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Potential of Artificial Intelligence in Mitigating Inclusive and Affordable Housing Crisis in India

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Executive Summary

This report explores the problems posed by the affordable housing crisis in India and seeks to integrate a technological solution in AI to mitigate the conundrum. The paper studies the ongoing Pradhan Matri Awas Yojana-Urban (PMAY-U) mission and the problems related to the affordable housing scheme. The research maps the activity groups or areas amenable to technological intervention in the affordable housing scheme. It then attempts to integrate AI into the mission and thus drive efficient allocation of affordable housing for Economically Weaker Sections (EWS) and Lower Income Groups (LIG). The research also seeks to solve the affordability crisis in designing households and tries to optimise construction costs. Following the technological assimilation, the paper maps the changing dynamics of the mission. It showcases how the system becomes complex and tightly coupled. Finally, the paper maps the impact groups based on literature reviews and then classifies them according to Charles Perrow's Normal Accident theory. The paper ends with the advantages of integrating AI into the process and cites a California case study to showcase how the chimes of change are ringing.

2. Sector and Sectorial Applications

> **“**The right of every woman, and man, youth and child- in both urban and rural areas- to gain and sustain a safe and secure home and community in which to live in peace and dignity.**”**
>
> **-Miloon Kothari, first Special Rapporteur on Adequate Housing, United Nations, 2005**

a. Explanation of the sector of interest

In India, households with an annual income between INR 2 and 3 lakhs can only save up to 35% of their earnings for housing investments (Wahi & Sharma, 2016). This highlights a structural constraint (or a wicked policy problem) for Economically Weaker Sections (EWS), Lower Income Groups (LIG) and Middle-Income Groups (MIG) in accessing sustainable housing options. The pressing nature of this pugnacious problem is highlighted through the latest Income and Wealth Inequality in India Report, which states that 90% of Indian households earn less than 1.7 lakhs per annum (Bharti, et al., 2024). The authors add that as per the AIDIS micro-data estimate only 28% of the total population in the country owns a wealth-generating asset like a building. This indicates that housing is an aspiration out of reach for a staggering 72% of the country’s populace (Bharti, et al., 2024).

Housing’s role and functionality are multifaceted. Its impact is directly proportional to an individual’s access to “infrastructure, employment, household wealth, health, education, poverty levels, maternal and child mortality, women’s participation in [the] workforce”, and a slew of other well-being indicators (Gopalan & Venkataraman, 2015). It has multiple connections to an individual’s well-being, as suggested by the

research of Mueller and Tighe (2007), who provide irrefutable evidence showing how affordable housing provides a stable environment for a child, making it easier for them to attend school. Similarly, the research demonstrates that adequate housing can prevent health issues by protecting residents from extreme heat and cold (Mueller, E. J. & Tighe, J.R., 2007).

Article 25 of the Universal Declaration of Human Rights (United Nations, 1948) and 11.1 of the International Covenant on Economic, Social and Cultural Rights (United Nations, 1966) have enshrined the right to adequate housing in human rights law. While India is a signatory to several human rights doctrines and guidelines that uphold the human right to adequate housing, neither the country's Constitution nor its legislative framework explicitly mentions or recognises it (Chaudhry and Kothari, 2019). However, the Indian judiciary has persistently upheld several aspects of the right to adequate housing by corroborating it with Article 21 of the Constitution, "protection of life and personal liberty" (Chaudhry and Kothari, 2019).

Given the information presented above, the real estate sector must "reinvent itself to improve its productivity standards" to meet India's progressive urbanisation and rapid population growth, much like its global counterparts (Sivarudran, P. V., & Matus, 2020). As the global construction market is projected to reach USD 15.5 trillion by 2030, 54% of the growth will originate from China, India and the US (Sivarudran, P. V., & Matus, 2020). The real estate, construction and financial sectors are expected to gain substantially from this predicted growth (Gopalan & Venkataraman, 2015). Therefore, a thrust to affordable housing "will not only lead to a better quality of life but also

significantly provide a boost to the GDP of the country" (Gopalan & Venkataraman, 2015).

b. What is the potential for AI application in the sector of interest?

