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ARTICLE

Science Centres: Catalysts for Smart and Sustainable Cities

Shatadal Ghosh[1], Sayan Ghosh[2], Shivranjanee Bhattacharya[2], Pratyusha Bhattacharya[2], Sajal Sharma[2]*

[1] National Council of Science Museum, Kolkata, India
[2] School of Computer Applications, Kalinga Institute of Industrial Technology (KIIT), Bhubaneswar, Odisha, India,

Corresponding Authors Email: shatadal88@gmail.com,
**sg777631@gmail.com; 2305651@kiit.ac.in,*
pratyushahiya2005@gmail.com, sajalsharma67@gmail.com

ABSTRACT

Science centres play an active role in promoting sustainability in smart cities through education, innovation, and citizen participation. This paper examines how they support funding, public service design, public relations, and outreach campaigns to advance SDGs and other development goals. They also contribute to problem-solving efforts. Science centres act as public laboratories where people of all ages explore emerging technologies like Artificial Intelligence, Virtual Reality, and Augmented Reality. These technologies are becoming an integral part of smart cities. By offering modern facilities, science centres help communities adopt sustainable practices. They also encourage young minds through maker spaces and citizen science projects. They allow people in the community to talk about problems in cities, increase the need for sustainable engineering, and impact policymaking from the ground up. As Dean states, "Science centres act as conversation and implementation hubs between knowledge and action, making an important contribution to sustainable urban sustainability." This paper also explores the challenges of limited internet access in sustainable city initiatives.

This paper is presented as a research article based on new empirical data, examining the role of science centres in advancing smart and sustainable city initiatives.

KEYWORDS- Science Centres; Smart Cities; Sustainable Development; Innovation; Emerging Technologies and Informal Learning.

1. Introduction

In the 21st century, cities, which are the focal points of human progress and development, have come under attack due to rampant urbanisation, resource depletion, and climate crises that threaten their very existence (*World Cities Report, 2024*). On the other hand, "smart cities" have emerged as the technology-based panacea to allow for ease of operation, equality, and environmental care (*World Cities Report, 2024*). While smart cities require new infrastructures to be built, they also need a shift in culture where citizens actively collaborate with policy and innovation to build the infrastructure (Kourtit *et al.*, 2014).

This is where we have "science centres" that act as change-enabling catalysts. Science centres serve as dynamic spaces for informal learning, where individuals of all ages explore science and technology outside traditional classrooms. They function as interactive environments where visitors engage with real-world challenges, including urban sustainability. Experts argue that these spaces are essential for making complex scientific and technological concepts accessible to diverse audiences (Falk & Dierking, 2010).

This paper demonstrates precisely how science centres are not merely educational facilities but rather pillars of city development and therefore transform the visionary declarations of smart cities into reality for everyone. The chapter also looks into the possibility of adapting science centres to facilitate experimentation in urban governance and hands-on teaching in STEM disciplines and the arts. With concrete instances, it evaluates their role in sustainable urbanisation and in closing the gap between the newer technologies and the society (Falk & Dierking, 2010).

Despite various challenges of modern cities, science centres can serve an important role as "living laboratories", where concepts are developed and tested. They provide advanced science museum exhibits that also serve as maker spaces and citizen science workshops/schools (Falk & Dierking, 2010).

They enable the general public, which includes non-STEM groups, to become STEM literate and help create solutions to community problems. For instance, Kolkata's and Puspa gujral

Science City (Science City Kolkata; Pushpa Gujral Science City) immersively teaches the science of climate change (CIMAM, 2024), while Belgium's Technopolis joins with companies to create sustainable technology demonstrators (Bell *et al*., 2009). Through public engagement, citizen empowerment, and community-based policies, science centres make the general goals of sustainability more specific and first-order action.

Research Questions

1. How do science centres contribute to translating smart-city ambitions into inclusive, actionable urban practices? In what ways can science centres serve as experimental platforms for citizen participation in urban innovation and governance?

Objectives

- To analyse the potential roles of science centres in promoting sustainable urban development.
- To investigate how informal learning environments facilitate citizen participation and STEM literacy in smart-city contexts.
- To compare case examples that demonstrate different models of integration between science centres and urban sustainability initiatives.

