian logistics. Unlike a tower crane, which costs approximately USD 15,000 to 25,000 per month to lease and operate in lower-income country contexts, or a concrete 3D printing gantry with high capital and material logistics costs, a CDPR's infrastructure is reusable across sites and deployments. At scale, recurring costs are operator labour and materials, both of which can draw on local supply, reducing costs relative to imported prefabricated solutions. A formal techno-economic analysis comparing CDPR-based construction against modular and manual construction alternatives across representative disaster contexts is identified in Section 7 as a component of the research agenda. Section 4 reviews the cable-driven parallel robot systems that currently exist in construction contexts, assessing how their demonstrated capabilities map onto these requirements.

4 CABLE DRIVEN PARALLEL ROBOTS IN CONSTRUCTION: EXISTING SYSTEMS

4.1 Principles of Cable Driven Parallel Robots

Cable driven parallel robots (CDPRs) are a class of robotic system in which flexible cables replace the rigid links of a conventional parallel manipulator. Cables are wound on servo driven winches mounted (motor-controlled spools that wind or unwind cables under precise torque control to regulate cable length and tension) at fixed anchor points, and their lengths are coordinated to position and orient a mobile platform within the enclosed workspace. The fundamental constraint of cable actuation, whereby cables can only pull not push, means that at least n+1 cables are required for n degrees of freedom, with additional cables providing actuation redundancy and improved force isotropy (Pott 2018).

The properties of CDPRs that distinguish them from conventional robotic systems are well established in the literature (Pott 2018; Qian, S. et al. 2018). Workspace volume scales with anchor separation rather than with robot mass, enabling workspaces of tens to hundreds of metres with relatively lightweight infrastructure. The system footprint is defined by anchor positions rather than by a structural frame, so the robot can operate within a building under construction by anchoring to its own structural elements. The lightweight cable and winch components can be transported and assembled without crane access. The anchor configuration can also be reconfigured between tasks by moving winches to new positions, redefining the workspace without replacing the robot. The key components of a CDPR system are illustrated in Figure 1.

A common concern about robotic systems in post-disaster contexts is power supply. Unlike concrete 3D printing, which requires continuous high-pressure pumps drawing several kilowatts to maintain material flow, CDPR winch motors operate intermittently: they draw power only when repositioning the platform and can hold position under cable tension without continuous power input. Field estimates from IPAnema 3 testing indicate a typical operational draw of 2 to 4 kW across the winch array during active motion (Fraunhofer IPA 2024), comparable to a small generator. A 5 to 10 kVA diesel or solar-hybrid generator, standard equipment in humanitarian logistics supply chains through organisations such as UNHCR and the International Federation of Red Cross and Red Crescent Societies, is sufficient to power a CDPR system in the field without a mains grid connection, a materially lower power requirement than concrete 3D printing gantry systems.