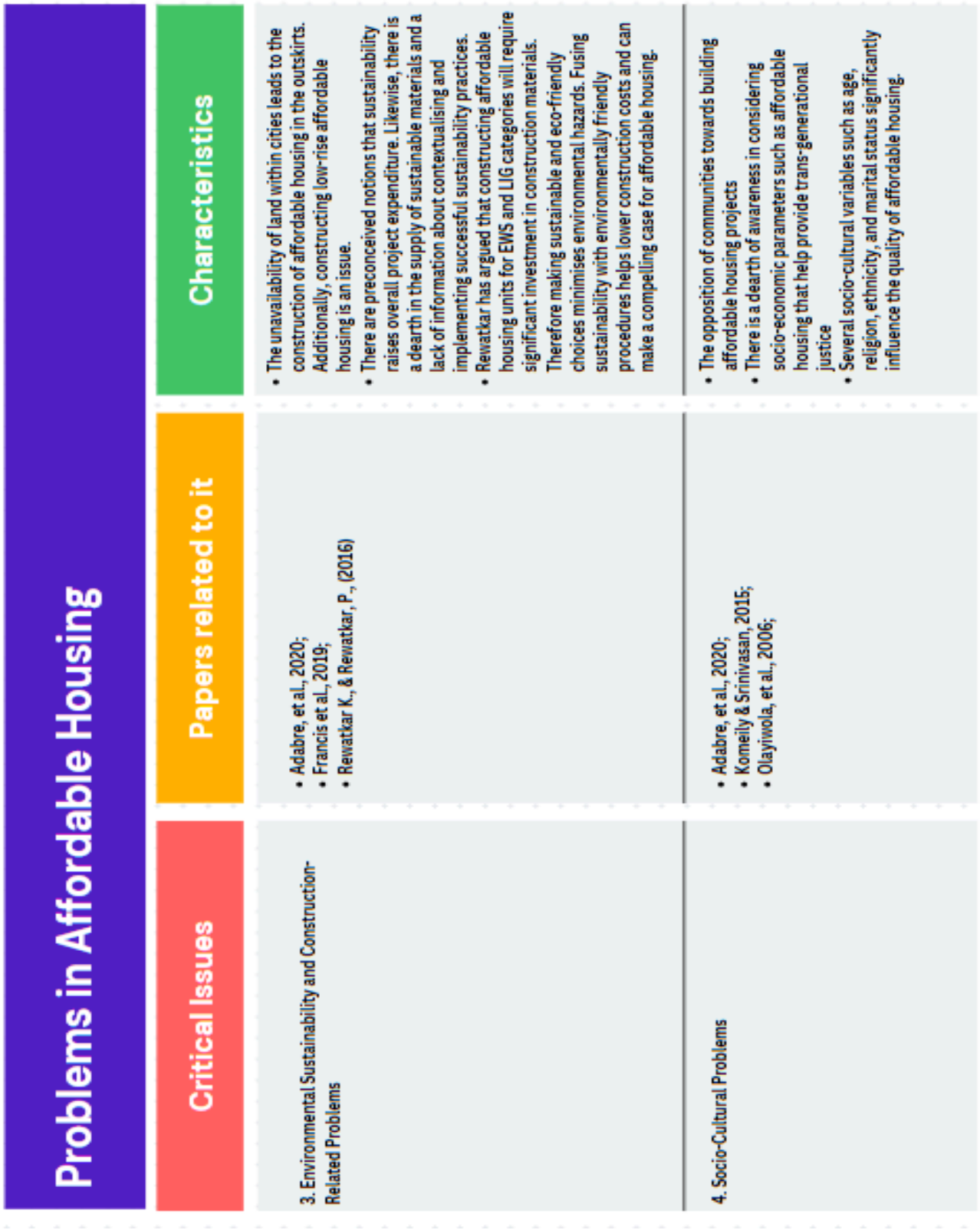
A World Bank analysis states that Artificial Intelligence (AI) can play a pivotal role in mitigating the global housing deficit by **ensuring affordable housing in emerging markets.** AI provides scope for **a precision-based and efficient approach to housing development and management** (Walley, et.al, 2023). **Similarly, the UN-Habitat's report mentions** that by 2030**,** approximately 40% of the global population will require affordable housing. This equates to a daily count of 96,000 new and affordable housing units (United Nations-Habitat, 2024). Artificial Intelligence (AI) provides a unique opportunity to manage this compounding crisis by using tools like Building Information Modeling, enabling Digital Twins for efficient planning, optimal resource allocation, and reduced design costs (Walley et.al, 2023). Likewise, AI can contribute to **building climate-resilient housing that is sustainable and energy efficient** (Panaro, P., et al., 2024).

