The Role of Innovative Technologies in Addressing Gender-Related Barriers in the Construction Sector

TECH4EU CONSTRUCTION

A White Paper based on evidence from the Tech4EU Construction Cluster with its flagship projects: BEEYONDERS, INCUBE, RoBétArmé and HUMANTECH

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This white paper reflects a collective effort across the Tech4EU Construction Cluster to better understand how technological innovation can contribute to shaping a more inclusive construction sector. Bringing together insights from the BEEYONDERS, INCUBE, RoBétArmé and HUMANTECH projects, it captures a moment of transition in which digitalisation, automation and new ways of working are redefining the nature of construction work. These transformations create an important opportunity to challenge long-standing barriers and open the sector to a broader and more diverse workforce. At the same time, the findings highlight that inclusion cannot be achieved through technology alone. Real progress depends on how these innovations are embedded within organisational practices, skills systems and cultural change. By combining evidence and experience across projects, this paper aims to contribute to a shared reflection on how to ensure that the future of construction is not only more advanced, but also more equitable and inclusive.

Table of Contents

List of Figures

List of Tables

Executive summary

The construction sector is undergoing a profound transformation driven by digitalisation, automation, and the integration of advanced technologies. These changes present a significant opportunity not only to improve productivity and safety, but also to address long-standing gender-related barriers that have historically limited women's participation in the sector. This white paper examines **the extent to which emerging technologies can contribute to fostering a more inclusive construction industry**, drawing on evidence from the **Tech4EU Construction Cluster** and insights from the **BEEYONDERS, InCUBE, RoBétArmé and HUMANTECH projects.** The analysis draws on questionnaire-based evidence collected across participating projects, capturing the perspectives of construction stakeholders on emerging technologies and gender-related barriers. The results therefore provide insight into how technologies are understood in relation to gender inclusion, rather than measuring their direct impact on participation outcomes.

The analysis reveals a nuanced picture of both challenges and opportunities. At a general level, barriers within the construction sector are primarily perceived as **organisational and structural**, relating to working conditions, career progression, training access and sector entry pathways. However, when focusing specifically on women's participation, **cultural barriers emerge as the most significant constraint.** Persistent perceptions of construction as a male-dominated sector, gendered expectations around roles and capabilities, and implicit biases in workplace environments continue to shape women's access, progression and retention. Within this context, **emerging technologies are widely recognised as having a positive**, though differentiated, **potential to support gender inclusion**. Technologies such as exoskeletons, demolition robots, and autonomous or teleoperated systems are perceived as particularly impactful in reducing physical strain, improving safety and enabling a shift from manual labour toward more technical and supervisory roles. Similarly, digital tools such as UAV-based photogrammetry, digital twins and 3D printing contribute to the increasing importance of skill-based, design-oriented and data-driven activities within the sector.

However, the findings also highlight a critical misalignment – already anticipated in the conceptual framing of the physical threshold. While technologies primarily address structural and organisational dimensions by improving working conditions and reshaping tasks, the main barriers to women's participation are perceived to be cultural. As a result, the contribution of technologies to gender inclusion remains conditional. Without complementary measures addressing workplace culture, organisational practices and sector perceptions, technological innovation alone is unlikely to lead to substantial changes in participation patterns.

The analysis further underscores that **the inclusive potential of technologies depends on several enabling conditions**. These include equitable access to training and upskilling opportunities, particularly in emerging technical domains; inclusive design and usability of technologies, ensuring they accommodate diverse users; and the existence of organisational environments that support fair career progression and participation. In addition, concerns related to data governance and worker monitoring highlight the importance of ethical frameworks to ensure that technologies enhance working conditions, rather than undermine them. Based on these findings, the white paper calls for a **coordinated approach involving policy makers, industry actors and technology developers**. Key priorities include strengthening training and education pathways aligned with technology-driven roles, addressing sector image and early pipeline barriers, embedding inclusive design standards in technological development, and ensuring that organisational practices evolve alongside technological adoption. Moreover, technologies should be strategically leveraged not only as productivity tools, but also as instruments to reshape how construction work is perceived, highlighting its increasingly technical, innovative, and less physically constrained nature.

Ultimately, this white paper demonstrates that **emerging technologies can play a meaningful role in supporting a more gender-inclusive construction sector**. However, their impact is neither automatic nor sufficient in isolation. Achieving lasting change requires **aligning technological innovation with broader structural, organisational, and cultural transformations**, ensuring that the future of construction is both more advanced and more inclusive.

1 Introduction

The **Tech4EU Construction Cluster** brings together a group of EU-funded research and innovation projects working collaboratively to accelerate this transition. The cluster, initiated by projects such as **BEEYONDERS, InCUBE, RoBétArmé** and **HUMANTECH,** aims to develop and demonstrate cutting-edge solutions that enhance safety, productivity, sustainability and attractiveness of the construction sector.

The cluster reflects a shared ambition to address key structural challenges of the industry, including low productivity, labour shortages and demanding working conditions, while strengthening Europe's technological sovereignty. Through collaboration, knowledge exchange and joint events and communication, these projects contribute to advancing Construction 4.0 by integrating artificial intelligence, robotics, digital twins and data-driven processes into real construction environments.

Each project within the cluster brings a distinct yet complementary perspective:

PROJECT	CONCEPT & CONTRIBUTION
BEEYONDERS	Focuses on the **development and large-scale deployment** of **worker-friendly technologies**, leveraging AI, automation, and digitalisation to improve safety, efficiency, and usability in construction processes
InCUBE	Complements BEEYONDERS' technological focus by **promoting industrialised, digitalised, and energy-efficient solutions** to accelerate the renovation wave, integrating new processes, technologies, and market actors across the construction value chain
RoBétArmé	Advances **human–robot collaboration** by automating labour-intensive tasks, particularly through robotic systems for shotcrete application, enhancing both productivity and worker safety
HUMANTECH	Develops **human-centred technologies**, including exoskeletons, robotics, and digital twins, to create safer, greener and more attractive working environments

Together, these projects illustrate the **breadth of innovation currently shaping the sector**, from **automation of on-site activities to digital management systems and sustainable construction approaches.** Importantly, beyond their technical contributions, they collectively emphasise a **human-centric perspective**, recognising that the future of construction depends not only on technological advancement, but also on improving working conditions, enhancing skills, and making the sector more inclusive and attractive to a diverse workforce.

Building on this foundation, this white paper explores how these technological developments interact with gender-related barriers in the construction sector, with particular attention to the extent to which they can contribute to more inclusive forms of participation. Specifically, it addresses three key questions:

- **What types of barriers are most salient** in shaping women's participation in construction?
- **How emerging technologies are perceived** in relation to these barriers?
- **Under what conditions technological innovation can contribute** to more inclusive workforce participation?

2 Policy Background and Strategic Framework

2.1 A strategic moment for gender equality in construction

Over the past decade, the European Union has positioned **gender equality** not simply as a social objective but **as a structural condition for sustainable and inclusive economic development**. Principle 2 of the European Pillar of Social Rights affirms that equality of treatment and opportunities between women and men must be ensured across **labour market participation**, **working conditions** and **career progression** [1]. This commitment has been operationalised through the EU Gender Equality Strategy 2020–2025 and reinforced by the forthcoming Roadmap for Women's Rights, embedding gender mainstreaming and intersectionality across EU policy domains [2].

This policy framework coincides with a transformative moment for the construction sector. The EU's green and digital transitions, particularly through the Renovation Wave Strategy, require a rapid expansion of construction capacity across Member States [3]. Labour shortages in the sector have nearly tripled over the past decade, and the green transition alone is projected to generate between 1 and 2.5 million additional jobs by 2030 [4]. Yet women account for only 10% of the EU construction workforce and just 2% of workers in skilled manual occupations [5], [6]. Indeed, **the sector faces the dual challenge of meeting unprecedented demand while continuing to draw from a limited and gender-segregated labour pool**.

Within this context, emerging technologies are already reshaping construction practices through **automation, digitalisation** and **industrialised methods** [6]. The question is not whether transformation will occur, but whether it will **reinforce existing inequalities** or be leveraged as a strategic opportunity to **redesign participation**.

2.2 The architecture of exclusion: where gender inequality is produced

Women's underrepresentation in construction reflects interacting **structural, cultural and organisational dynamics** that reinforce one another across education, recruitment, working conditions and career progression.

Structural barriers begin early, as gender stereotypes shape educational choices and discourage women from pursuing STEM and construction-related pathways. Women are often perceived as less suited to fields associated with brilliance or technical intensity [7], while being socially directed toward caring-oriented roles [8]. This contributes to a "leaky pipeline" in which women disengage from technical trajectories despite comparable capability [9], [10]. And for those women who do actually enter the construction sector, it remains difficult to reconcile with caregiving responsibilities because of rigid schedules, long site hours, and limited flexibility [11]. Worksite design can intensify exclusion: equipment, PPE and even basic facilities are frequently calibrated around male norms, increasing discomfort and risk for women [12], [13], [14].

In addition, the material conditions at construction sites – such as the availability and adequacy of sanitary facilities, changing rooms and general cleanliness – remain an often overlooked but significant dimension of exclusion. The lack of appropriately designed and maintained spaces can disproportionally affect women's daily experience of work, reinforcing discomfort, limiting accessibility and contributing to perceptions of the sector as unwelcoming. These factors, while less visible than task-related constraints, play a critical role in shaping overall participation [15]. Economic inequalities reinforce these dynamics, with persistent pay and pension gaps continuing to shape long-term security and career incentives [16], [17], even as regulatory instruments such as the Pay Transparency Directive aim to strengthen accountability [18].

Cultural barriers further entrench exclusion by defining construction as a masculine domain associated with toughness and endurance. Women report experiences of isolation, harassment, discriminatory behaviours and pressure to overperform in male-dominated teams [11], [19], [20]. Underrepresentation itself becomes self-reinforcing, as the lack of role models shapes expectations and perceptions of belonging [21], [10]. **Organisational barriers** intersect with these structural and cultural dynamics through informal recruitment networks, opaque promotion pathways and uneven access to technical training and advancement opportunities [22], [23]. Research highlights that workplace safety, structured progression, diversity training, anti-discrimination policies and explicit top-management commitment are foundational attributes for improving gender inclusion [24].

Not all barriers are equally "tech-addressable," but several are tightly connected to how work is physically performed, how competence is demonstrated and how authority is allocated. These become the most strategic entry points for technology-enabled redesign.

2.3 The physical threshold, a strategic entry point for technology-enabled change?

Within the broader barrier architecture, physical strength norms operate as one of the main gatekeeping mechanisms that concentrates and reinforces multiple forms of exclusion. Construction occupations requiring frequent lifting, kneeling and repetitive overhead motion show a strong negative association with women's representation. Worker-level analyses confirm that being female or having strength and mobility impairments is associated with significant employment and wage penalties in construction compared to other sectors [25].

The significance of this mechanism is not that it excludes women from many production-oriented roles, but that it shapes the social and organisational definition of "who belongs" in construction environments. Physical thresholds influence recruitment norms, training expectations, safety cultures and informal hierarchies. In other words, strength is not simply a functional job requirement; it is also a social marker of legitimacy within a masculinised occupational identity.

This is also the point where emerging technologies can have unusually direct impact. **While many barriers require long-term institutional reform, the physical threshold is embedded in task design and work processes. This means it can, in principle, be modified through technologies that change how work is performed, supported, and valued**. At the same time, the literature on gender-biased technological change warns that such modification does not automatically lead to inclusion: the effects of automation vary by institutional context and can either widen or narrow gender gaps depending on how roles, skills and access are governed [26]. This makes the physical threshold a strategic entry point not only for innovation, but for policy-driven inclusion design.