2. Literature Review

To understand the global scenario, we need to study literature from various perspectives, including science centres and smart cities with a focus on sustainable approaches. Smart cities are the cities that merge digital technology with urban infrastructure to make an effective and livable, environmentally friendly urban environment. The study underlines the requirement for sustainability in the planning of smart cities with leading green energy, digital governance, and urban mobility systems (Giffinger *et al*., 2007). In addition to that, the realisation of smart cities relies much on such factors as citizens' involvement, technological infrastructure, as well as governance

efficiency (Falk & Dierking, 2010; Manika, 2020). All these variables would mean that smart cities would not be mere technological cities but would be inclusive and community-based urban areas with a sustainable approach.

Science centres have historically been knowledge institutions. Implicitly, they have responded to a much more extended and broader mandate of public understanding, citizen- driven innovation, and sustainability awareness enhancement. A study on the role of interactive science exhibitions and citizen science projects in urban sustainability reveals these mediums stimulate behavioural change in urban sustainability and trigger public interest in environmental matters (Eco-Cycle, 2022). Focusing on citizens to raise their awareness of the challenges society faces regarding sustainability and encouraging long-term changes in behaviour that support initiatives in smart cities, learning by doing proves to be highly successful (Falk & Dierking,2010; Pellegrino et al., 2012 ; Lepore *et al*., 2024). Studies have proved that experiential learning and an opportunity for hands-on activities shall greatly increase retention and create an interest in sustainable solutions (Eco-Cycle, 2022). Also, science centres help bridge the gap that is the digital divide through programmes of technological literacy, which, besides the youth, are particularly directed towards the ageing generations and underprivileged communities (Manika, 2020). By widening the knowledge in the emerging technologies of smart cities of so many people from different ages and the variety of settings with which they associate, science centres guarantee that there is another section of the society that is passed knowledge that will enable it to travel through and positively contribute to the new urban environments (Giffinger *et al., 2007*).

In conclusion, the available literature suggests that science plays a vital role in achieving various global goals, particularly those aligned with smart city initiatives. The United Nations' Sustainable Development Goals (SDGs) offer a comprehensive framework for tackling global challenges, including urbanisation. Science centres actively contribute to several SDGs, notably Quality Education (SDG 4), Sustainable Cities and Communities (SDG 11), and Climate Action (SDG 13), by

promoting awareness, education, and innovation (UN DESA, 2018).

3. Research Methodology

This study adopts a qualitative, exploratory, and interpretive research design to examine how science centres contribute to building smart and sustainable cities. The research focuses on understanding the educational, environmental, and civic roles of science centres and how they align with broader smart-city frameworks and sustainability goals such as the UN Sustainable Development Goals (SDGs).

3.1 Research Approach

The inquiry follows an interpretivist paradigm, emphasizing the meaning and context behind human actions, institutional practices, and community interactions. A qualitative approach allows for an in-depth exploration of how science centres operate as social institutions—bridging science, policy, and citizen participation.

3.2 Research Design

An exploratory case study design was employed to identify recurring patterns and conceptual linkages between science centres and urban sustainability. The study integrates descriptive and analytical perspectives, seeking to understand how these institutions evolve as hubs of innovation, learning, and behavioural change.

3.3 Data Collection

The data for this research were obtained primarily from secondary sources, including:

- Official publications, annual reports, and policy documents from institutions such as Science City, Kolkata and Technopolis, Belgium.
- Peer-reviewed literature on smart-city planning, sustainability education, and informal learning environments. Reports and

frameworks from global agencies such as the United Nations, UN-Habitat, and World Cities Report (2024).

- Online archives, expert interviews, and case-specific digital documentation of exhibitions, workshops, and outreach programmes.

This diverse mix of sources ensured the reliability and contextual richness required for interpretive analysis.

3.4 Case Study Selection

Two cases were strategically chosen to illustrate how science centres operate within different cultural and socio-economic contexts:

- **Science City, Kolkata (India)** – representing a large-scale, publicly funded institution built on a reclaimed landfill site, which has become a model of sustainable urban redevelopment and public science engagement.
- **Technopolis, Mechelen (Belgium)** – representing a European example that integrates industrial collaboration, technology-based learning, and sustainability education through innovation-driven partnerships.

The comparative nature of these cases—Global South and Global North—provides insight into how differing governance systems, technological capacities, and community participation models shape science centres' contributions to smart-city development.

3.5 Analytical Framework

A **thematic content analysis** was applied to the collected data. The analysis was structured around three core dimensions:

1. **Educational and Scientific Literacy** – how science centres promote awareness and learning about science, technology, and sustainability (Technopolis, 2025).
2. **Civic and Community Engagement** – how they foster participation, citizen science, and grassroots innovation in urban governance.
3. **Sustainability Integration** – how these institutions embed environmental stewardship and sustainable practices into their operations and programming.