Problems in Affordable Housing		
Critical Issues	**Papers related to it**	**Characteristics**
1. Governance Problem: Identification of the Right Clientele	• Bhate, A & Samuel, M., 2022; • Youth for Unity and Voluntary Actions, 2018; • Garg, Y., et al., 2014	• The necessity for appropriate identification of beneficiaries, and ensuring a system of linkages to avail the benefits • There is a mismatch of expectations as the eligibility criteria exclude a significant portion of targeted populations thus preventing EWS and LIG from accessing the benefits. • Understanding contextual nuances and deciding between a Sell-Then-Build Model or a Build-Then-Sell Model helps reduce house buyer dissatisfaction.
2. Economic/Finance-Related Problem: Economic Sustainability related to land and securing basic amenities	• Rana, P. D., & Rana, K. A., 2016; • Gopalan & Venkataraman, 2015; • Abhijith V, &Shanbhag, A., 2013	• The exorbitant cost of borrowing for the poor, the unavailability of easy credit, and the dearth of housing financing companies prevent investment in affordable housing. Similarly, as inflation and interest rates are high it becomes impossible for low-income households to secure housing finance • The drastic rise in the cost of land and construction which is exacerbated by the increase in the price of materials for construction • Lack of financing opportunities for the poor due to insufficient identification, and non-existent household savings

Table 1: Critical Issues in the Affordable Housing Sector

According to the 2011 Census, 65.5 million Indians suffer from disordered urbanisation as they reside in urban slums (Wahi & Sharma, 2016). In 2015, the estimated housing deficit in the country stood at 19 million units and is expected to double to 38 million units by 2030 (Kacholia & Nigam, 2021). This spiraling crisis is predominantly concentrated within the EWS and LIG segments, with 95% of these households lacking access to affordable and adequate housing solutions (Mahadevan, 2015).

This paper focuses on exploring the potential for solving the problems of affordable housing development and accommodating EWS and lower-income households through efficient allocation (Gopalan & Venkataraman, 2015) and optimising the costs of construction and design of affordable housing (Rewatkar K., & Rewatkar, P., 2016).



Problems in Affordable Housing		
Critical Issues	**Papers related to it**	**Characteristics**
3. Environmental Sustainability and Construction-Related Problems	• Adabre, et al., 2020; • Francis et al., 2019; • Rewatkar K., & Rewatkar, P., (2016)	• The unavailability of land within cities leads to the construction of affordable housing in the outskirts. Additionally, constructing low-rise affordable housing is an issue. • There are preconceived notions that sustainability raises overall project expenditure. Likewise, there is a dearth in the supply of sustainable materials and a lack of information about contextualising and implementing successful sustainability practices. • Rewatkar has argued that constructing affordable housing units for EWS and LIG categories will require significant investment in construction materials. Therefore making sustainable and eco-friendly choices minimises environmental hazards. Fusing sustainability with environmentally friendly procedures helps lower construction costs and can make a compelling case for affordable housing.
4. Socio-Cultural Problems	• Adabre, et al., 2020; • Komeily & Srinivasan, 2015; • Olayiwola, et al., 2006;	• The opposition of communities towards building affordable housing projects • There is a dearth of awareness in considering socio-economic parameters such as affordable housing that help provide trans-generational justice • Several socio-cultural variables such as age, religion, ethnicity, and marital status significantly influence the quality of affordable housing.

Table 2: Critical Issues in the Affordable Housing Sector

Predictive analysis propelled by AI and Machine Learning (ML) can transform affordable housing and make accurate predictions about housing demands on a granular level as suggested by the research of Akinsulire et al., 2024. Based on a comprehensive analysis of economic, demographic and environmental data, precise, nuanced and context-based predictions can be made to predict the housing needs of residents in a particular area (Akinsulire et al., 2024). Walley, et.al, 2023, have demonstrated that AI can make strategic suggestions on housing demands by critically evaluating housing demand and supply, through socioeconomic markers of households.

Research by Baduge et al., 2022, states that generative deep learning models like Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs) can provide architectural designs ranging from "building masses, floor plans, interior design plans and facades" thereby facilitating architectural design, material design, visualisation and optimisation process to drive down costs, material consumption and time. Likewise, AI's integration helps ease the workload of civil engineers by creating regenerative systems that operate on circularity principles. AI can play a pivotal role in expediting a transition to the circular economy by embracing the principles of Reuse, Repair and Recycle (Baduge et al., 2022). This shows the fundamental role of AI in optimising construction costs and design efficiency for affordable housing. Similarly, research by Bibri and Krogstie, 2020 shows that AI and machine learning play a critical role in resource allocation and reduce inefficiencies.