At the same time, **it is important to recognise a potential limitation** in focusing primarily on the physical threshold as an entry point for technology-enabled change. While physical demands constitute a visible barrier, gender inequality in construction is produced and re-produced through the interaction of structural, organisational and cultural dynamics, many of which are not directly addressed through changes in task execution alone. This raises an important consideration for the role of emerging technologies. Technological innovations are particularly well suited to intervening in the structural and organisational dimensions of work, such as reducing physical strain, improving safety or reshaping workflows. However, their capacity to influence more deeply embedded cultural norms, perceptions and informal practices is inherently more indirect. As a result, there is a risk that technology-driven interventions may disproportionately target those dimensions that are more easily transformed, while leaving less visible but more persistent barriers relatively unaddressed. This does not diminish the strategic importance of the physical threshold. Rather, it suggests that **its transformation should be understood as one component within a broader, multi-dimensional approach to inclusion**. Without complementary efforts addressing cultural dynamics, the inclusive potential of technological change may remain partial.

2.4 Technology-enabled redesign: how emerging technologies can target key barriers

Emerging technologies should be understood **not as generic "solutions," but as mechanisms that can reshape specific elements of the barrier architecture** described above. Their inclusion potential depends on whether they modify task demands, reduce exposure to exclusionary environments, open credible pathways into high-value roles and redistribute opportunities that have historically been structured along gendered lines.

Wearable exoskeletons are particularly relevant because they directly intervene in the strength threshold that underpins occupational segregation. Biomechanical evidence shows that back-support exoskeletons reduce hip extensor muscle activity by 24% and neck strain by 50%, while knee-assistive devices reduce knee muscle activation by up to 39% and lower pressure during kneeling tasks [25]. These effects matter because they can lower the physical demands of tasks and reduce fatigue, thereby expanding the feasible pool of workers who can perform physically intensive roles safely and consistently. From a policy perspective, exoskeletons can be framed as tools for capability equalisation, occupational health improvement and retention, provided access is equitable and implementation is embedded within inclusive organisational practices [24].

Immersive training technologies such as VR and AR address a different but complementary set of barriers. Digital inclusion research shows that gender inequality persists not only in access to tools but in usage and outcomes, where differences in confidence, digital skills and organisational support translate into unequal career returns [27]. VR and AR can provide psychologically safer learning environments, allowing workers to build competence without exposure to harassment or informal judgement that can occur in male-dominated training settings. The policy value of immersive training lies in its capacity to reduce second- and third-level digital divides and create more equitable on-ramps into increasingly digital work practices [27].

Finally, digital coordination systems such as Building Information modelling (BIM) and digital twins are reshaping how authority and competence are defined. As construction becomes more data-driven, value creation shifts from manual execution toward coordination, modelling and oversight. This can weaken informal gatekeeping and increase the importance of demonstrable technical competence. However, digitalisation can also create new exclusion risks if training pathways are not equitably accessible and if emerging technical roles are disproportionately allocated to men based on stereotypes about competence [27]. When aligned with inclusion strategies, digital coordination can support more transparent performance criteria and enable hybrid or flexible work arrangements that directly address work-life incompatibility barriers emphasised in EU policy frameworks [2].

2.5 Technology as a conditional equaliser: why governance determines outcomes

Across these technological domains, the literature converges on a crucial insight: **technology is not inherently inclusive**. Its distributional effects depend on how adoption is **governed and** how **access, training and career progression** are **structured**. Evidence on robotisation shows that technological change can either increase or decrease women's representation depending on institutional context and labour market design [26]. The same logic applies in construction. Exoskeletons may reduce physical strain, but if access is uneven or controlled through informal hierarchies, the benefits will not translate into broader inclusion. Digital transformation may shift authority toward data skills, but without targeted digital upskilling, women may be excluded from precisely those roles where value and progression concentrate [27].

This is why **enabling conditions matter**. Gender-responsive procurement can prevent technologies from being designed around a male default and can support inclusive deployment from the outset. Pay transparency mechanisms remain essential to ensure that technological upgrading does not produce new forms of wage stratification, particularly as digital roles become higher value [18]. At organisational level, inclusion attributes such as top-management commitment, diversity training, safety protocols and formal anti-discrimination policies are necessary to translate innovation into equitable participation [24]. In practice, **technology can amplify the orientation of governance**: it can strengthen inclusion where inclusion is designed, and it can accelerate segmentation where it is not.

2.6 A structural window of opportunity: from workforce constraint to inclusion strategy

Construction now sits at the intersection of three forces: increasing labour demand driven by the green transition, rapid technological change and binding EU commitments to equality. This convergence creates a rare opportunity to move beyond incremental diversity initiatives and instead redesign participation structurally. Emerging technologies can lower physical thresholds through assistive robotics, reduce exclusionary entry dynamics through immersive training, and redistribute authority through data-driven coordination systems. They can also support worker retention by enabling more flexible models of work organisation, aligning with the broader EU objective of equal opportunity and sustainable participation [2].

Critically, **the opportunity is time sensitive**. Technologies are being integrated into construction at pace. Decisions taken now about design standards, procurement criteria, training pathways and organisational implementation will shape whether Construction 4.0 becomes a mechanism for inclusion or a new architecture of exclusion. If aligned strategically, emerging technologies can function not only as productivity tools but as **structural instruments for reshaping who enters the sector**, **how competence is recognised** and **how careers develop over time.**

3 Role of Technologies in Addressing Gender Barriers in the Construction Sector

This section presents the methodology and results of the analysis of **construction professionals' perceptions** of challenges and barriers to inclusion in the sector, alongside their views on emerging technologies. The results presented draw on questionnaire answers collected from professionals across the cluster projects. The survey gathered responses from **89 participants**, capturing their perceptions on how these technological innovations are understood in relation to women's participation and their potential to support a more gender-inclusive construction sector.

The **sample is predominantly composed of women**, who represent 75.3% of respondents, while men account for 24.7%. Respondents are geographically distributed across several European countries, with the largest shares working in Spain (32.6%), Italy (18.0%), France (11.2%), Greece (7.9%) and Switzerland (6.7%). The respondent profile is largely **concentrated in early and mid-career stages**, with the largest age group being 30 to 39 years old (42.7%). Professionally, the sample is mainly composed of respondents in operational roles (64.0%), referring to professionals working in private companies, non-governmental entities, architectural firms, construction companies, technology providers or similar organisations who contribute to the implementation and support of construction or renovation processes. The remaining share occupies strategic roles, referring to professionals working in institutions such as public authorities, universities or research organisations that shape policies, establish knowledge frameworks or influence sectoral standards. In terms of professional experience, **the sample includes both relatively recent entrants and experienced professionals**. The largest group has worked in the sector for 1 to 5 years (37.1%), followed by respondents with more than 15 years of experience (28.1%).

The questionnaire (Annex 1) combined closed-ended and open-ended questions in order to capture both quantitative assessments and qualitative insights. Participants were asked about the barriers they had personally experienced or observed in the construction sector, with particular attention to women's participation, as well as their views on the role of innovative technologies in addressing gender inclusion. Furthermore, the survey included specific questions on selected technologies developed or demonstrated within the Tech4EU Construction Cluster, enabling a comparative assessment of how different technological solutions are perceived in relation to inclusion.

To support a structured interpretation of the data, the authors adopted an analytical framework, comprising of three categories of barriers identified, namely, **cultural, organisational**, and **structural**, as they reflect different, yet interrelated, layers shaping women's participation in the construction sector (Box 1). This categorisation was developed ad hoc for this paper, building on established literature on gender inequalities in STEM and construction sectors, where similar distinctions are commonly used to differentiate between normative, institutional and systemic constraints [26], [21].

Box 1. Analytical framework and categories description

CULTURAL

Refer to deeply embedded **social norms**, **perceptions, and informal practices** that influence how women are viewed and treated within the sector. These include persistent gender stereotypes around STEM professions, perceptions of construction as physically demanding or unsuitable for women, and experiences of exclusion, discrimination, or harassment in workplace environments.

ORGANIZATIONAL

Relate to **formal and informal practices within companies and institutions** that directly affect women's access, progression, and working conditions. These encompass gender biases in recruitment and promotion, unequal pay, limited access to training opportunities, insufficient work-life balance policies, and inadequate safety measures on-site. Importantly, this category also captures responses related to **organisational transformation driven by technological change**, such as the need for new technical skills, shifts in productivity and efficiency, and the emergence of more inclusive, tech-driven workplace cultures

STRUCTURAL

Operate at a **broader systemic level, shaping the conditions under which individuals can enter and remain in the sector**. These include limited access to education and training pathways, lack of awareness about career opportunities, and the absence of mentorship or role models. In addition, this category incorporates responses pointing to **how technological advancements can transform the structural nature of work in construction**—such as reducing heavy manual labour, improving health and safety conditions, enabling better work-life balance through less physical strain, fostering more skill-based roles, and ultimately making the sector more accessible and attractive to a diverse workforce.

For the analysis, responses were coded into the three analytical dimensions: structural, organisational and cultural. Each survey item was assigned to the dimension it most reflected based on the categories' descriptions. For each respondent and for each section of the questionnaire, a domain-specific index was then calculated as the **mean of the items associated with that dimension**, based on the total of items assigned to the specific dimension, generating values between **0 and 1**. Higher values indicate a stronger presence of that type of barrier or perceived contribution in the responses. The indexes were used as **independent measures**, allowing comparison of the relative salience of each analytical dimension across the different technologies and in the overall workers' perception section. The figures presented, therefore, reflect average domain scores rather than percentages of a single total.

3.1 Overall perception of challenges and gender-related barriers within the construction sector

The analysis highlights a **clear divergence** between **how challenges in general are perceived** at the sector level and **how barriers to women's participation are specifically understood**. When considering challenges in general, respondents primarily point to **organisational factors (0.31),** followed by **structural (0.26)** and **cultural** dimensions (0.21) (**Errore. L'origine riferimento non è stata trovata.**). This indicates that challenges are largely experienced through day-to-day work organisation, coordination and management practices. Barriers at this level are mainly associated with **limited career progression**, **opaque promotion systems, biased task allocation** and **insufficient support for training and professional development.**

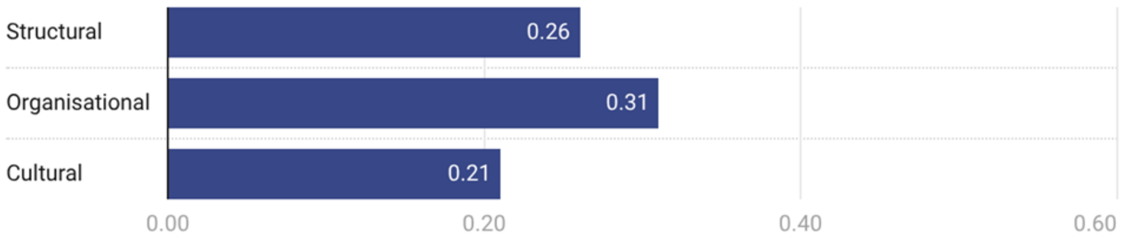

Figure 1. Perceived barriers in the sector, presented on a 0–1 index where values reflect the proportion of respondents selecting each category.