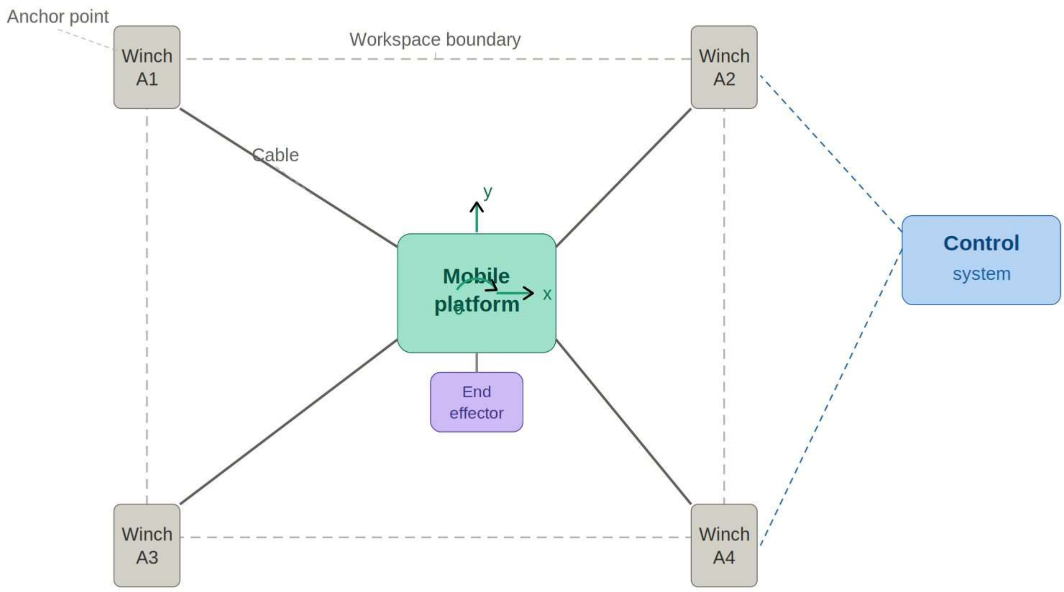

Figure 1. Schematic of a cable-driven parallel robot (CDPR) system: anchor-mounted winches (A1–A4), cables, mobile platform with end effector, workspace boundary and motion axes. Adapted from Pott (2018).

4.2 SPIDERobot

SPIDERobot, developed by Pinto, Moreira, Lima, Sousa and colleagues at the University of Porto, is a four cable, four degrees of freedom (the four independent axes of motion the platform can control: translation in x, y and z, plus rotation about the vertical axis) CDPR developed specifically for automated on-site construction in architectural projects (Pinto et al. 2017; Moreira et al. 2015). The system features a rotating claw end effector capable of picking and placing construction material with controlled orientation. A vision-based feedback dynamic control system localises the platform and generates collision avoiding trajectories in real time, achieving positional precision of 0.006 m in experimental validation (Moreira et al. 2015). Of particular relevance for humanitarian applications, the system was designed for non-standard architectural geometries and unstructured on-site conditions, not for controlled factory environments.

4.3 CU-Brick

CU-Brick, developed by Professor Darwin Lau and collaborators at the Chinese University of Hong Kong (CUHK), is a cable-driven parallel robot system for automated brick structure construction (Wu et al. 2018; Lau et al. 2025). The system consists of a gripper end effector and cable actuators that can be mounted on a range of different environments, from metal frame structures to the walls and roofs of buildings (Fingrut and Lau 2022). CU-Brick has completed a real on-site pilot construction project: a single storey brick structure spanning approximately 13 m

× 9 m, standing 2.5 m in height, comprising more than 5,800 bricks (Lau et al. 2025). The fourth generation of the system is currently in active development and has also been applied to building facade inspection and cleaning using different end effectors, demonstrating the reconfigurability of the cable platform across task types (Fingrut and Lau 2022).

4.4 IPAnema Family

The IPAnema family of cable-driven parallel robots, developed at Fraunhofer IPA in Stuttgart by Pott and colleagues, represents the most industrially mature CDPR platform (Pott et al. 2013). The current demonstrator, IPAnema 3, has an installation space of 16 × 11 × 6 metres and a payload capacity of up to 250 kg, controlled by a real-time capable computer numerical control (CNC) system programmable using standard G-Code (Fraunhofer IPA 2024). The system has been used for additive manufacturing of concrete structures in the HINDCON project using a 3D print head end effector (Fraunhofer IPA 2024). Fraunhofer IPA notes that workspaces of up to 100 m edge length are achievable, and each cable can bear loads of up to several tons in heavy duty configurations (Fraunhofer IPA 2024).

4.5 Other Relevant Systems

The RoboCrane, developed by the National Institute of Standards and Technology (NIST) from 1989, was one of the earliest large-scale CDPR implementations intended for construction and cargo handling including bridge construction and port logistics (Qian, L. et al. 2018). The FAST telescope feed support system in China positions the feed cabin of a 500-metre aperture spherical radio telescope using a cable-driven structure, representing one of the largest cable robot deployments in the world and demonstrating the technology's scalability (Qian, L. et al. 2018). Bruckmann and colleagues at the University of Duisburg-Essen have conducted concept studies of automated construction using CDPRs, analysing workspace requirements and cable force distributions for building construction tasks specifically (Bruckmann et al. 2018). Section 5 draws on this body of evidence to assess how well these systems align with the requirements established in Section 3.2, and to identify where gaps remain.

5 CROSS ANALYSIS: SHELTER REQUIREMENTS VERSUS CDPR CAPABILITIES

Table 1 presents a structured cross analysis of the humanitarian shelter requirements identified in Section 3.2 against the demonstrated capabilities of the existing CDPR systems reviewed in Section 4. For comparison, the performance of the three alternative technologies examined in Section 2 is also indicated. Four rating levels are used, each grounded in the literature reviewed. “Strong match” indicates the technology has demonstrated the relevant capability in published field or prototype trials. “Partial” indicates capability exists but with significant limitations in the humanitarian deployment context. “Poor” indicates a structural barrier identified in the literature. “Gap” indicates the requirement has not been addressed by any existing system of that type. “Not applicable” indicates the requirement does not arise for that technology.