Activity Groups	Papers related to	Characteristics	Citations
AG 1 (Planning)	Using efficient data processing, it identifies the need for efficient and rationalised housing allocation to the EWS and LIC categories. AI is used in decision-making/planning, demand assessment, and location determination.	This highlights data discrepancies and a paucity of information: AI/ML integration for data processing can mitigate the existing pitfalls in planning.	1. Bawa, A. J. and Zhiri, H. G., 2024 2. Himeur, et al., 2023 3. Alavi, H., et al., 2024 4. Abioye et al., 2021
AG 2 (Design)	Related to cost optimisation (drawing, sustainable designs that drive down costs)	Highlights sustainability and economic efficiency; AI/ML integration can streamline design through digitalisation and pattern monitoring. BIM and AI-driven predictive analysis improves design precision and reduces wastage	1. Ohakawa et al., 2024 2. Himeur, et al., 2023 3. Alavi, H., et al., 2024 4. Abioye et al., 2021
AG 3 (Execution)	Efficiently building affordable houses on the ground	Highlights how AI and VR are combining to provide better outcomes and ensure customer satisfaction	1. Bryden, et al., 2022 2. Abioye et al., 2021
AG 4 (Safety-Related Activities)	Checks and balances to ensure the delivery of a quality product to the beneficiaries of the scheme	Highlights how AI is being used to improve the safety of houses built, create dynamic safety barriers in housing sites, improve the overall safety of the process	1. Abioye et al., 2021 2. Chen K., et al., 2024

Table 3: Activity Groups based on a literature review of articles related to the affordable housing scheme

c. Provide a systems perspective concerning the change in complexity and coupling

Current Scenario:

Since this study only aims to understand the affordable housing crisis at the national policy level, it can safely be stated that all affordable housing policies, both past and present, implemented by the centre were **complex systems but were loosely coupled,** much like Charles Perrow's example of multi-goal agencies (mentioned in the book "Normal Accidents")**. Affordable housing can safely be categorised as a multi-goal agency** as it fulfils several purposes ranging from societal well-being, reducing crime, providing employment stability, education, healthcare and sustainable development (Gopalan & Venkataraman, 2015).

As outlined in a Ministry of Housing and Urban Affairs (MoHUA) document titled "Discourses on Affordable Housing in India and Best Practices under PMAY-U," the current affordable housing scheme Pradhan Mantri Awas Yojana- Urban (PMAY-U) aims to achieve several Sustainable Development Goals including No Poverty, Zero Hunger, Good Health and Well-Being, and Quality Education (Narayan, K., et al., 2022). Following a comprehensive stakeholder analysis, the Pradhan Mantri Awas Yojana-Urban can be classified as a complex system incorporating several levels of governance. The relevant ministries under the scheme's ambit are central authorities (MoHUA), state-level nodal authorities, urban local bodies, private players, financial institutions and the beneficiaries. Despite its complex systems and intricate interconnection, the system remains loosely coupled.

Following Perrow's classification of complex systems, the affordable housing scheme in India is characterised by the tight spacing of government organisations from the centre and the municipality to the private players. Similarly, there is a limited understanding of transformational processes (Perrow, 2011). Akshay Joshi's report for MoneyControl highlights the problem of

multiple stakeholder engagement and information asymmetry between the centre, states and private developers (Joshi, A., 2022). The report adds that the project's offtake has been limited and fraught with challenges like project delays and inefficient delegation of operational workflows (Joshi, A., 2022). The feedback loops can be unfamiliar and unintended, and personnel employed to carry out the functionalities of the scheme are specialists in their particular domains.

These issues have been highlighted by the Standing Committee on Housing and Urban Affairs through its report on the Evaluation of the Implementation of PMAY (Urban) (Standing Committee on Housing and Urban Affairs,2023). It notes that houses were denoted as completed despite inadequate infrastructure, highlighting the unintended feedback loops within the system. Likewise, the problem of specialised personnel with limited cross-functional capabilities has led to delays in statutory clearances, lack of encumbrance-free lands and challenges in the In-Situ Slum Redevelopment (ISSR) vertical (Standing Committee on Housing and Urban Affairs,2023). All these have contributed to the dearth of affordable housing for the EWS and LIG categories.

Despite being a complex system, India's affordable housing scheme is characterised by processing delays and slack in resources, making it loosely coupled (Haque, I. et al., 2022). There have been numerous reports about the implementation of the scheme being delayed across the country due to funding gaps (The Hindu, 2021), and even when houses have been built, they remain unoccupied due to incomplete infrastructure and non-allocation to beneficiaries (Nath, D., 2024). This depicts how the system is characterised by slack in resources, besides being riddled with inefficiencies and redundancies (D' Souza, R., 2019). All these points add up to make the affordable housing crisis in India a complex system that is loosely coupled.