These constraints are further reinforced by rigid or inconsistently applied workplace policies and gaps in management practices, such as weak onboarding processes and limited mentorship opportunities. Structural constraints, while secondary, relate to education pathways, labour-market entry, and working conditions, including limited access to specialised training, weak education–employment linkages and low awareness of career opportunities. These are compounded by long working hours, wage disparities and workplace infrastructure designed around male norms, which collectively reinforce exclusion.

However, when focusing specifically on women's challenges to entry into the sector, the pattern shifts significantly. **Cultural barriers emerge as the most prominent (0.28),** followed by organisational barriers (0.23), while structural barriers are perceived as marginal (0.05) (**Errore. L'origine riferimento non è stata trovata.**)

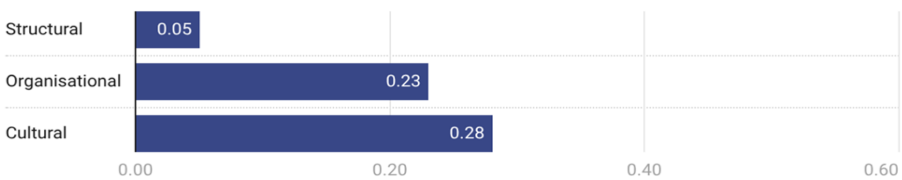

Figure 2. Perceived barriers to women's entry in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category.

This divergence is particularly prominent. It indicates that while the sector is generally understood and perceived as facing organisational and structural inefficiencies, **gender inequalities are perceived to be rooted primarily in cultural norms, perceptions, and implicit biases**, rather than in physical or structural constraints alone. These dynamics are reflected in women's accounts describing a persistent masculinised sector culture, gendered expectations around competence and leadership, and the need to continually demonstrate credibility in professional settings.

This has direct implications for how technologies are interpreted and experienced. Innovations that reduce physical effort or improve workflows may be recognised as beneficial, but their potential to foster gender inclusion depends on whether they are perceived as also addressing **deeply embedded cultural perceptions of construction work as a male-dominated domain** (Box 2).

Box 2. Perspectives from female respondents working in the sector

Respondent X, Spain (1-5 years of professional experience): *'Another issue is the lack of properly fitting safety gear.* ***Most of the protective clothing and equipment is designed for men's bodies****, and often there are only men's sizes available, which compromises both comfort and safety for women on site.'*
Respondent Y, Austria (6-10 years of professional experience): *'In several offices,* ***I was paid less than my male colleagues despite having the same or even a higher workload.*** *During my job search in my early thirties, I was directly asked about potential plans to have children.'*
Respondent Z Spain (1-5 years of professional experience): *'The work culture on construction sites is still very closed. I've heard things like,* ***"people will respect a man more,"*** *or* ***"we just understand each other better among men."*** *These comments clearly reflect the biases that still exist. Throughout these years, I've experienced sexist remarks and attitudes that clearly aim to undermine my work. They're not always direct, but they happen often enough to affect your motivation and make it harder to stay committed to the industry.'*

3.2 How Tech4EU technologies contribute to fostering inclusion in the construction sector

The projects within the **Tech4EU Construction Cluster** are developing and testing a range of innovative technologies aimed at transforming how construction work is performed, organised and experienced. Through real-life demonstrations and pilot activities, these initiatives explore not only the technical performance of solutions, but also their implications for working conditions, safety, and workforce participation.

The following section presents **selected technologies as case studies to examine their perceived contribution to gender inclusio**n. Rather than assessing technologies in isolation, the analysis focuses on how they interact with identified barriers, particularly in terms of reducing physical constraints, reshaping tasks and roles, and influencing sector perceptions. This approach provides a grounded understanding of where and how technological innovation can support a more inclusive construction sector, as well as the conditions under which this potential can be realised.

3.3 Use Case 1

The **Demolition Robot**, solution deployed within the **InCUBE** project, refers to the use of highly innovative BIM-connected robotic systems. The demolition robot automates the demolition process (e.g., facades) and attains a higher process speed, which enables savings of execution time and raw material requirements. The robot is compact, supports semi-automated navigation (human operator is required), and is fully equipped with warning sensors to minimize any unexpected damage to the surroundings (e.g., due to human error).

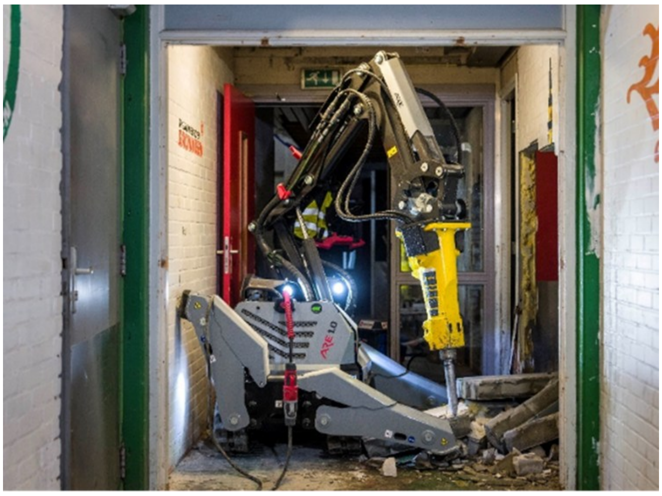

Figure 3. Demolition Robot, InCUBE Project

Demolition robots are perceived as having a **clear and tangible contribution to gender inclusion**, with 52.33% of respondents indicating a moderate contribution and 31.40% a strong one (**Errore. L'origine riferimento non è stata trovata.**). This reflects **their role in reducing physically demanding and hazardous tasks**, thereby lowering a key perceived barrier to participation. By shifting work toward technical skills, coordination and machine operation, these technologies may broaden access and create new roles in programming, supervision and maintenance, thereby enhancing sector attractiveness and entry pathways. However, their impact remains conditional on equitable access to training and digital skills.

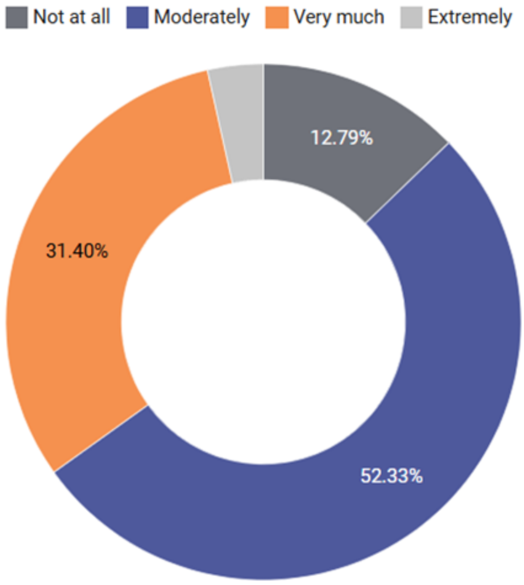

Figure 4. Percentage of respondents assessing the extent to which the Demolition Robot could support gender inclusion in the sector.

On the other hand, their perceived impact on the sector is **slightly more structural** (0.51) than **organisational** (0.47) (Figure 5), reflecting **their role in reducing exposure to hazardous and physically demanding tasks**. Structural emphasis stems from their direct effect on task execution, particularly by lowering physical constraints. However, their overall contribution is perceived as incremental and task-specific, as many construction activities remain labour-intensive.

Figure 5. Perceived impact of the Demolition Robot in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category.

These findings underscore the strategic importance of technologies that visibly reshape the physical nature of construction work. Demolition Robots not only **improve safety and reduce physical strain** but also act as **tangible signals of a broader shift** toward skill-based, technology-driven practices. In this sense, their contribution extends beyond task optimisation: by altering how construction work is performed and perceived, they have the potential to challenge entrenched cultural narratives that frame the sector as physically exclusive.

3.4 Use Case 2

The **Autonomous and Teleoperated Vehicle** developed within the **BEEYONDERS** project uses an advanced multi-sensor system to enhance situational awareness and navigation, particularly in hazardous environments. These machines generate and share real-time 3D maps of the environment as it changes. By integrating reinforcement learning, they improve task execution and decision-making, enabling coordination between multiple machines. Within this category, two distinct but complementary systems are developed, addressing different phases of the infrastructure lifecycle. On one hand, the autonomous wheel loader is designed for construction environments, supporting earthworks and material handling operations. It operates in complex, often unstructured sites, where tasks such as loading, transporting and dumping materials are performed with minimal human intervention. On the other hand, the autonomous maintenance robot is tailored for road infrastructure maintenance, focusing on inspection and intervention tasks such as defect detection, vegetation control and surface condition monitoring. This system operates in more structured environments, often in coordination with aerial platforms and digital twin systems, enabling continuous and data-driven maintenance workflows. Autonomous systems operate with minimal human intervention, ensuring efficiency and safety in complex operations.

Figure 6. Autonomous and Teleoperated Vehicles, BEEYONDERS project

The Autonomous and Teleoperated Vehicle is also **perceived positively**, with 48.84% of respondents indicating a moderate contribution to gender inclusivity and 33.72% a strong contribution, whilst only 12.79% express a negative perception (**Errore. L'origine riferimento non è stata trovata.**). Its potential lies in **reducing reliance on physically demanding and hazardous tasks**, particularly through remote operation, which limits exposure to high-risk environments. These technologies contribute to a shift toward technical and specialised roles, such as system operation, supervision and maintenance. However, respondents highlight that **their inclusive potential depends on equitable access to training and upskilling**, especially given existing gender imbalances in machinery and robotics-related fields.

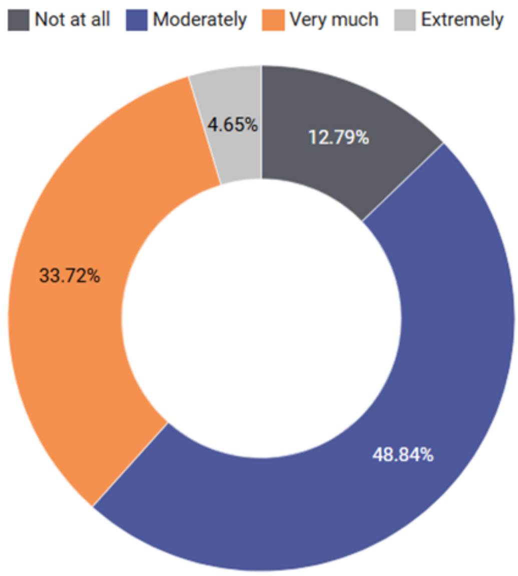

Figure 7. Percentage of respondents assessing the extent to which the Autonomous and Teleoperated Vehicle could support gender inclusion in the sector.

Their perceived impact is **slightly more organisational** (0.53) **than structural** (0.47) (**Errore. L'origine riferimento non è stata trovata.**), reflecting their dual role in **reshaping both how work is organised and how tasks are physically executed**. On the one hand, these technologies introduce new coordination models, remote operation practices and digitally mediated workflows, requiring adjustments in team structures, supervision and skill allocation. On the other, they contribute to reducing direct exposure to physically demanding and hazardous environments, thereby partially addressing structural constraints related to task execution. The marginal difference between the two dimensions suggests that their contribution is not confined to task adjustments but extends to **broader transformations** in how construction activities are planned, managed, and performed.

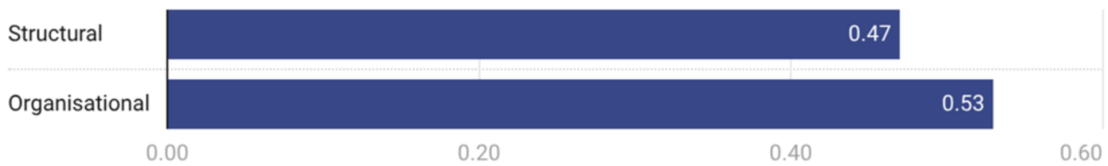

Figure 8. Perceived impact of the Autonomous and Teleoperated Vehicle in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category.