Patterns and relationships identified through this analysis were synthesised to develop a conceptual understanding of science centres as transformative agents within smart-city ecosystems.

3.6 Validation and Limitations

To strengthen credibility, information from multiple sources—academic studies, institutional documents, and media reports—was cross-verified. Triangulation ensured that key insights were consistent across independent data points.

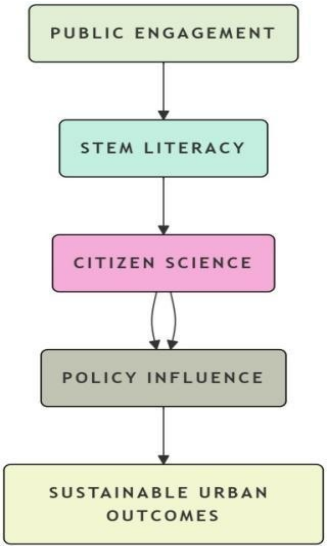
However, the study recognises certain limitations. It relies primarily on secondary data, without primary field observations or empirical surveys, which limits the ability to assess direct behavioural or policy outcomes. Future research could address these gaps by adopting mixed-methods approaches, combining quantitative visitor studies, focus-group interviews, and longitudinal impact assessments.

4. The Role of Science centres in Smart and Sustainable Cities

Science centres are essential for raising sustainability and environmental consciousness in the context of smart cities. These institutions use cutting-edge technology, interactive exhibits, and community-driven initiatives to help diverse audiences understand the complex challenges and solutions to urban environmental issues. Visitors learn valuable skills for making wise, sustainable decisions in their daily lives through immersive experiences that focus on waste management, water conservation, and biodiversity protection (Rákosi & Pongrácz, 2023).

4.1 Promoting Environmental Awareness and Sustainable Practices

The presentation brings scientific data to life on a large scale and uses both innovative visualisation techniques and interactive experiences to illustrate what all these impacts will be on ecosystems and human communities. Through compelling visuals, games, and interactive activities visitors will gain an understanding not only of the mounting threat to biodiversity but the practical solutions that can be used for mitigating those threats in order to achieve a sustainable future (Falk & Dierking, 2010).



Science centres can also extend their impact to broader audiences through educational programmes designed to engage individuals outside the exhibition space. Learn more about our Environmental Science Centres workshops and learning experiences in natural settings, such as beaches, streams and school gardens. These activities allow attendees to 'get in the field' and gain relevant experience in waste management, conservation of water resources and protecting natural ecosystems. Through in-the-field expertise and real-life experience, science centres provide individuals with the tools to engage in conservation in both personal and community contexts(Falk & Dierking, 2010).

Zero waste programmes have proven to be another valuable tool science centres can use to provide information and raise awareness. One of the larger environmental organisations in the United States is Eco-Cycle which works with science centres to run school programmes that teach children about recycling, composting and other environmentally sound practices. These programmes not only educate school children on the science behind reducing their use of resources but also provide them with practical ideas for improving their own habits for reducing their environmental impact (Eco-cycle, 2022).

In partnership with educational programs, combining immersive art exhibitions with informative programming, science centres are an important tool in raising awareness of environmental issues and instating eco-responsible behaviour. Science centres provide audiences with the opportunity to learn about environmental science in meaningful and memorable ways, gain hands-on experience with environmental stewardship and environmental change, and ultimately foster a culture of environmental responsibility and positive change (Persson, 2015).

4.2 Educational Hubs for Sustainability

Science centres are at the forefront of implementing interactive education for sustainability, and through workshops, exhibitions and hands-on activities, they work with everyone from schoolchildren to adults to better understand complicated environmental and technological issues (Rákosi & Pongrácz, 2023).

The role of science centres as educational venues for sustainability City science centres aim to develop an audience for sustainable practices and ideas in the form of experiential learning and stimulating activities. They do this by dispensing technical material such as climate change, renewable energy and sustainability in an accessible way and in a practical way, taking advantage of innovative teaching methods. Science centres combine basic science knowledge with applications to make sustainability ideas more popular and sensible(Rákosi & Pongrácz, 2023). Workshops, hands-on exhibits and informal demonstrations are all examples of how science centres try to encourage sustainable practices. For example, hands-on activities like making solar ovens, designing water saving irrigation systems or playing around with smart energy systems allow participants to apply their knowledge of theoretical concepts to the problems they're facing, helping them to develop the skills to come up with novel sustainability solutions.