Current Status: Complex System, Loosely Coupled (much like multi-goal agencies)

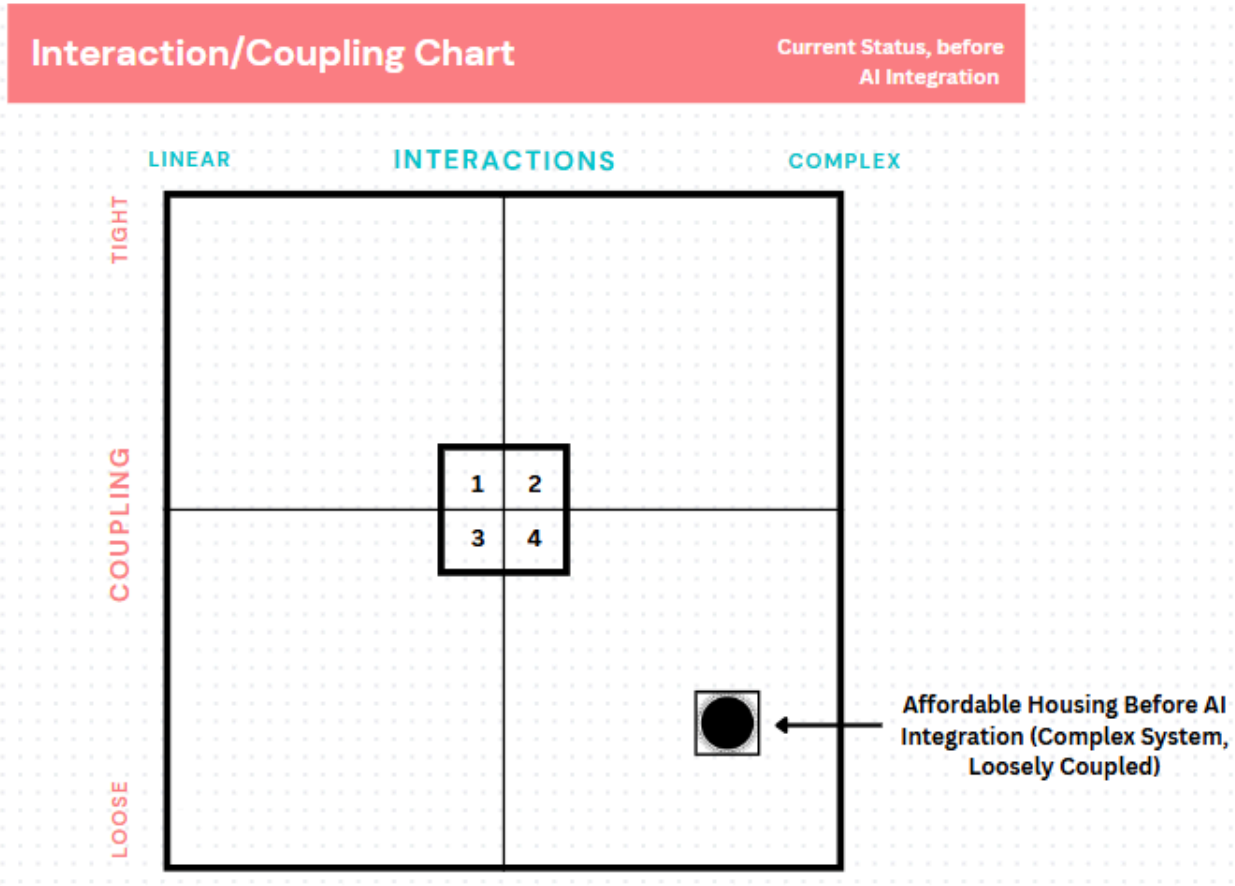


Chart 1: Current status of interaction and coupling in the Indian affordable housing context

After AI integration: Following the technological intervention, the organisational structure of the affordable housing scheme in India will change. Since AI is being deployed to rationalise the allocation of affordable housing and optimise construction and design costs, the system will continue to be complex but will now be tightly coupled. Its complexity might rise further.

AI's incorporation into governance (here, affordable housing) allows the administration to streamline and accelerate their workflows and remove processing delays (Iosad et al., 2024),

thus making the system tightly coupled. Likewise, AI can be deployed to drive insights from data available to the government and extract insights rapidly (Iosad et al., 2024). By mitigating the problem of inept resource allocation, the government can reduce inefficient housing allocation for the EWS and LIG categories, thereby making it tightly coupled. Likewise, the system's tight coupling will increase further as AI identifies inefficiencies, improves designs and removes redundancies (Iosad et al., 2024).