These technologies are understood as contributing to both **operational efficiency and task transformation**, particularly by reducing the need for direct physical interaction with machinery. In a context where cultural barriers are dominant, their significance lies less in the extent of physical substitution and more in their capacity to redefine the nature of construction work itself. By enabling remote, digitally mediated and precision-based operations, **they help reposition the sector** away from traditional, physically intensive models toward more technology-oriented roles. This shift has the potential to challenge entrenched perceptions of construction as a male-dominated domain and to broaden its appeal to a more diverse workforce, including women.

3.5 Use Case 3

The **Personal Protective Equipment (PPE) Monitoring System** developed by the **InCUBE** project monitors the correct use of PPE devices by workers. It is based on android apps installed on smartphones, enabling verification of proper use of PPE (helmet, harness, shoes, and other safety gear) through continuous monitoring of Bluetooth Low Energy (BLE) tags installed on the PPE. It also monitors 'man down' and dynamic shock detection, as well as indoor and outdoor geo-localisation of workers. If a worker is missing PPE, the system sends immediate alert notifications to workers and supervisors, reducing the risk of accidents. Apart from increased safety, cost savings is another benefit since fewer workplace injuries mean lower insurance costs and reduced downtime.

Figure 9. PPE monitoring system, InCUBE project

The PPE Monitoring System is perceived as having **limited relevance for gender inclusion**. Responses are evenly split between moderate (46.51%) and not at all (47.67%) (**Errore. L'origine riferimento non è stata trovata.**), with very few respondents identifying a very strong contribution. Although widely recognised for enhancing safety, risk management and compliance, **their contribution to inclusion is considered indirect and secondary**. Findings highlight that improved safety conditions may contribute to a positive perception of the sector. However, a key limitation is that these systems do not reduce the physically demanding nature of construction work, which remains a salient perceived barrier to entry. Moreover, PPE monitoring may be perceived as surveillance or control, which could negatively affect worker acceptance without contributing to inclusivity.

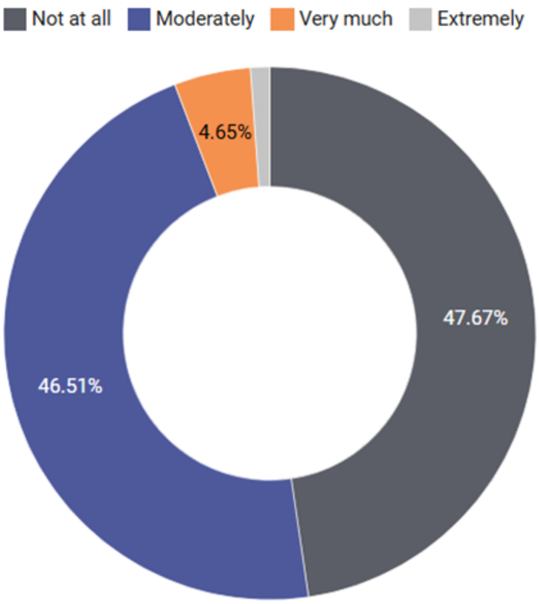

Figure 10. Percentage of respondents assessing the extent to which the PPE Monitoring System could support gender inclusion in the sector.

Similarly, its **perceived impact is rated low** across both **organisational** (0.15) **and structural** (0.22) dimensions**,** reflecting that PPE monitoring improves safety and compliance without substantially altering work organisation or reducing physical task demands. It therefore has limited influence on the key drivers of gender inequality.

Figure 11. Perceived impact of the PPE Monitoring System in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

These findings suggest that while safety is a fundamental requirement, **incremental improvements in monitoring and compliance do not significantly influence perceptions of accessibility or attractiveness**. In a context where cultural barriers prevail, PPE MONITORING SYSTEMS are not seen as addressing the underlying dynamics that shape women's participation.

3.6 Use Case 4

The **Unmanned Aerial Vehicle (UAV) Based Aerial Photogrammetry** technology developed within the **BEEYONDERS** and **InCUBE** projects enables the collection of accurate, georeferenced geometric data across a wide range of construction environments and assets. When combined with complementary techniques such as 3D laser scanning, it allows for the generation of detailed point clouds supporting comprehensive analysis of existing conditions, structural features and potential defects. The use of high-resolution UAV surveys facilitates data acquisition in high-risk or hard-to-reach locations, including elevated, confined, or hazardous areas across different types of construction sites and infrastructures. By integrating these datasets into BIM-based modelling environments, the technology enhances coordination, communication and workflow efficiency across planning, design and execution phases. The deployment of this technology relies primarily on trained UAV operators and BIM specialists, reflecting the growing importance of digitally enabled roles within the sector.

Figure 12. UAV based aerial photogrammetry, BEEYONDERS project

UAV-based technologies are perceived as offering **moderate but uneven potential** to support gender inclusion. While 39.53% of respondents identify a moderate contribution and 34.89% a strong or very strong contribution, a notable 25.58% perceive no contribution (**Errore. L'origine riferimento non è stata trovata.**). This reflects a dual perception of their impact. On one hand, UAVs reduce exposure to certain hazardous or hard-to-access environments through remote inspections, **lowering specific operational barriers and expanding accessibility**. On the other hand, their contribution is seen as limited because **surveying and inspection tasks are not considered the most physically demanding** aspects of construction. As a result, the reduction in physical effort is viewed as partial, and the technologies are often perceived as gender-neutral tools that do not directly address deeper barriers for women's entry.

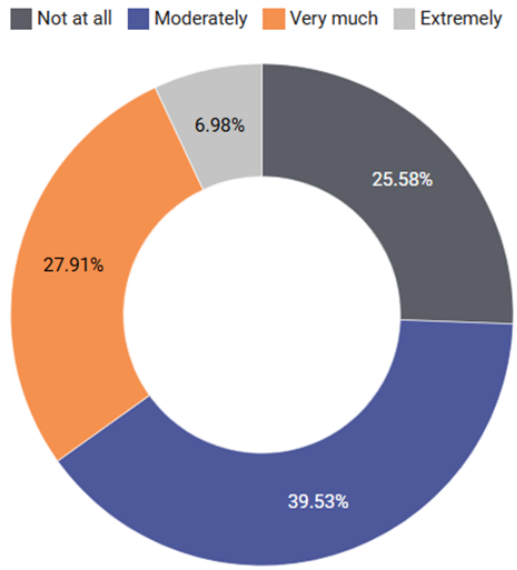

Figure 13. Percentage of respondents assessing the extent to which the UAVs support gender inclusion in the sector.

Their perceived impact is primarily associated with **organisational improvements** (0.60), compared to a lower structural impact (0.41) (Figure 14). This highlights their role in **improving workflows, coordination and data-driven processes** rather than fundamentally transforming task structures. UAV-based technologies may facilitate new technical and digital roles such as drone operation and data analysis, contributing to a gradual redefinition of work. However, their broader inclusive potential **remains contingent** on access to training, certification pathways and the visibility of these roles, without which existing inequalities may persist within these emerging domains.

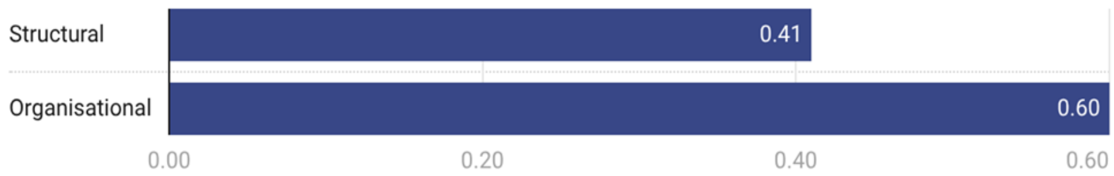

Figure 14. Perceived impact of the UAVs in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

This indicates that UAVs are mainly associated with **enhancing coordination, monitoring and data-driven processes**, potentially enabling less physically intensive or remote roles. However, their contribution to inclusion remains **less clearly perceived**, as these changes do not directly address cultural perceptions of construction work or visibly redefine who can participate.

3.7 Use Case 5

The **Smart Wearables** technologies developed within the **BEEYONDERS** project use wearable sensors and inertial measurement units (IMUs) to analyse workers' physical actions, assessing muscular strain and potentially hazardous movements to enhance well-being. An example of a smart wearable is the indoor positioning system. It is designed to enhance worker safety by providing real-time location tracking of workers within buildings, especially in emergency situations. In outdoor scenarios such as road construction, the system includes a smart wearable device equipped with a high-precision real-time kinematic (RTK) receiver that enables continuous monitoring of workers' proximity to autonomous vehicles, with a buzzer alerting the worker if they get too close.

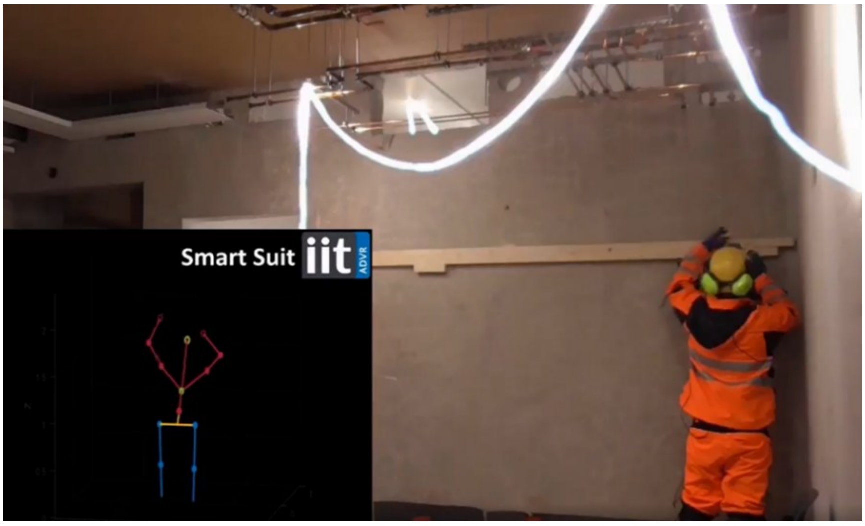

Figure 15. Smart wearables, BEEYONDERS project.

Smart Wearables are characterised by **moderate expectations and relatively high scepticism**. While 55.81% of respondents identify a moderate contribution to gender inclusivity, 30.23% perceive no contribution, and only a small share report strong positive effects (**Errore. L'origine riferimento non è stata trovata.**). Their primary contribution lies in **improving occupational health and safety** by monitoring physical strain, detecting unsafe movements and preventing injuries. However, respondents consistently note that these functions do not directly **influence women's participation**, as they do not reduce physical demands or alter job roles. Any positive effect is therefore considered indirect, mainly through improved working conditions or a slightly enhanced perception of safety, which is insufficient to drive meaningful change in gender diversity.