Table 1. Cross analysis of shelter requirements, CDPR capabilities and alternative technologies.

Requirement	CDPR	3D print / serial arm	Modular unit
Transport without crane	Strong match	Poor	Poor
Irregular terrain	Strong match	Poor	Poor
Structural quality consistency	Strong match	Partial	Strong match
Large workspace	Strong match	Partial	Strong match
Reconfigurability	Strong match	Poor	Partial
Low carbon footprint	Partial	Poor	Partial
Local operator training	Gap	Gap	Partial
GPS-degraded localisation	Gap	Gap	Not applicable
Weatherproofing in field	Gap	Gap	Strong match

The analysis confirms that CDPRs perform well across the requirements that matter most for humanitarian deployment: workspace scale, transportability, reconfigurability and construction precision. The two constraints that disqualify each of the alternatives examined in Section 2 do not apply to CDPRs: crane-free deployment and operation on uneven ground are both fundamental to how the technology works. The gaps identified are genuine but bounded, and each is addressable through targeted development, as discussed in Section 6.

The basis for each rating is as follows. CDPRs are rated Strong match for transport without crane because all three reviewed systems comprise winches and cables that can be hand-carried and assembled without lifting equipment (Pott et al. 2013; Wu et al. 2018; Pinto et al. 2017). CDPRs are rated Strong match for irregular terrain because the workspace is defined by cable anchor positions on existing structure rather than the robot's physical footprint, and CU-Brick has been demonstrated on non-flat surfaces (Fingrut and Lau 2022). 3D printing and serial arms are rated Poor for irregular terrain because gantry structures and mobile arm bases both require level stable ground, as documented in Perez-de-la-Mora et al. (2023) and Bock (2015). 3D printing is rated Poor for reconfigurability because the gantry geometry is fixed at installation and cannot be repositioned without full dismantlement (Razkenari et al. 2025). Modular units are rated Partial for reconfigurability because unit sizes are fixed, though units can be combined in different arrangements (Lacey et al. 2025). All automated systems are rated Gap for local operator training because none has been designed for non-specialist operation (Bock 2015; Melenbrink et al. 2020). Modular units are rated Not applicable for GPS-degraded localisation because crane-directed placement does not depend on autonomous positioning.

6 GAPS AND BARRIERS TO HUMANITARIAN DEPLOYMENT

6.1 Localisation Without GPS or Structured Environment

All existing construction CDPR systems assume either controlled laboratory conditions or structured sites where reference points can be pre-surveyed. SPIDERobot's vision-based control system relies on a camera network with clear lines of sight (Moreira et al. 2015). Post-disaster environments, characterised by dust, debris, partial structure collapse and radio frequency interference from emergency communications, degrade both visual and GPS localisation. A humanitarian deployment would require ultra-wideband (UWB) ranging anchored to the cable masts, inertial measurement unit (IMU) bridging, and fiducial markers on structural elements as candidate localisation approaches drawn from the broader construction robotics literature (Melenbrink et al. 2020), but none has been integrated into an existing CDPR construction system.

6.2 Rapid Operator Training

Existing CDPR systems are operated by specialist robotics researchers or highly trained technicians. For deployment in a humanitarian context, the system would need to be operable by locally recruited workers with no prior robotics experience, trained within days of site arrival. Tablet-based interfaces with local language support, simplified task programming through waypoint selection, and automated safety interlocks that do not require operator expertise to configure are likely necessary features (Bock 2015).

6.3 Environmental Durability

The IPAnema, CU-Brick and SPIDERobot systems have all been demonstrated in controlled or semi-controlled environments. None has been tested under the sustained rain, dust, heat and vibration of a post-disaster construction site in a tropical or arid climate. The winch and cable components of CDPRs are broadly industrial grade and likely more weather tolerant than the sensing and control electronics, which would require ruggedisation and sealed housing for reliable field operation.