However, AI's incorporation establishes a technological determinism that forces the government to abide by a strict set of operations with predefined order or invariant sequencing. Only AI-driven strategic decision-making will be used to achieve the goal. Similarly, the system will be characterised by a limited substitution of supplies, equipment, and personnel as the AI workforce in the country is in short supply (Rungta et al., 2024). Thus, an AI intervention increases the system's complexity, making it tightly coupled.

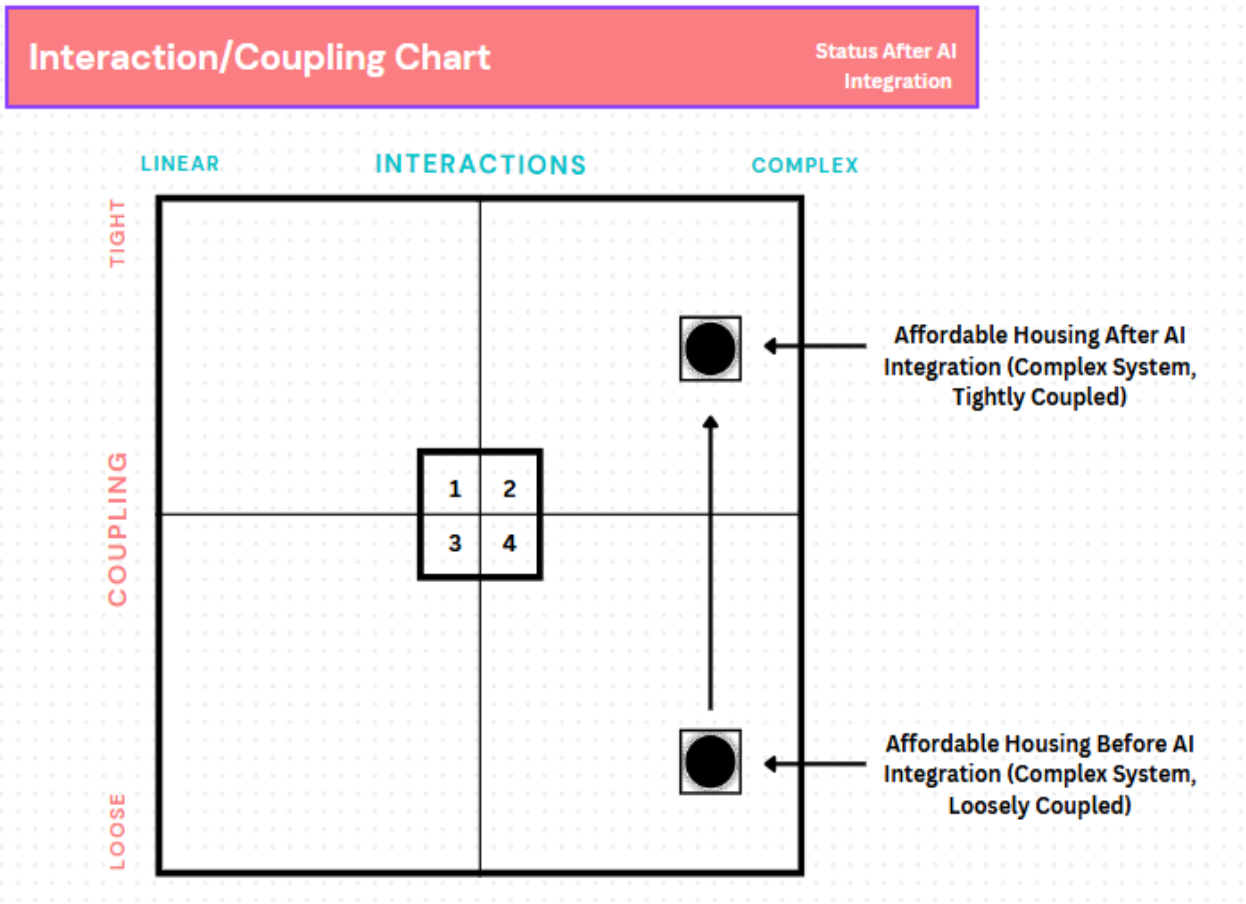


Chart 2: Status of interaction and coupling in the Indian affordable housing context after AI integration

3. Discussion on the Potential Risks and Impact Groups

a. What are the various impact groups of these diverse AI applications on the sector of interest?