Furthermore, in addition to structured educational events, science centres also offer interactive education. Displays like virtual reality shows, 3D simulations and virtual reality tours show how certain technologies like nanotechnology help with promoting sustainable agriculture, as well as green building to encourage people to learn sustainable ways of living. With

self-directed educational activities for all age groups and learning styles, all people can develop a more comprehensive understanding of sustainability.

In addition, science centres excel at connecting sustainability education with the local context by demonstrating the challenges of sustainability in the region (water supply shortages, air quality, waste management) to generate awareness among the public on their part to solve these problems. Displays of local ecosystems, climate impacts and sustainable technologies make sustainability more relevant, thereby encouraging the visitor to take action for an environmentally sustainable lifestyle in their own community.

A key takeaway is that science centres may also foster interdisciplinary learning by inculcating sustainability as a social, cultural, and technological issue. Exhibits that link environmental practices with issues such as social equity, urban planning, and economic development encourage visitors to consider sustainability as a multi-faceted challenge worthy of all its participants – a view rooted in a common goal that encourages informed decisions for environmental sustainability in the long term.

By developing problem-solving skills through critical thinking, innovation, and practical experience, science centres help develop the skills of sustainability in the community. Through innovative, engaging learning that links scientific knowledge with real-world issues, science centres empower people to make informed decisions and contribute to an increasingly sustainable society (Persson, 2015).

4.3. Facilitating Community Engagement and Citizen Science

Through citizen science interventions, science centres engage communities in scientific research dedicated to problems they face in their local urban environment. Projects, for example, air quality monitoring, biodiversity mapping or data collection with the aim of reducing pollution, can enable citizens to provide us with useful insights aimed at supporting sustainability in cities.

Science centres provide many benefits for promoting community engagement and citizen science initiatives that may not come as a surprise. The main advantage for science centres is their open-source structure and use of technologies and tools. In contrast, in the case of traditional research laboratories, human-centred and more isolated scientific methods are used, often by a subset of experts. As such, science centres can also encourage citizen science by contributing in an engaged manner to urban sustainability goals (Kourtit & Nijkamp, 2014).

For example, in efforts to monitor air quality, science centres are typically at the forefront of using pollution sensors in public spaces and encouraging visitors to measure the amount of pollutants present in their surroundings. This exercise not only provides insights into what's at stake for the environment but also gives participants the tools to provide useful information for scientists and policymakers in order to design comprehensive solutions. In efforts to map biodiversity, science centres create opportunities for citizens to observe, record and collect information about their surroundings, using identification guides, mobile apps, and interactive displays. These mechanisms allow these local encounters to be documented and information to be taken from a wide range of different environments (e.g., neighbourhoods, parks, and school campuses), which greatly contributes to research being done more broadly.

Also on the other hand, science centres can provide support for pollution control measures, through guided workshops and less manual data-gathering kits. Guided workshops and data-gathering kits can help citizens collect data from rivers, lakes and urban spaces, including where they live and work. Whereas laboratories are good at doing exact analysis, science centres are good at mobilizing many large numbers of volunteers over long periods to collect data on various environmental variables and thus generate quite rich datasets that can be used to inform decision-making about environmental conditions. Another advantage of science centres is that they involve communities actively in urban planning and mobility projects by conducting thematic workshops, including mapping exercises and virtual reality simulations, asking visitors to tell them where the most pressing issues on public infrastructure are or what the best routes for walking are, and measuring traffic flow.

In areas with a high risk of natural disasters, science centres can lead flood monitoring activities. Through workshops and a range of readily accessible training resources, they can help people to monitor rising flood levels and provide real-time data that can inform policymakers. By drawing from the community's experiences, research findings are accurate and contextualised with that community's reality. In addition, science centres can promote energy efficiency through their implementation of sustainable practice at the local level. By using instrumented display cases to track how much energy family members use in their home and through a variety of hands-on solutions to reduce energy use, science centres provide community members with tools to make practical changes (Falk & Dierking, 2010; Pederson, 2020).

4.4 Innovation Incubators

Innovation is fostered in science centres thanks to the maker labs and collaborative spaces provided. These centres and their staff try to implement the use of new technology and actively participate in it. That's the direction where smart cities are heading in order to achieve sustainable urban development alongside educational innovations.