6.4 Panel and Material Handling for Lightweight Construction

CU-Brick's gripper is designed for standard bricks; SPIDERobot's rotating claw targets architectural material of unspecified geometry. Humanitarian transitional shelter typically uses lightweight panel systems such as structural insulated panels (SIPs), bamboo composite panels or prefabricated timber frames. An end effector capable of handling panel weights of 100 to 200 kg with controlled orientation would be required. The underlying CDPR capability is well established: CU-Brick achieves brick placement with gripper-based position control and IPAnema 3 handles 250 kg payloads (Lau et al. 2025; Fraunhofer IPA 2024), indicating this is technically achievable, but the specific end effector design has not been developed. These four gaps collectively define the development work required before a CDPR system can be deployed in a humanitarian housing context. Section 7 sets out a structured research agenda to address them.

7 PROPOSED RESEARCH AGENDA

This review identifies that CDPRs are, in principle, better suited to post-disaster housing construction than any of the three automated approaches examined in Section 2. They are better than concrete 3D printing because they require no fixed gantry infrastructure, no continuous concrete supply and no power grid. They are better than serial robotic arms because their workspace is defined by cable anchor geometry rather than arm reach, eliminating the need for a level mobile base on irregular terrain. They are better than modular units in terrain-constrained deployment contexts because they can operate without crane access and can adapt their construction output to non-rectangular site geometries. The research programme below sets out the steps required to develop a CDPR system suited to this deployment context.

The first priority is localisation in GPS-degraded and visually cluttered environments. This requires adaptation of UWB and IMU sensor fusion approaches from the broader construction robotics literature to the specific geometry of a CDPR anchor network, and validation under simulated post-disaster conditions.

The second priority is end effector design for lightweight panel systems, building on the gripper architectures of CU-Brick and IPAnema 3 but adapted to the panel dimensions, weights and connection details of standard humanitarian transitional shelter typologies.

The third priority is operator interface design for non-specialist users. This is a human-computer interaction research problem as much as a robotics one and should involve co-design with humanitarian field workers from the outset.

The fourth priority is field durability testing, subjecting the adapted system to the environmental conditions of target deployment archetypes including tropical coastal, highland seismic and arid camp contexts, before any live humanitarian deployment is attempted.

A fifth priority, cross cutting all the above, is the design of the system for material and construction methodology adaptability. The humanitarian shelter context is not uniform: appropriate construction materials and structural typologies vary significantly by region, climate and available supply chain. In tropical coastal environments, bamboo composite panels or lightweight timber frames may be preferred; in arid or highland contexts, compressed earth blocks or thin-shell masonry may be more appropriate; in camp settings with organised logistics, standardised SIP panels may be most practicable. The cable robot platform itself (the winches, cables and anchor framework) can remain constant across these material types. What changes is the end effector and the task programming. CU-Brick already demonstrates this principle directly: the same cable platform has been used with a brick gripper for construction, a cleaning nozzle for façade maintenance, and an inspection module for building survey (Fingrut and Lau 2022). A humanitarian CDPR should therefore be designed from the outset with a standardised end effector interface and a library of interchangeable tool heads, allowing the same deployed system to switch between, for example, panel lifting and placement, masonry block laying, and cable-tie or structural fastener installation, depending on the construction methodology selected for that site. This modular tool approach would also extend the system's utility beyond initial shelter construction to repair, retrofit and inspection tasks in the recovery phase, significantly improving the economic case for deployment.

A sixth priority is a scenario-based analysis of CDPR deployment across representative disaster contexts, addressing the call for validation in the review process. In the absence of a physical prototype, scenario analysis provides a tractable intermediate validation method. Three archetypes would be evaluated: a seismic event in hillside terrain (modelled on the 2023 Turkey-Syria earthquake context); a flood event on flat low-lying land (modelled on the 2022 Pakistan floods); and a conflict-driven camp setting (modelled on the Cox's Bazar context). Each scenario would assess technical requirements for localisation, terrain access, anchor configuration, material handling and operator workflow, identifying where current CDPR capability is sufficient and where adaptation is required. This provides a structured basis for prototype specification before physical development begins, consistent with established practice in conceptual humanitarian engineering research (Davis and Alexander 2016; Shelter Centre 2012).

None of the gaps identified represents a barrier to the underlying technology; each is a bounded engineering or design problem with a tractable solution path. The CDPR systems reviewed here, SPIDERobot, CU-Brick and IPAnema, show that the core robotics capability required for humanitarian housing construction is already proven. The work that remains is the adaptation of that capability to the specific constraints of post-disaster deployment, and these constraints differ in important ways depending on the disaster type. Seismic events generate rubble-strewn irregular terrain and collapsed infrastructure, requiring robust localisation and debris-tolerant cable routing. Flood events demand elevated construction and corrosion-resistant components suited to waterlogged ground. Conflict-driven displacement typically operates in organised camp settings where standardised panel logistics and rapid operator turnover place particular demands on the operator interface and material handling system. A humanitarian CDPR system must therefore be designed and validated across these archetypes, not optimised for a single deployment context. Figure 2 illustrates the conceptual deployment configuration for such a system.