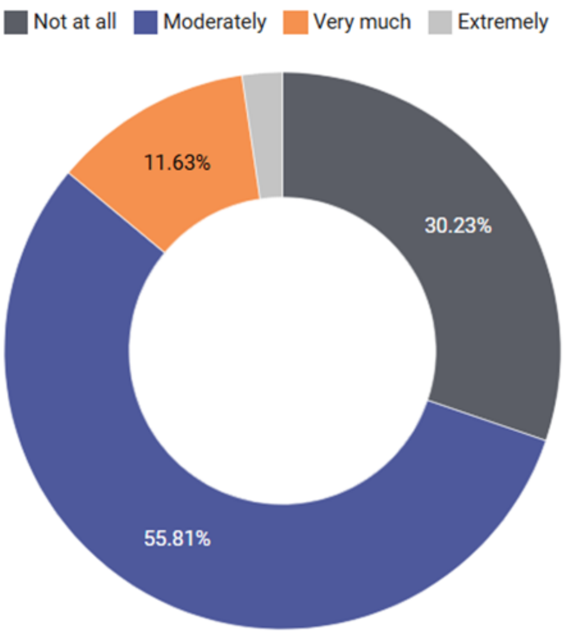

Figure 16. Percentage of respondents assessing the extent to which Smart Wearables support gender inclusion in the sector.

Their perceived impact is slightly more **structural** (0.43) **than organisational** (0.35) (**Errore. L'origine riferimento non è stata trovata.**). This reflects their role in **monitoring and assessing physical workload** rather than transforming workflows or organisational practices. Smart Wearables generate data on fatigue and task demands, which **could support more ergonomic and personalised work allocation**, particularly in contexts where standards are based on male physical norms. However, their effectiveness depends on how this data is used in practice. Concerns related to governance, including worker resistance to monitoring, lack of trust and potential misuse of data for performance control, further limit their impact.

Figure 17. Perceived impact of Smart Wearables in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

These technologies are associated with improvements in **safety and working conditions**, particularly through monitoring physical strain and enhancing situational awareness. However, in light of the broader finding that cultural barriers are the primary constraint to women's participation, these results suggest that **improving physical conditions alone is insufficient to drive inclusion**, unless accompanied by changes in roles, career pathways and sector perception.

3.8 Use Case 6

The **Exoskeletons** technology developed within the **BEEYONDERS** and **HUMANTECH** projects was designed to support a wide range of duties and work activities by assisting the lower back and arms through a coordinated system that dynamically detects worker movements. It integrates smart cognitive control, bioinspired sensor fusion and machine learning to enhance performance. The design includes a mechanical structure, wearable sensors and a mechatronic system, supported by a multi-layer control algorithm for stable and adaptive assistance. It provides targeted support for tasks such as walking, lifting, carrying, pulling and pushing. The exoskeleton intuitively responds to the user's movements, inferred through a distributed network of inertial sensors (BSN), enabling seamless and adaptive assistance without manual adjustments. This reduces fatigue, enhances safety and improves task efficiency. The synergy between wearable robotics and motion prediction technologies exemplifies a new paradigm in construction, where human well-being and productivity are jointly optimised. Key actors include robotics engineers, ergonomics specialists and construction site managers.

Figure 18. Exoskeleton, BEEYONDERS and HUMANTECH projects

Exoskeletons are among the technologies most strongly associated with **supporting a more gender-friendly sector**. Most respondents perceive a moderate (46.51%), strong (33.72%), or very strong (8.14%) contribution, with limited scepticism (11.63%) (**Errore. L'origine riferimento non è stata trovata.**). Strong positive perception reflects their direct role in **reducing physical effort** and **supporting demanding tasks**, such as lifting, repetitive movements and posture. By mitigating fatigue and improving long-term physical health, Exoskeletons are seen as addressing one of the **most visible barriers to women's participation**. They are also perceived as enabling **access to manual and on-site roles** traditionally considered less accessible, while simultaneously improving overall working conditions and safety through better ergonomics and reduced risk of injury.

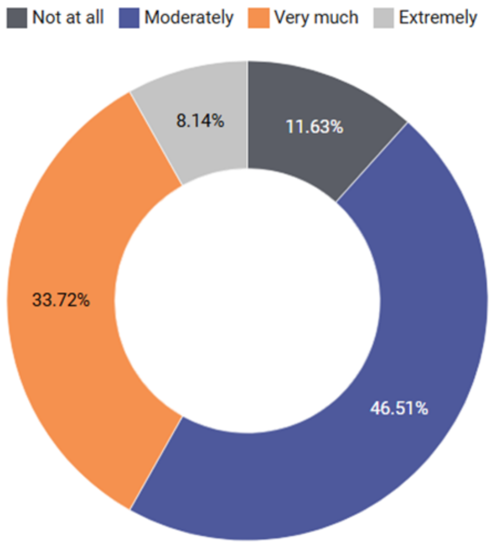

Figure 19. Percentage of respondents assessing the extent to which Exoskeletons support gender inclusion in the sector.

On the other hand, their perceived impact is balanced between **structural** (0.50) and **organisational** (0.40) (**Errore. L'origine riferimento non è stata trovata.**). This reflects their dual effect on both **task execution and work conditions**. Structurally, they reduce reliance on physical strength and expand access to operational roles, while organisationally they contribute to safer and more efficient work practices. However, their overall impact **remains conditional**. Respondents emphasise that cultural and organisational barriers such as **stereotypes and lack of acceptance**, persist beyond physical constraints. In addition, practical limitations related to usability, cost and adaptation to different body types, especially for women, may restrict adoption, while poorly framed implementation could risk reinforcing gender distinctions rather than reducing them.

Figure 20. Perceived impact of Exoskeletons in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

Exoskeletons contribute to weakening the centrality of physical strength as a defining feature of construction work, thereby opening up roles that have traditionally been perceived as less accessible. Their significance lies not only in **enabling task performance**, but also in **signalling a broader shift toward** more adaptable and inclusive work practices. Their impact, however, depends on their uptake and integration within existing organisational and cultural contexts.

3.9 Use Case 7

The **3D Printer** technology developed within the **BEEYONDERS** and **RoBétArmé** projects leverages IoT and AI technologies to optimise material mixing and ensure structural integrity throughout the printing process. This advanced approach to 3D printing allows for the replacement of some of the most labour-intensive and hazardous construction tasks. These technologies support additive manufacturing with both metal and concrete, applicable to both construction and repair scenarios. One example is the integration of direct energy deposition (DED) metal 3D printing technology into a mobile inspection and reconnaissance (MIR) manipulator. This system enables in situ reinforcement of rebar prior to the application of shotcrete. Combined with a perception system capable of detecting areas where the metal mesh requires reinforcement, the metallic framework is built layer by layer during the preparatory phase. This method results in a robust steel skeleton within the concrete structure, eliminating the need for manual on-site welding. Another notable application is 3D concrete printing (3DCP), which is used to fabricate artificial reefs and enhance the design of caissons, offering environmental benefits by supporting marine life.

Figure 21. 3D printer, BEEYONDERS and RoBétArmé projects

3D printing is perceived as having **strong potential to support a more gender-inclusive sector**. A large majority of respondents rate its contribution as moderate (47.67%) or high (30.23% "very much" and 8.14% "extremely"), with only 13.95% expressing a sceptical view (**Errore. L'origine riferimento non è stata trovata.**). This perception reflects its ability to **automate selected construction processes and reduce physically demanding and hazardous tasks,** thereby improving safety and lowering physical barriers in specific phases. More importantly, respondents associate 3D printing with **a shift toward technical, digital and design-oriented roles**, such as system operation and modelling, which are skill-based and less dependent on physical strength. It is also seen as contributing to a more **innovative and technologically advanced sector image**, potentially attracting younger and more diverse talent, including women.

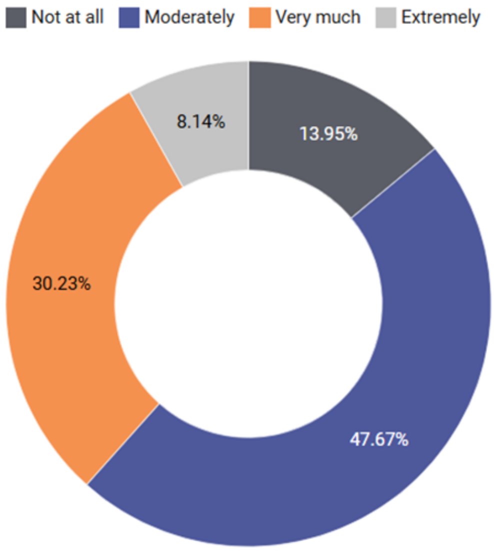

Figure 22. Percentage of respondents assessing the extent to which 3D Printers support gender inclusion in the sector.

Its perceived impact is seen as **balanced between organisational** (0.58) **and structural dimensions** (0.49) (Figure 23), reflecting its dual role in improving processes and transforming how work is performed. It highlights improvements in workflows and efficiency, and changes in task execution through automation and digitalisation. However, respondents also highlight that the impact of 3D printing depends on factors such as scale of adoption, access to specialised training and economic feasibility, with current applications often limited to specific project contexts rather than the sector as a whole.

Figure 23. Perceived impact of 3D Printers in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

These results suggest that 3D printing is understood as both a **process innovation and a transformation of task execution**, reducing manual intensity while introducing more technology-oriented roles. In a context where cultural barriers dominate, its contribution lies in its ability to **reframe construction as a more accessible and innovation-driven sector**, thereby supporting greater participation of women.

3.10 Use Case 8

The **Digital Twin (DT)** technologies developed in the **BEEYONDERS, INCUBE** and **RoBétArmé** projects are a shared digital platform designed to support decision-making in construction by enabling dynamic monitoring and optimisation of activities, ultimately improving both efficiency and sustainability. The DT integrates BIM models and planning data with real-time inputs from construction site elements, including workers, machines, robots and drones, via sensors. This data is incorporated into an interactive platform that provides visualisation, simulation and monitoring of construction processes. The system incorporates several tools, including a 4D planning component, an Internet of Things (IoT) module for historical and real-time structural health monitoring, a robot simulation tool for site planning, and a shotcrete simulation module. These inputs generate KPIs, environmental impact assessments, and status modelling. The platform supports more agile, responsive construction management by capturing near-real-time data and adapting to changing site conditions. Additionally, its real-time diagnostics and visualisation capabilities enhance project transparency and facilitate more informed decision-making throughout the construction lifecycle.

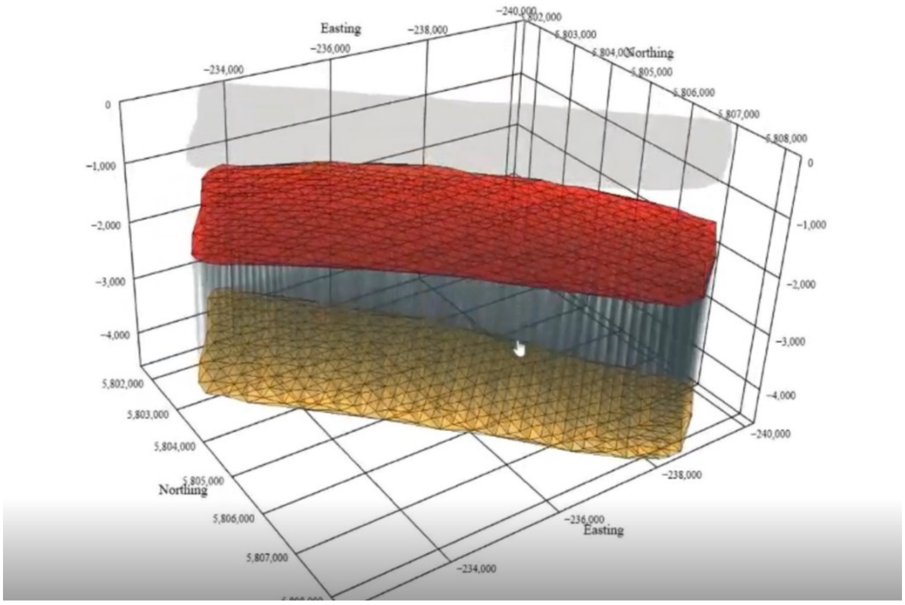

Figure 24. DT technology, BEEYONDERS, InCUBE and RoBétArmé projects

DT technologies present **a more ambivalent perception in relation to gender inclusivity**. While 46.51% of respondents consider their contribution moderate, responses are evenly split between positive (24.42%) and no contribution (24.42%), with only 4.65% indicating a very strong contribution (**Errore. L'origine riferimento non è stata trovata.**5). As desk-based, knowledge-intensive technologies focused on data analysis, modelling and decision-making, they are perceived as gender-neutral and accessible across profiles, particularly within engineering, design and planning domains. They also contribute to the creation of specialised digital roles, such as BIM specialists and data analysts, which may attract more diverse talent and reinforce inclusion in certain segments of the sector. However, their limited visibility in transforming core construction activities constrains their perceived impact.