Within science centres, innovation incubators exist to allow people of all ages, experience and education backgrounds to participate and prototype emerging technologies and novel solutions. These labs enable local innovations by providing modern equipment like 3D printers, laser cutters, coding stations and robotics kits, which also enables further innovation at academic institutions as well. Local entrepreneurs, students, and other community members are often supported in creating smart city solutions such as new waste systems, energy-saving lights, and public health monitoring systems.

As a rule, science centres foster groups and collaborative learning. To this end, innovation incubators hold workshops, hackathons, and mentoring events that connect young innovators with professionals from science, engineering, and design and are designed to promote participation and a sense of belonging in an emerging community that prioritises ideas exchange and creative collaboration. For example, cooperative projects between

environmental science and engineering have led to the development of smart urban water management systems that reduce water wastage.

Moreover, science centres incorporate vocational paradigms into classroom instruction. Innovation incubators usually collaborate with universities, research centres, and regional businesses to provide comprehensive guidance during hands-on problem-solving sessions. This method allows learners to acquire competencies needed in smart city development, which include data skills, IoT technologies, and sustainable architectural design.

Science centres utilise digital platforms for their awareness campaigns in addition to physical exhibits. Interactive web-based resources together with online videos and social media posts reach audiences beyond museum boundaries. Science centres can expand their influence through digital content which stimulates sustainable living practices and scientific curiosity as well as health awareness among online audiences.

Science centres are also important teaching locations for schools through targeted awareness programs that combine interactive exhibits with real-world knowledge in order to lead to positive changes in student behaviour. Science centres play an important role in developing the well-being of urban populations by providing outreach on environmental issues along with healthy lifestyle choices as well as disaster preparedness (Pellegrino & Hilton, 2013).

4.5 Bridging Generational Gaps

Many science centres are active sites that enable people of different ages to learn and explore together. Each science centre, through its outreach policies, makes it possible for individuals of any age to participate in the activities. In this way, science centres help to close the gap between generations and build communities.

Science centres offer older learners a chance to practise active ageing. With specially designed programs, workshops, and lectures, these seniors are invited to comprehend contemporary scientific developments. Owing to areas like biotechnology and

artificial intelligence coupled with environmental sustainability, seniors can and are encouraged to actively deepen their knowledge utilising new technological devices. Oftentimes, these engagements increase the older participants' digital literacy and enable them to cope with the rapid changes in the digital world. These initiatives go beyond the intellectual by aiding in social and self-identity strengthening, allowing older generations to open up and offer their experiences and wisdom and encouraging people from younger generations to engage with older visitors.

An instance of such involvement was at the Nehru Science Centre in Mumbai, where computers and the internet were relatively new. The centre conducted a workshop for the elderly, teaching them how to send emails. After the workshop, participants gave touching testimonials. One retired gentleman expressed his thanks by stating, "I can now send an email to talk to my grandson thanks to this training." This instance shows how science centres can directly reduce the generational divide by allowing older people to use modern technology to communicate with younger family members.

Younger tourists, however, perceive the science centres as places of awe and exploration. The stems of their inquisitiveness are wonderfully sophisticated; the children can see how much and with what excitement they use virtual reality, interactive exhibits, and sophisticated makers spaces. Using active learning techniques, children acquire not only understanding of the scientific topics but also develop skills of scientific reasoning. Such education processes usually include scientific mentoring of young learners by established professionals and even retired scientists. These people not only give such profound advice but also take so many positive attitudes to relationships that exist in their societies.

Science centres are uniquely positioned to facilitate intergenerational exchange by cultivating shared learning opportunities. Family visits, during which grandparents, parents and children explore exhibits together, encourage conversations in which knowledge and values are passed down through generations. Citizen science projects also promote community involvement, uniting older adults providing experience and

wisdom with younger participants who bring new ideas and technical abilities. This collective setting helps to bond the social fabric and implicates the collective learning process.

In adopting this model of intergenerational engagement, science centres help to create inclusive and sustainable communities. They facilitate these shared learning experiences that help foster empathy, respect, and a sense of belonging, and they provide access to knowledge across all generations. As society faces complex challenges such as climate change, public health concerns, and digital transformation, science centres emerge as vital spaces where individuals from all walks of life can unite to build a better future together (Meadowcroft & Fiorino, 2007; Pellegrino & Hilton, 2013).

4.6 Public Awareness Campaigns

About Science Centres Science centres are critical to public awareness and are essential elements for allowing people to make informed decisions about their urban environments. Awareness is the seed for change since individuals need to be convinced and aware to take on sustainable practices or healthy lifestyles. By teaching the public why certain behaviours matter, science centres give communities the tools they need to make informed and responsible decisions.