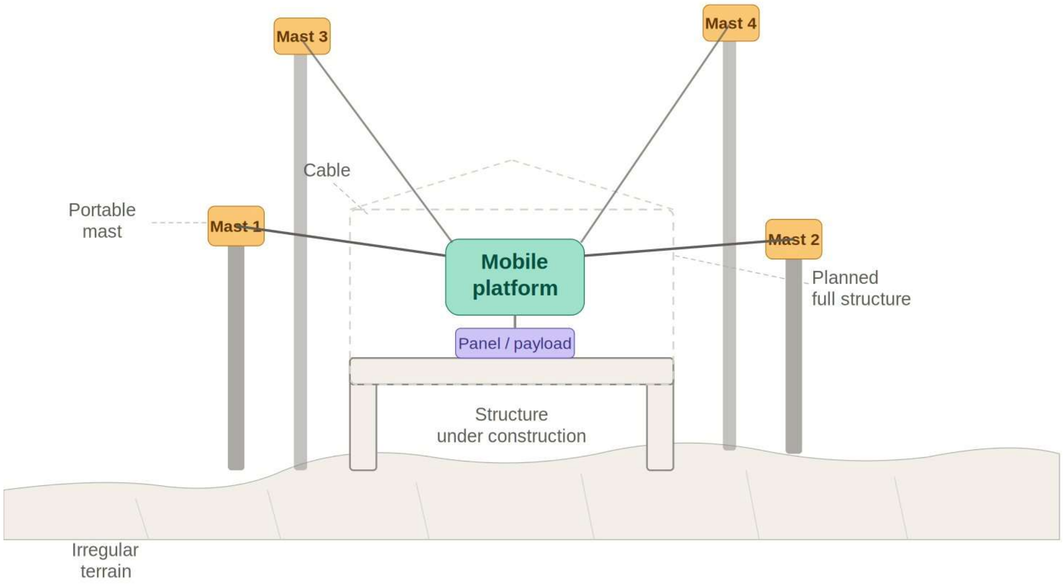

Figure 2. Conceptual deployment of a humanitarian CDPR: lightweight portable masts anchor on irregular terrain while the suspended platform places panels onto a structure under construction.

8 CONCLUSION

This paper has reviewed the humanitarian shelter context and the state of cable-driven parallel robot technology in construction and has argued that CDPRs represent a credible but so far unexamined approach to the robotic construction of post-disaster and displaced community housing.

Section 2 established why the three most commonly proposed automated alternatives are insufficient in disaster contexts. Concrete 3D printing depends on stable power, pressurised material supply and heavy gantry infrastructure. Serial robotic arms require a level mobile base and have workspace constrained by arm reach, making them unsuitable for irregular post-disaster terrain. Prefabricated modular units, while proven at scale, are geometry-rigid and crane-dependent, and fail to reach hillside or road-damaged sites. CDPRs, by contrast, anchor to existing structure, require no level ground for the robot itself and need no crane access for deployment.

The cross analysis in Section 5 shows that the core properties of CDPRs align directly with the requirements of humanitarian shelter deployment. Real existing systems, including SPIDERobot developed at the University of Porto, CU-Brick developed at the Chinese University of Hong Kong, and the IPAnema family from Fraunhofer IPA, provide a credible technical foundation. The gaps identified in Section 6, namely localisation in GPS-degraded environments, rapid non-specialist operator training, field environmental durability and panel appropriate end effector design, are each bounded and addressable. Section 7 sets out a six-priority research programme to realise a system suited to this context. The fifth and cross-cutting priority, designing for material and construction methodology adaptability across different shelter typologies, reflects the reality that appropriate materials and structural approaches vary by region, climate and supply chain, and that the cable robot platform can remain constant while end effectors and task programming change to suit each context. The research programme also recognises that deployment requirements differ meaningfully by disaster type: seismic, flood and conflict-driven contexts each impose distinct demands on localisation, materials and operator workflow, and any prototype system must be validated across these archetypes before field deployment. This paper is intended as a first step in establishing that research agenda.

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