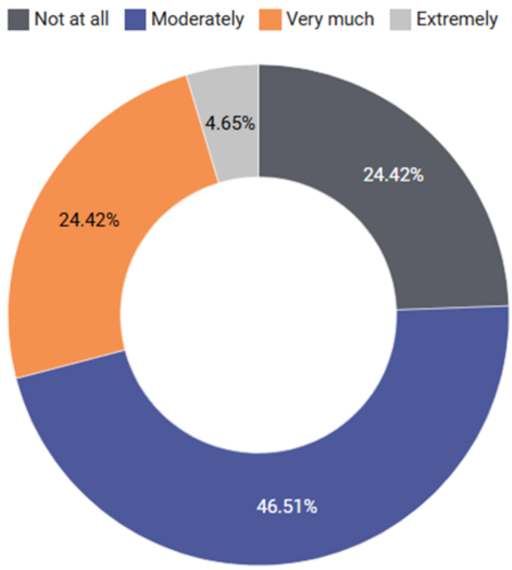

Figure 25. Percentage of respondents assessing the extent to which DT technologies support gender inclusion in the sector.

On the other hand, their perceived impact is strongly perceived as **organisational** (0.54), with limited structural relevance (0.29) (**Errore. L'origine riferimento non è stata trovata.**6). This highlights their primary role in **improving coordination, planning** and **decision-making processes** rather than altering task execution or reducing physical labour. **DT** technologies **do not significantly change** on-site work conditions, and their inclusive potential **depends on access** to advanced STEM skills, training pathways and awareness of related career opportunities. Without these enabling conditions, **there is a risk that they may reproduce** existing gender disparities within higher-value, knowledge-intensive roles rather than broaden overall participation.

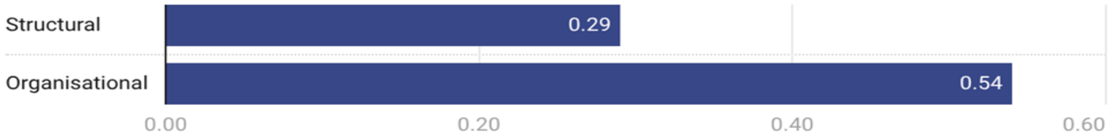

Figure 26. Perceived impact of DT in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

This indicates that digital twins are perceived primarily as **planning and decision-support tools**, with an indirect link to workforce participation. Their contribution to inclusion depends on whether they are connected to **clear and accessible career pathways**, particularly in digital and coordination roles, which are not yet strongly associated with gender inclusion by respondents.

3.11 Use Case 9

The **Human Robot Collaboration (HRC)-based Teleoperated Mastic Application System** developed in the **HUMANTECH** and **RoBétArmé** combines collaborative robotics and haptic feedback to enhance precision and safety in construction tasks. Using a UR10e robotic arm integrated with a high-force haptic interface (Haption Virtuose 6D), operators can remotely control the application of mastic in complex or hazardous environments.

The system includes a foot switch for secure activation and a modified commercial mastic gun, adapted for robotic use via a pneumatic trigger mechanism. This setup allows for intuitive and responsive control, enabling accurate filling of dilatation joints while minimising physical strain and risk to workers. The teleoperation approach is particularly valuable in confined or sensitive areas where manual access is limited. Engineers, robotics specialists and site safety coordinators are key actors in deploying and operating this technology. Another potential scenario is the adoption of a multimodal HRC enabling high quality construction. This includes control algorithms for physical-HRC and human-machine interfaces (HMI) including augmented reality (AR) systems for true collaboration and methods for robot navigation. For the scenario of shotcreting, HMI fosters the versatile interaction of operators with the mobile manipulators, consisting of an (i) inspection-reconnaissance mobile manipulator (IRR) to address fast, high precision modelling and rebar reinforcement through metal additive manufacturing in the preparatory phase and (ii) a shotcrete and finishing mobile manipulator (SFR) to address autonomous shotcrete application and surface finishing during the construction and finishing phase, respectively. These tools will ease the hard job of shotcreting mostly performed by nozzlemen allowing women to enter the construction domain of shotcrete through the exploitation of more user-friendly technologies.

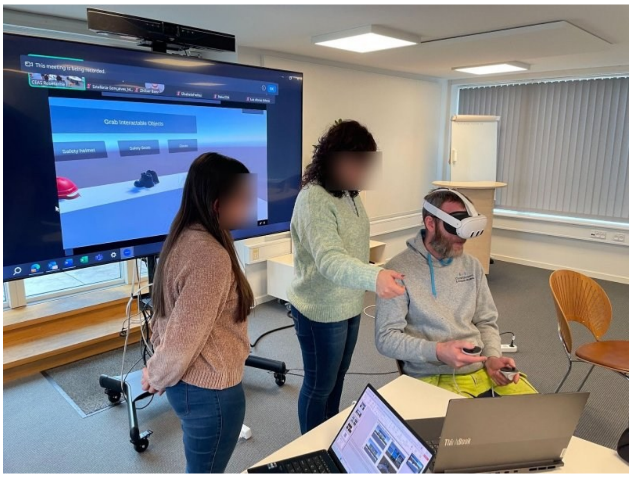

Figure 27. HRC-based teleoperated mastic application system, HUMANTECH and RoBétArmé projects

The HRC-based Teleoperated Mastic Application System is perceived as **moderately supportive of gender inclusion**, with responses concentrated around "moderate" (46.51%) and "very much" (32.56%), and a smaller share indicating either very strong (8.14%) or no contribution (12.79%) (**Errore. L'origine riferimento non è stata trovata.**8). Findings highlight its capacity to reduce physically demanding tasks by shifting work toward supervision, control and interaction with digital systems. Through the integration of AR, VR, and AI-supported tools, HRC reorients construction work toward technical and cognitive competencies that are less dependent on physical strength and more accessible across genders. Such technologies can create more equal task conditions and expand participation, including for individuals with physical limitations. However, this potential remains contingent on equitable access to digital skills and training.

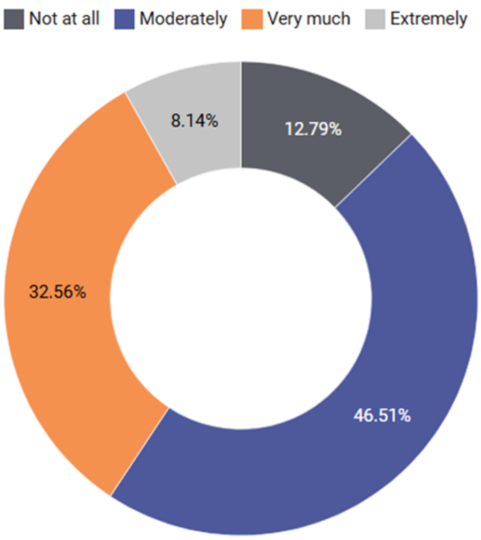

Figure 28. Percentage of respondents assessing the extent to which the HRC-based

Teleoperated Mastic Application System supports gender inclusion in the sector

Its perceived impact is **evenly distributed between organisational** (0.48) and **structural** (0.46) dimensions (**Errore. L'origine riferimento non è stata trovata.**29), suggesting that it enhances both **workflows** and **task execution** without fundamentally transforming either. HRC-based Teleoperated Mastic Application System enhances **efficiency, safety and coordination**, while also **reducing physical strain** through automation. At the same time, **its impact remains incremental**, as it does not fundamentally alter the broader structure of construction work. Persistent stereotypes, sector norms and workplace dynamics continue to shape participation, indicating that the contribution of HRC-based Teleoperated Mastic Application System to gender inclusion depends on complementary changes in training systems, organisational practices and sector culture.

Figure 29. Perceived impact of HRC-BASED TELEOPERATED MASTIC APPLICATION SYSTEM in the construction industry, presented on a 0–1 index where values reflect the proportion of respondents selecting each category

These results suggest that the HRC-based Teleoperated Mastic Application System is understood as an **incremental innovation**, improving task execution and supporting workers without fundamentally transforming the structure of work. While it contributes to reducing strain and improving accessibility, its potential to address gender barriers remains **conditional on implementation**, particularly in relation to inclusive role design and access to training.

4 Shaping an Inclusive Future for Construction: Conclusions and Recommendations

Construction 4.0 presents a pivotal inflection point. Empirical evidence demonstrates measurable biomechanical benefits from assistive robotics [24]. At the same time, inclusion research clarifies the organisational and governance conditions required to translate innovation into equitable participation [23]. However, digital inclusion scholarship warns that unequal adoption can reproduce stratification in new forms [26]. This is further reinforced by macro-level evidence showing that automation's gender impact is shaped by institutional design rather than technology alone [25]. Emerging technologies therefore hold transformative potential, but this potential is conditional. When embedded within deliberate, gender-responsive strategies, they can serve not only as productivity tools, but also as structural enablers of equality in one of Europe's most gender-segregated sectors.

4.1 Cross-cutting insights

The analysis of technology-specific findings reveals a set of cross-cutting patterns that clarify how emerging innovations are perceived in relation to gender inclusion in the construction sector. When read in conjunction with the broader results on sectoral challenges, these patterns highlight a consistent misalignment between **where barriers are perceived to originate** and **where technologies are seen to have the strongest impact**.

A *first overarching theme* concerns the **predominance of physical and task-related transformation as the primary channel through which technologies are understood to support inclusion**. Across multiple solutions (including demolition robots, exoskeletons, autonomous and teleoperated vehicles, and 3D printing) respondents consistently associate positive contributions with the reduction of physical strain, exposure to hazardous environments, and the reallocation of work toward more technical and skill-based roles. These technologies are therefore perceived as most impactful where they directly modify how tasks are executed, lowering entry thresholds linked to physical strength and improving working conditions. This explains the relatively strong structural scores observed across several technologies, even in cases where their adoption remains partial or context specific.

At the same time, *a second key pattern* emerges: **technologies that primarily enhance coordination, monitoring or data-driven decision-making are perceived as having a more indirect and less visible contribution to inclusion**. Solutions such as digital twins, UAV-based systems and PPE monitoring tools are predominantly associated with organisational improvements, enhancing workflows, safety management and planning efficiency, rather than with fundamental changes in task accessibility. While these technologies support the broader digital transformation of the sector and create new professional roles, their contribution to gender inclusion is often perceived as contingent, mediated through access to training, and less directly connected to the barriers identified by respondents.