Awareness is vital in the formation of behavioral changes. As Hemenway and a team of other researchers have posited, simply asking individuals to stop littering, conserve water, or adopt healthy practices likely falls flat if those individuals do not understand why. Science centres are adept at unpacking complicated issues through emphasising the "why" we should care about that work. This in-depth understanding pushes people towards better habits due to the nexus between knowledge and standing in the world.

Science centres utilise digital platforms for their awareness campaigns in addition to physical exhibits. Interactive web-based resources together with online videos and social media posts reach audiences beyond museum boundaries. Science centres can expand their influence through digital content which stimulates sustainable living practices and scientific curiosity as well as health awareness among online audiences.

Science centres serve as essential educational facilities through targeted awareness programs which merge interactive displays with real-world knowledge to stimulate beneficial transformations. Science centres play a crucial role in enhancing urban communities by advocating for environmental responsibility together with healthy lifestyle choices and disaster preparedness (Falk & Dierking, 2010; Pederson et al, 202; Lepore, 2023).

4.7 Enhancing Public Understanding of Emerging Technologies

Science centres provide essential support toward public comprehension of new technologies, which proves crucial for smart city development. The fundamental role of digital infrastructure together with IoT (Internet of Things), AI (Artificial Intelligence), and data systems in smart cities requires citizens to understand these technologies to participate in and benefit from urban transformation.

Science centres clarify complex digital technologies by creating engaging exhibitions with interactive installations and practical demonstrations. AI application exhibits illustrate how machine learning algorithms enhance traffic management while optimising waste disposal processes and boosting energy efficiency in smart cities. Science centres simplify complex technological concepts so visitors can understand both the advantages and potential dangers of these innovations.

Through Virtual Reality (VR) and Augmented Reality (AR) exhibits, visitors can experience immersive demonstrations of digital twins and simulation models applied in urban planning, disaster management and public safety. Interactive tools help visitors gain an intuitive visualisation of complex urban systems, which leads to a better understanding of how technology influences smart city development.

Additionally, science centres offer specific areas for workshops and open forums that cover ethical issues, data privacy, and digital literacy. Science centres enable people to make informed decisions, protect their privacy, and promote the

creation of just and sustainable smart city solutions by involving guests in discussions about responsible innovation.

Science centres can showcase effective applications of smart city technologies, like AI- powered surveillance systems, smart grids, and e-governance platforms, by incorporating real-world case studies. Science centres encourage critical thinking about how technology affects urban life while stimulating curiosity by showcasing both the revolutionary possibilities and the societal difficulties of these advancements.

Essentially, science centres are important educational resources that give residents the information and abilities they need to successfully navigate the digital environment of smart cities. They help build technologically inclusive societies where innovation is in line with moral principles and the welfare of the community by raising public awareness and encouraging participation (Lepore, 2023).

4.8 Supporting Policy Advocacy and Grassroots Movements

Science centres actively promote citizen participation in sustainability discussions, which subsequently develops public civic engagement through effective reference material. These Facilities organise public interaction events featuring forums, workshops and debates that give citizens opportunities to share their concerns alongside improving suggestions.

Workshops designed for interaction allow citizens to directly exchange ideas with experts regarding major city problems which include waste management and energy efficiency together with public health issues, among others. The platforms allow users to discover community issues so they can develop solutions for these concerns.

Science centres offer both resources and assistance to grassroots groups to develop their own locally driven work activities. Through digital tools, scientists offer crowdsourcing platforms that enable the exchange of information combined with public opinion surveys to engage citizens in developing their own communities.

The science centres organise dialogues which enable citizens to exchange ideas with policymakers face-to-face regarding that

matter. The involvement of local citizens through this method strengthens democratic access to urban development strategy formulation. The model gives citizens power to join actively with policymaking through accessible ways to engage and connect with decision-making authorities at both local and grassroots levels (Kammen & Sunter, 2016).

4.9 Strengthening Collaborations with Local Institutions

Science centres are particularly crucial in encouraging cooperation with surrounding universities and consequently significantly support sustainable urban development. Working with local governments, technological companies, and academic institutions, science centres can motivate creative ideas tackling contemporary urban challenges. These cooperative projects not only provide intelligent analysis and feasible solutions for sustainable city planning but also help science institutes to be more efficient.