Following the integration of AI into the affordable housing scheme, the impact groups affected by the technological assimilation process have been listed in the table below. The prime operators in these cases would be impact group one or the central government. They and impact group five, the enablers and specialists of technology (mostly private players), will integrate the technology within the affordable housing scheme. Impact Group 1 designs the scheme for affordable housing and, on the advice of Group 5, integrates AI into the process. The former has limited awareness of technological integration. Still, it ensures that the technology is integrated into the operational works of the scheme while mitigating the potential political, economic, and sociocultural implications of such an initiative.

The enablers/specialists (Impact Group 5) collaborate with Impact Groups 1, 2, 3, and 4, facilitating the systematic planning, design, implementation and monitoring of the technological interventions. Impact Group 2 (Middle Operators) or the state nodal authorities work in coordination with 1, 3, 4 and 5 to implement and execute the scheme. They also provide essential feedback to the prime operators and supervisors. They are also responsible for operationalising the safety mechanisms (i.e. checks and balances) necessary to implement the scheme. Impact Group 3 (Ground/Project Operators) are the urban local bodies that execute the scheme on the ground. They coordinate with Impact groups 2, 4, and 5 to implement the plans on the ground and conduct safety changes before the beneficiaries receive the end product.

Impact Group (IG)	Characteristics	Example	Activity Group
Impact Group 1 (Prime Operators)	Designing the policy (currently PMAY-Urban, previously Rajiv Awas Yojana, etc), the Centre manages the operational workflows, political, economic and socio-cultural implications. Limited awareness of technological interventions and advancements	The central government, i.e. MoHUA	1 and 2
Impact Group 2 (Middle Operators)	Concerned with the implementation, execution and safety-related activities. However, they might provide suggestions on the design and planning of the scheme based on feedback from urban local bodies and private players.	State-level nodal authorities	3 and 4
Impact Group 3 (Ground/Field Operators)	Municipal corporations manage the resources related to the program and are mostly associated with ground-level execution and conducting safety changes	Urban Local Bodies	3 and 4
Impact Group 4 (Procedural Experts)	Works in tandem with the government and performs delegated responsibilities	Private players	3
Impact Group 5 (Enablers and Specialists)	Enforces/enables technological integration within the affordable housing scheme. They are the specialist in technological integration.	Technology providers are generally private players	1, 2, 3, and 4
Impact Group 6 (End Users or Clients)	Uses the product and is mostly concerned with safety, speed and usability. They may or may not be aware of the technological integration	The beneficiaries of the affordable housing scheme (EWS and LIG communities)	4
Impact Group 7 (Local Community)	Innocent bystanders, do not participate in the process. They do not possess any knowledge about technological integration in the scheme	The outside world at large	4

Table 4: Impact Groups based on the understanding of the affordable housing scheme

The procedural experts are part of impact group 4, they are private players who perform specific responsibilities designated to them by government authorities (centre, state or local). Impact group 5, primarily private players, are the enablers and technology specialists who integrate AI into the process. Through their expertise, they drive the planning, designing and execution of the scheme. They may or may not be responsible for monitoring the safety-related procedures. They work with groups 1, 2, and 3 while impacting the lives of groups 5, 6 and 7. Impact Groups 6 and 7 are the beneficiaries/clients and the local community.

Victim Classification by Perrow (2011)	Classification by author (Impact Groups)
Individuals and organisations directly involved in the activity of providing affordable housing	The central government, i.e. MoHUA; State-level nodal authorities; Urban Local Bodies; Private players; Technology providers
The beneficiaries	EWS and LIG communities
The innocent bystander	Community
The future generation	Community

Table 5: Classification of victims according to Perrow's Normal Accident Theory

b. What are the impacts of the technology interventions on the impact groups?

Integrating AI to mitigate the affordable housing crisis can lead to several challenges. Some of them are highlighted below:

1. **Explainability crisis:** One of the major problems emanating from AI integration is its explainability crisis, commonly called the black box conundrum (Sanchez et al., 2024). Unless users, beneficiaries and other arms of the government fully comprehend the decision-making process leading to a particular prediction, it will lack the trust factor. The complex AI algorithms that allocate the houses efficiently to the EWS and low-income groups must be transparent. This will instil a sense of confidence in the minds of the beneficiaries and the people executing the scheme. Impact groups 1, 2, 3 and 5 must mitigate the challenges of the explainability crisis as the technology's integration introduces a new layer of complexity (Sanchez et al., 2024). AI algorithms can make the affordable housing process opaque, making it challenging for the beneficiaries to understand why they have been excluded from the allocation process (Sanchez et al., 2024).