These patterns must be interpreted in light of the overall perception of challenges, which show that **cultural barriers are perceived as the primary constraint to women's entry into the sector**, while structural barriers are considered comparatively limited. This creates a structural tension: **the technologies most positively perceived are those that address physical and operational aspects of work, whereas the most salient barriers are understood to be cultural in nature**. As a result, even when technologies are recognised as improving safety, reducing physical demands or increasing efficiency, their contribution to gender inclusion is not always considered sufficient to shift underlying perceptions of construction as a male-dominated domain.

A third emerging theme relates to the **increasing centrality of skills, digital capabilities and access to training as enabling conditions for inclusion**. Across all the technologies analysed, respondents repeatedly emphasise that their inclusive potential depends on equitable access to upskilling pathways, particularly in areas such as robotics, digital modelling, remote operation and data analysis. Technologies that enable new roles, rather than simply modifying existing ones, are seen as offering greater long-term potential to diversify participation. However, without targeted measures to ensure accessibility and uptake, there is a recognised risk that these roles may reproduce existing gender imbalances within higher-value, technology-intensive segments of the sector.

A fourth pattern concerns the **importance of visibility and signalling effects**. Technologies that visibly alter the nature of construction work, by reducing manual intensity, enabling remote operation or introducing advanced automation, are more likely to be associated with gender inclusion. Their impact extends beyond functional improvements, contributing to a redefinition of the sector's image and potentially influencing perceptions of accessibility among prospective entrants. In contrast, technologies whose effects are less visible at the level of task execution or worker experience tend to be perceived as gender-neutral, even when they contribute to efficiency or safety improvements.

Finally, the analysis highlights that **technological impact is consistently understood as conditional rather than transformative in isolation**. Across all cases, respondents indicate that the contribution of technologies to gender inclusion depends on how they are implemented, governed and embedded within existing organisational and cultural contexts. Issues such as unequal access to training, resistance to change, usability constraints and persistent gender norms are identified as limiting factors that can attenuate or even counteract the inclusive potential of innovation.

To synthesise these dynamics, the heat map below (Table 1) compares how each technology is perceived to contribute across cultural, organisational, and structural dimensions. Rather than showing a uniform pattern, the results reveal clearly differentiated impact profiles across technologies, both in terms of **where** their contribution is concentrated and **how strongly** it is perceived. A first group of technologies is predominantly associated with **organisational transformations**, particularly those enhancing coordination, monitoring and data-driven workflows. This is most evident in **UAV-based systems** (organisational: 0.60 vs structural: 0.41) and **digital twins** (0.54 vs 0.29), where the primary contribution lies in improving planning, communication and decision-making processes. **3D printing** (0.58 vs 0.49) also reflects a strong organisational component, while simultaneously contributing to process optimisation and partial task transformation.

	Structural	Organisational
UAV-based Systems	0.41	0.60
Autonomous & teleoperated ground vehicles	0.47	0.53
Smart wearables	0.43	0.35
Exoskeleton	0.50	0.40
3D printer	0.49	0.58
Digital twin	0.29	0.54
Demolition robot	0.51	0.47
PPE monitoring system	0.22	0.15
HRC	0.46	0.48

0.00 0.50 1.00

Table 1. Heatmap of perceived contributions of emerging construction technologies to gender inclusion across structural, organisational, and cultural dimensions (0–1 index). Values represent average domain scores derived from respondent assessments; higher values indicate stronger perceived contributions

In contrast, other technologies show a stronger or more direct **structural orientation**, particularly those intervening in task execution and physical demands. **Demolition**

robots (structural: 0.51 vs organisational: 0.47) and **exoskeletons** (0.50 vs 0.40) are more closely associated with reducing physical strain, improving safety and expanding access to operational roles. **Smart wearables** (0.43 vs 0.35) follow a similar pattern, though with a more moderate overall contribution, reflecting their role in monitoring rather than fundamentally transforming task conditions. A third group, including **autonomous and teleoperated systems** (0.53 vs 0.47) and **HRC-based solutions** (0.48 vs 0.46), reflects a more **balanced but incremental contribution**, simultaneously reshaping both task execution and organisational processes without strongly dominating either dimension. At the lower end of the spectrum, **PPE monitoring systems** (organisational: 0.15; structural: 0.22) stand out for their **limited perceived impact across both dimensions**, indicating that improvements in safety compliance and monitoring, while important, are not seen as substantially altering either work organisation or the underlying conditions that shape access and participation.

This differentiation is critical, as it shows that **technologies do not contribute to inclusion evenly,** but rather through distinct mechanisms and with varying intensity—ranging from transformative shifts in task execution to more incremental improvements in workflows and safety. However, the heatmap also shows a structural limitation: none of the technologies display a measurable contribution to cultural change, despite cultural barriers being identified as the most significant constraint to women's participation (0.28). This contrast reinforces a central finding of this paper:

While emerging technologies are widely recognised as enablers of improved working conditions, enhanced safety and evolving skill demands, their impact remains largely confined to the operational and physical dimensions of work. As a result, their capacity to address the deeper, culturally embedded foundations of gender inequality is limited unless accompanied by broader organisational transformation and systemic efforts to reshape sector norms, perceptions and workplace cultures.

4.2 Recommendations

Addressing gender inequalities in the construction sector, therefore, requires **coordinated action across policy, industry and innovation ecosystems**, reflecting the multi-dimensional nature of barriers identified in this analysis. While emerging technologies **contribute to improving working conditions and reshaping tasks,** their inclusive potential depends on how they are **designed, implemented, and governed**. The following recommendations outline targeted actions for key actors:

POLICY MAKERS AND PUBLIC AUTHORITIES

ENSURE EQUITABLE ACCESS TO TRAINING AND DIGITAL UPSKILLING PATHWAYS

As the transition toward technology-driven roles intensifies, targeted training programmes should be developed to support women's participation in areas such as robotics, digital tools and advanced construction technologies. This should be complemented by the integration of gender-sensitive outreach within vocational education and STEM pathways, alongside efforts to improve the affordability and accessibility of certification and training schemes. Such measures are essential to prevent the reproduction of existing gender disparities within higher-value, technology-intensive roles and to ensure that technological transformation contributes to, rather than constrains, workforce diversification.

In addition, public policies should support the alignment of training systems with emerging technology-enabled roles (e.g. remote operation, data-driven coordination), ensuring that skills development pathways correspond to evolving labour market demands.

ADDRESS SECTOR IMAGE AND EARLY PIPELINE BARRIERS

Findings suggest that the perception of construction as a male-dominated field persists despite technological advancements. Efforts should combine technological innovation with targeted outreach at school and early career stages, increasing awareness of diverse career pathways and promoting more inclusive narratives that challenge traditional representations of the sector. This should be reinforced through national and EU-level communication strategies, as well as partnerships with educational institutions, to ensure that the transformation of construction work is reflected in how the sector is presented to future entrants.

ALIGN TECHNOLOGY DEPLOYMENT WITH INCLUSIVE STANDARDS

Qualitative findings highlight that infrastructure, equipment and working conditions often reflect male norms. Addressing this requires action at the system level. Policy makers should ensure that inclusive design becomes a requirement rather than an option, by embedding gender-responsiveness into procurement frameworks, standardisation processes and funding criteria. This includes setting clear expectations that publicly funded or regulated technologies must be suitable for diverse body types and user profiles. By defining minimum inclusion standards and incentivising compliance from early stages of innovation, policy frameworks can steer the market towards more equitable technological solutions.

CONSTRUCTION COMPANIES AND INDUSTRY ACTORS

EMBED INCLUSIVE ORGANISATIONAL PRACTICES ALONGSIDE TECHNOLOGICAL ADOPTION

Given that cultural barriers are perceived as the primary constraint to women's participation, companies should complement technological adoption with deliberate organisational measures addressing workplace culture, behaviours and management practices. This includes strengthening transparent recruitment and promotion processes, ensuring equitable task allocation and implementing structured onboarding and mentorship systems. This should also include the use of gender-neutral and bias-free job descriptions, avoiding language and requirements that may unintentionally discourage diverse applicants or reinforce stereotypical role expectations.

Without such measures, improvements in physical working conditions are unlikely to translate into meaningful changes in participation.

STRENGTHEN THE VISIBILITY OF NEW TECHNOLOGY-ENABLED ROLES

While technologies such as 3D printing, UAVs, and digital twins are associated with more skill-based, innovative and less physically demanding work, their potential to attract a more diverse workforce could be enhanced. Targeted communication strategies and career guidance initiatives should therefore be developed to promote these roles, particularly by highlighting their alignment with fields where female participation is higher, such as design and engineering. In parallel, the development of role model initiatives showcasing women engaged in technology-driven construction roles can contribute to reshaping sector perceptions, thereby supporting both entry into and retention within the industry. Companies should also ensure that internal career pathways linked to these roles are clearly defined and accessible.

LEVERAGE TECHNOLOGY DEPLOYMENT TO RESHAPE SECTOR PERCEPTION

Technologies that visibly alter how construction work is performed, such as robotics, exoskeletons and automation, should be strategically used to signal a shift toward more inclusive and technology-driven work environments. Companies play a critical role in making these changes visible, both internally and externally, helping to challenge entrenched perceptions of the sector as physically exclusive and male-dominated.

TECHNOLOGY DEVELOPERS AND INNOVATION ACTORS

INTEGRATE INCLUSIVE AND HUMAN-CENTRED DESIGN PRINCIPLES

Technology developers therefore play a critical role in translating inclusive principles into concrete design choices. This requires embedding human-centred and inclusive design approaches throughout the development lifecycle, ensuring that technologies are adaptable to a wide range of body types, physical capabilities and user needs. In practice, this involves testing prototypes with diverse user groups, integrating iterative feedback mechanisms and ensuring usability across different contexts of use. Beyond physical equipment, digital tools and application interfaces should also follow inclusive design principles, avoiding gender bias in interaction, accessibility, and representation. These steps are essential to reduce barriers to adoption and prevent the reproduction of exclusion through design.

ESTABLISH GOVERNANCE FRAMEWORKS FOR ETHICAL AND INCLUSIVE USE OF DATA

For monitoring technologies, concerns around surveillance and misuse are significant. Some suggested measures include:

- Developing clear data governance protocols, ensuring that wearable and monitoring technologies are used for safety and well-being, not penalisation.
- Engaging workers in co-design and implementation, building trust and acceptance.

This is essential to prevent technologies from negatively affecting workplace conditions. In addition, developers should ensure that data-driven systems do not introduce or reinforce biases in performance assessment, task allocation or decision-making processes.

ENSURE TECHNOLOGIES ARE EMBEDDED WITHIN INCLUSIVE IMPLEMENTATION ECOSYSTEMS

The findings indicate that the impact of technologies is strongly dependent on access to skills, training and organisational uptake. Developers should therefore work in coordination with industry and training providers to ensure that technologies are accompanied by accessible learning pathways, clear use cases and support mechanisms that enable broad adoption. Without such alignment, there is a risk that innovation will remain concentrated among already advantaged groups, limiting its contribution to inclusion.