Cooperation mostly takes place through educational institutions. Through educational initiatives in cooperation with colleges, companies, and universities, science centres can encourage ideas for sustainability. Through well-coordinated events like lectures, environmental campaigns, and student-led initiatives, these alliances provide young brains the opportunity to address pragmatic sustainability challenges. Including problems like urban ecology, energy efficiency, and climate change in courses helps the following generation of ecologically sensitive people.

Working with technology businesses also gives scientific institutes an opportunity to advance current ideas in resource management, smart infrastructure, and energy economy. Coordinated development of interactive exhibitions allows such partnerships to highlight pragmatic solutions such as solar panel systems, energy-efficient lighting, and smart grid technologies. These initiatives not only direct the general public but also inspire companies and local governments to use greener technologies.

Since municipal authorities usually control urban planning, science centres can be rather beneficial in producing

environmentally friendly substitutes. Science centres help to make cities more livable and ecologically sustainable by means of cooperative creation of better public transportation networks, waste management systems, and urban green areas. Science centres also offer venues for community involvement so that people may voice ideas and concerns by means of interactions with legislators and urban designers.

The connection between the Ontario Science Centre and the City of Toronto is one very remarkable example of such teamwork. The science centre helped to design the "Toronto Green Roof Strategy", which uses instructional exhibits stressing the benefits of green roofs for energy economy and stormwater control. This cooperation greatly helped the city to approve green roofing practices. Working with local officials, the San Francisco Exploratorium created displays on sustainable water management, including real-time monitoring of Bay Area water conditions, in order to train visitors on climate resiliency strategies.

When one actively interacts with local authorities, technological companies, and educational institutions, science centres become vital hubs for innovation and sustainable development. These alliances help communities to embrace environmentally friendly habits, therefore encouraging long-term constructive improvements in urban environments (Manika 2020).

4.10 Encouraging Behavioral Change for Sustainable Living

Science bases campaigns and designs exhibits on both personal and group behavioural modification. They help guests to adopt sustainable behaviours that support the general well-being of urban environments by encouraging responsible consumption, recycling practices, and energy economy.

The success of smart cities depends on behavioural modification since these metropolitan settings are built with presumptions about responsible citizen behaviour. Smart cities heavily fund creative infrastructure projects meant to raise quality of living while supporting environmental sustainability and efficiency by means of advanced technologies. These expenditures run the danger of being

underused or failing completely, though, without matching behavioural changes among residents.

Many smart cities, for instance, have automated dustbins that open without physical touch, thus promoting good waste disposal and hygiene. This system is predicated on citizens using the dustbins actively instead of littering public areas. Should people fail to engage in the desired behaviour, the effect of the technology is lessened, compromising the larger objective of preserving clean, healthy urban areas. Likewise, smart lighting systems meant to save energy by turning on only when motion is detected depend on users not purposefully changing sensors or avoiding specified paths.

Smart cities sometimes fund integrated public transit systems in transportation networks that help to lower traffic congestion and pollution. When people embrace public transport as a reasonable substitute for private cars, these systems run most effectively. The city's sustainable mobility objectives may suffer, though, if citizens still prefer personal vehicles even with better public transit choices.

By aggressively supporting sustainable practices that fit smart city infrastructure, science centres are especially positioned to close this behavioural gap. Science centres can show how small behavioural changes—like appropriate waste management, effective use of public transportation, or adoption of energy-saving practices—can magnify the benefits of smart city investments by means of interactive exhibits, narrative, and immersive experiences. A science centre's simulation of a smart city's waste management system, for example, might show how littering compromises automated solutions, highlighting the need for personal accountability.

Furthermore, science centres help the urban surroundings to inspire pride and responsibility. Visitors are more likely to see themselves as active participants in the success of the city if awareness of how clever city technologies are meant to enhance citizens' lives is raised. Showcases of actual success stories—where communities embraced good practices that improved the functionality of smart infrastructure—may motivate guests to follow in a similar manner.

Smart cities ultimately depend on people who are informed, cooperative, and thoughtful of their behaviour. Science centres are very important in forming this attitude since they help to close the gap between technology and behaviour so that expenditures in smart city innovations produce the expected results (UN DESA, 2018).