    They will only be reassured when both **algorithmic and social transparency are ensured.** Adding social transparency to AI systems will help explain who did what with the technology (Ehsan et al., 2021). It will also answer the questions of when and why (Ehsan et al., 2021), bring about transparency in the technological context, and help usher the decision-making context, and the organisational context (Ehsan et al., 2021). This will be effective for a scheme like affordable housing that facilitates multiple stakeholder

interactions. However, if these challenges are not sufficiently addressed, then the compounding of the explainability crisis adds to the accountability challenge.

2. **Privacy:** Certain challenges will emerge with the integration of AI in the process and must be addressed. One of the major challenges that the government must guard against is safeguarding the rights of individuals and particular groups/castes to control their information. This will involve respecting their boundaries and group/caste autonomy, which can only be ensured by collecting and storing their data in a just, equitable and fair manner that ensures their representation (Braun et al., 2018). Braun suggests that by incorporating privacy-enhancing techniques, ensuring policy compliance during data management, and retaining a "human overseer", malicious activities can be prevented. The problem of extensive data collection in urban planning has been highlighted in the paper by Sanchez et al., 2024, which warns against data surveillance and privacy infringement. Problems with privacy in the affordable housing scheme can affect all government players (Impact groups 1, 2 and 3) and the beneficiaries. The paper by Sanchez et al., 2024, also addresses another major aspect of privacy, data storage; if the stored data is breached, it can disproportionately affect beneficiaries and lead to an institutional crisis. This can lead to policy paralysis and undermine the credibility and government's stature, thereby affecting Impact Groups 6 and 7.

3. **Flawed decision-making** in the affordable housing crisis can emerge from **biased data,** skewed datasets, and assumptions embedded in algorithms (Sanchez et al., 2024; Du et al., 2023). The problem can be compounded by missing or undercounted data from the

Census and low public survey participation, thus leading to representational bias, flawed decisions and skewed outcomes (Shahbazi et al., 2023). Decision-making propelled from flawed datasets will have unintended consequences, such as unequal outcomes in affordable housing, as well as disproportionate representation of specific communities/castes in the Indian context. This can lead to the scheme's failure as it may fail to adequately address the needs of the EWS and lower-income households (Sanchez et al., 2024). Flawed decision-making at a government level has the potential to affect all stakeholders (Impact 1 through 6) in the affordable housing scheme; it can undermine the beneficiary's trust in the process and also erode the confidence of local communities (Impact Group 7) in the government.

4. **Equity and Inclusivity:** AI algorithms and data can reinforce societal inequities as they are trained on historical (Census, Survey) data. Such data may be riveted with biases of the past and may also reflect systemic inequalities and past discrimination (Veale, M., Binns, R., 2017). Thus, using AI algorithms that build on such partial or biased data can lead to decisions that accentuate and exacerbate societal biases. Rina Chandra provides an Indianised example of this crisis in her article. She writes that AI's integration in the country has the potential to aggravate the systemic biases against disenfranchised groups like the Dalits and the Muslims, as they are missing from AI datasets (Chandran, R., 2023). Skewed data can entrench rifts with Muslim and Dalit populations who would be among the beneficiaries (Impact Group 6) of the affordable scheme. If they are underrepresented, the trust in the scheme will be undermined. The perpetuation of caste

and religious discrimination in a government scheme can disenchant the common public (Impact Group 7) against the powers that be.

The inclusion of AI in the affordable housing scheme to efficiently allocate houses, optimise resource allocation, and drive affordable design poses some critical challenges. Issues of accountability, fairness, and legal liability complicate the decision-making process, perpetuating discrimination. These ethical dilemmas can have cascading effects on the scheme's outcome, potentially undermining trust in governance by eroding public confidence. The government must address these challenges by incorporating a robust system of checks and balances that addresses the crisis without stifling innovation and compromising efficiency.

The incorporation of the technology, however, promises several upsides in solving the affordable housing crisis. Not only can it improve living standards, but it also has a generational impact on the beneficiaries (Impact Group 6). It can also influence the lives of the community (Impact Group 7) through a boost for sustainability designs and lifestyles. Besides providing access to safe, secure and affordable housing for the beneficiaries, it also addresses the challenges of employment, healthcare, schooling and much more (Gopalan & Venkataraman, 2015). At present, the Department of Housing and Urban Development in the United States is collaborating with LA County, California, to provide affordable housing to the most vulnerable and destitute (Stern, C., 2024). Maybe, in a decade, the Los Angeles model will serve as a roadmap for a just and equitable distribution of affordable housing.

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