References

[1] European Commission, Secretariat-General, European Pillar of Social Rights. Luxembourg: Publications Office of the European Union, 2017, doi: 10.2792/95934. [Online]. Available: https://op.europa.eu/en/publication-detail/-/publication/ce37482a-d0ca-11e7-a7df-01aa75ed71a1/language-en (last visited: 22/04/2026)

[2] European Commission, Secretariat-General, A Union of Equality: Gender Equality Strategy 2020–2025, COM(2020) 152 final, Brussels, Belgium, 2020. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0152 (last visited: 22/04/2026)

[3] European Commission, A Renovation Wave for Europe—Greening our buildings, creating jobs, improving lives, COM(2020) 662 final, Brussels, Belgium, 2020. [Online]. Available: https://energy.ec.europa.eu/system/files/2020-10/eu_renovation_wave_strategy_0.pdf (last visited: 22/04/2026)

[4] FIEC, “Shortage of labour in the construction industry,” European Construction Industry Federation, Oct. 12, 2023. [Online]. Available: https://www.fiec.eu/application/files/6216/9711/5277/2023-10-12_Shortage_of_Labour_in_the_Construction_industry.pdf (last visited: 22/04/2026)

[5] Eurostat, “Jobs with the highest share of women in Q3 2021,” Eurostat News, Mar. 4, 2022. [Online]. Available: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20220304-1 (last visited: 22/04/2026)

[6] Cedefop, “Construction workers: Skills opportunities and challenges – 2023 update,” European Centre for the Development of Vocational Training, 2023. [Online]. Available: https://www.cedefop.europa.eu/en/data-insights/construction-workers-skills-opportunities-and-challenges-2023-update (last visited: 22/04/2026)

[7] L. Bian, S. J. Leslie, and A. Cimpian, “Gender stereotypes about intellectual ability emerge early and influence children’s interests,” Science, vol. 355, no. 6323, pp. 389–391, 2017, doi: 10.1126/science.aah6524.

[8] I. Biemmi, “Gender stereotypes in childhood: When is difference born?” Education Sciences & Society, vol. 6, pp. 127–135, 2015.

[9] A. Berry, S. McKeever, B. Murphy, and S. J. Delany, “Addressing the ‘leaky pipeline’: A review and categorisation of actions to recruit and retain women in computing education,” arXiv preprint arXiv:2206.06113, 2022. [Online]. Available: https://arxiv.org/abs/2206.06113 (last visited: 22/04/2026)

[10] M. A. Silva and A. Dominguez, “Women in construction engineering: Improving the students’ experience throughout their careers,” in Proc. 2021 ASEE Virtual Annual Conference Content Access, 2021, doi: 10.18260/1-2--38106.

[11] I. Recalde-Esnoz, D. Ferrández, C. Morón, and G. Dorado, “Inequalities in the exercise and continuity in building engineering in Spain: Factor analysis including gender perspective,” Sustainability, vol. 13, no. 10, Art. no. 5514, 2021, doi: 10.3390/su13105514.

[12] L. Clarke and M. Sahin-Dikmen, “Why radical transformation is necessary for gender equality and a zero carbon European construction sector,” in Gender, Intersectionality and Climate Institutions in Industrialised States, pp. 164–180. Taylor & Francis, 2021, doi: 10.4324/9781003052821-10.

[13] Buildern, “7 Major Concerns Women in Construction May Have,” 2022. [Online]. Available: https://buildern.com/resources/blog/7-major-concerns-women-in-construction-may-have/ (last visited: 22/04/2026)

[14] CHAS, “Why PPE for Women Is a Major Issue in Construction,” 2024. [Online]. Available: https://www.chas.co.uk/blog/ppe-women-major-issue-construction/ (last visited: 22/04/2026)

[15] Eurostat, “Gender pay gap statistics,” Statistics Explained, 2025. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Gender_pay_gap_statistics (last visited: 22/04/2026)

[16] European Insurance and Occupational Pensions Authority, “The impact of social and behavioural aspects on the gender pension gap in Europe,” Jun. 26, 2024. [Online]. Available: https://www.eiopa.europa.eu/impact-social-and-behavioural-aspects-gender-pension-gap-europe-2024-06-26_en (last visited: 22/04/2026)

[17] Council of the European Union, “Gender pay gap: Council adopts new rules on pay transparency,” Apr. 24, 2023. [Online]. Available: https://www.consilium.europa.eu/en/press/press-releases/2023/04/24/gender-pay-gap-council-adopts-new-rules-on-pay-transparency/ (last visited: 22/04/2026)

[18] E. Donohoe, F. Camonita, V. Tageo, C. Guey, I. Zejerman, L. Todaro, L. Godderis, and A. Boone, Mental health in the construction sector: Preventing and managing psychosocial risks in the workplace. Luxembourg: Publications Office of the European Union, 2024, doi: 10.2802/7183661.

[19] H. M. Curtis, H. W. Meischke, N. J. Simcox, S. Laslett, L. M. Monsey, M. Baker, and N. S. Seixas, “Working safely in the trades as women: A qualitative exploration and call for women-supportive interventions,” Frontiers in Public Health, vol. 9, Art. no. 781572, 2022, doi: 10.3389/fpubh.2021.781572.

[20] J. D. Owolabi, K. E. Ogundipe, B. F. Ogunbayo, and C. O. Aigbavboa, “Barriers to attracting and retaining female construction graduates into academic careers in higher education institutions,” Buildings, vol. 13, no. 10, Art. no. 2673, 2023, doi: 10.3390/buildings13102673.

[21] S. Holdsworth, M. Turner, and O. Sandri, “Gender bias in the Australian construction industry: Women’s experience in trades and semi-skilled roles,” Social Sciences, vol. 12, no. 11, Art. no. 627, 2023, doi: 10.3390/socsci12110627.

[22] N. Galea, A. Powell, M. Loosemore, and L. Chappell, “The gendered dimensions of informal institutions in the Australian construction industry,” Gender, Work & Organization, vol. 27, no. 6, pp. 1214–1231, 2020, doi: 10.1111/gwao.12458.

[23] S. Husam, B. Laishram, and S. Johari, “Framework to enhance gender inclusion of workers in construction sites,” Journal of Construction Engineering and Management, vol. 150, no. 4, Art. no. 04024018, 2024, doi: 10.1061/JCEMD4.COENG-14124.

[24] Y. van der Meulen Rodgers, X. Liu, J. Yi, and L. Zhang, “Can wearable exoskeletons reduce gender and disability gaps in the construction industry?” Assistive Technology, pp. 1–10, 2026, doi: 10.1080/10400435.2026.2615356.

[25] I. Zuazu, “Robots and women in manufacturing,” working paper, Apr. 26, 2023. [Online]. Available: http://www.siepweb.it/siep/wp/wp-content/uploads/2023/05/27.EttaChiuri2023_ZUAZU_Robots-and-Women-in-Manufacturing.pdf (last visited: 22/04/2026)

[26] S. Singh, K. Rahul, M. Paliwal, I. A. Wani, and S. Suri, “Gendering the digital divide: A systematic review of women’s digital inclusion challenges and emerging research directions,” Digital Transformation and Society, vol. 4, no. 4, pp. 503–531, 2025, doi: 10.1108/DTS-04-2025-0083.

[27] X. Wang, M. Du, H. X. Li, A. Hasan, and A. Ahmadian Fard Fini, “Gender inequality and challenges of women in the construction industry: An evidenced-based analysis from China,” Engineering, Construction and Architectural Management, vol. 32, no. 13, pp. 213–233, 2025, doi: 10.1108/ECAM-03-2024-0389.

5 Annex 1: Questionnaire

GENERAL BLOCK: Participants Profile (i.e. gender, age, ethnicity etc….)

Please select your gender:	• Male • Female • Prefer not to say
In which country are you currently working?	• Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic (Czechia), Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom
What is your age?	• 18-29 • 30-39 • 40-49 • 50-59 • 60-70
Select the type of role you belong to in the construction sector, based on the descriptions provided below:	• Strategic role • Operational role • Frontline role **Strategic role** – if you work in institutions such as public authorities, universities, or research organisations that shape policies, set industry standards, or provide knowledge frameworks for the sector. **Operational role** – This category includes professionals working in private companies or non-governmental entities, such as architectural firms, construction companies, or technology providers, who contribute to implementing and supporting construction or renovation processes (i.e. engineers, researchers etc.). **Frontline role** – If you work directly on construction sites, such as a construction worker or site personnel involved in executing renovation and construction activities (i.e. manual workers, site managers, supervisors etc).
How long have you been working in the construction	• Less than 1 year • 1-5 years

or energy sector?	• 6-10 years • 11-15 years • More than 15 years

BLOCK 1: WORKERS' PERCEPTION OF WORKING IN THE CONSTRUCTION SECTOR AND CAREER DEVELOPMENT.

In this section we will explore the perception of gender-related challenges in the construction and energy sectors, focusing on how different dimensions, (1) access to education, (2) access to employment opportunities, (3) access to training, (4) nature of work, (5) workplace safety, (6) workplace environment, (7) pay gap and (8) work-life balance, can affect men and women differently.

In your professional experience, have you encountered challenges in the following areas? (You can select multiple options) Can you provide more details about the specific challenges you face?	• Limited access to educational opportunities • Lack of awareness about career prospects in the sector • Absence of mentorship or role models in the field • Limited access to internships and courses • Gender biases in hiring, promotions, or career advancement • Lack of workplace policies supporting work-life balance (e.g., flexible hours, parental leave) • Limited access to skill-building or professional training for career development • Unequal pay for equal work (e.g., salary disparities despite similar roles and experience) • Lack of an inclusive workplace culture (e.g., exclusion from networking opportunities, biased work assignments, or lack of diversity initiatives) • Limited access to leadership or decision-making roles • Inadequate safety measures on-site, such as lack of appropriate personal protective equipment, or sanitary facilities on-site • Workplace harassment or discrimination (e.g., verbal, physical, or systemic discrimination affecting job performance and well-being) • I did not face any challenges • Others (specify):
In your opinion, what are the primary barriers that limit women's entry into the construction sector? (You can select multiple options)	• Gender stereotypes about STEM (Science, Technology, Engineering, and Mathematics) fields discourage girls from pursuing these careers early on • Gender stereotypes and biases in hiring • Limited access to STEM education, technical training or internships • Perception of the sector as physically demanding or unsafe for women • Lack of flexibility in the workplace

	• Workplace bias or discriminatory practices • None • Others: (Please specify)
In your opinion, what is the expected timeframe for achieving greater gender equality in the construction industry? Could you provide a rationale for your chosen answer?	• 5-10 years • 10-15 years • 15-20 years • +20 years

BLOCK 2: HOW TECHNOLOGIES CONTRIBUTE TO FOSTERING INCLUSION IN THE CONSTRUCTION SECTOR[1]

Demolition robots use digital building models and plans, also known as BIM (Building Information Modelling), to guide them in tearing down structures like walls and facades. Equipped with sensors to prevent damage and accidents, they reduce the need for workers in hazardous tasks while improving efficiency and safety. Do you think the use of demolition robots could help engage or attract a more diverse workforce (e.g., more women) by reducing physically demanding tasks?	• Not at all • Moderately • Very much • Extremely
Could you provide a rationale for your chosen answer?	(Open question)
In what ways do you think the Demolition Robots could positively impact the	• Introduces workers to robotics and automation • Expands job opportunities for diverse

[1] The following questions and technology description format were applied across all technologies analysed in the study

construction sector? (Select all that apply).	workers • Requires new technical skills – training needed • Reduces heavy manual labour • Improves safety and health – Lowers risks of accidents • Enhances work-life balance – Less physical exhaustion can lead to better well-being • Fosters innovation and attracts a more diverse workforce by shifting focus to skills and technology • Creates skill-based jobs – Automation increases demand for specialised roles • Enhances workers' productivity and efficiency • Prevents early retirement - Automation can reduce health and safety risks. • None of the above • Other (please specify): ________________