5. Case Studies

The case studies can be categorised into two key aspects. The first highlights how science centres use various programs to communicate the vision of sustainable living, educating the public on the importance of environmental care and responsible practices. The second demonstrates how establishing a science centre on a former dumping site can transform the area into a thriving, habitable space through thoughtful development and sustained efforts, as exemplified by Science City, Kolkata

5.1 The Exploratorium, San Francisco

The famous San Francisco science museum has ideas for smart towns that go well with them. The Exploratorium presents a remarkable case study on how to bring sustainability into a metropolis. Located on Pier 15 on the waterfront of the city, the museum has shown a significant dedication to environmental responsibility by means of creative architectural design and running procedures. Turning now to Pier 15 in 2013, the Exploratorium transformed an old structure into a sustainable architectural model. Approaching the best standards of environmental design, the construction got a LEED® Platinum rating for Building Design and Construction (BD+C). This outcome underlines the museum's commitment to reduce its environmental impact and offers a perfect forum for public education (Exploratorium, 2018).

A historic first for the Exploratorium is reaching Net Zero Energy classification. The museum generates as much energy as it consumes annually using energy-efficient technologies and on-site renewable energy generation.

This milestone ranks the Exploratorium as the largest Net Zero Energy Museum in the United States, illustrating how cultural institutions might lead in sustainable operations inside a

smart city paradigm (Kammen & Sunter, 2016). San Francisco's larger smart city goals are much aided by the Exploratorium's environmentally friendly policies. The museum fosters the use of renewable energy and reduces energy consumption, thus enhancing the resilience and sustainability of the city. Furthermore, rather significant as a learning environment in raising public knowledge about sustainability, promoting community involvement, and inspiring behaviour—all of which are basic components of the social infrastructure of a smart city—is the Exploratorium (Meadowcroft & Fiorino, 2017).

The Exploratorium is one outstanding example of how science centres might reflect and forward sustainability in metropolitan settings. The museum models for including environmental responsibility into cultural institutions with their distinctive architectural design, Net Zero Energy operations attained, and link with smart city projects. This case study shows the possibilities of science centres to not only direct the public but also offer an example in the search of sustainable urban development (Kourtit *et al*., 2014).

5.2 Science City, Kolkata, India

From nothing but a 49.6-acre site flanking the Eastern Metropolitan Bypass—a century-old garbage disposal area—Science City Kolkata is living evidence of the urban mutation. Launched for the Ministry of Culture, Government of India, by the National Council of Science Museums (NCSM), it aims to create an institution bringing science to the public and making it fun and easily accessible.

Opening in two stages, the Convention Centre Complex opened on December 21, 1996, and then the main Science Centre on July 1, 1997. The Science Centre boasts Space Odyssey, Dynamotion, Science Exploration Hall, Maritime Centre, Earth Exploration Hall, and the vast Science Park among its attractions. From its opening, Science City, Kolkata, has recorded more than 29.90 million visitors overall, proving once more that it is still a major destination for both domestic and international travellers equally (CIMAM, 2024).

One such example of effective urban redevelopment of cultural and educational value is the conversion of this abandoned dumping ground into a lively centre for science education and public participation. Apart from a place for education, Science City Kolkata is a model of sustainable urban development that transforms a neglected urban area into a hub for public involvement and scientific research (Albino *et al*., 2015).

5.3 Nehru Science Centre, Mumbai, India

Before its transformation, the land where the Nehru Science Centre stands today in Mumbai was an underutilised low-lying area that had become a dumping and storage ground for construction debris and industrial waste during the city's rapid urban expansion in the 1970s. The National Council of Science Museums (NCSM) undertook an ambitious project to reclaim the neglected site and convert it into a public science complex that would promote scientific learning and awareness among citizens. Inaugurated in 1985, the centre became the largest science museum in Western India. The redevelopment included extensive landscaping, creation of open-air exhibits, and the installation of energy-efficient infrastructure, effectively revitalising a neglected industrial zone into a green educational space.

Today, the centre's galleries — such as *Energy*, *Sound*, *Human Biology*, and *Digital Technology* — attract large numbers of visitors each year. Its Innovation Hub and Mobile Science Exhibition Units extend learning beyond the museum walls, carrying forward the same spirit of transformation that turned an overlooked site into a symbol of sustainable and inclusive development.

5.4 Sikkim Science Centre, Gangtok, India

The Sikkim Science Centre, located on the outskirts of Gangtok, also emerged from a neglected patch of barren hillside that was once used as an informal dumping ground for solid waste and construction material. Prior to its development, the land was ecologically degraded and unstable. Recognising the need to integrate environmental education with land restoration,

the NCSM, in collaboration with the Government of Sikkim, rehabilitated the area using eco-engineering and slope-stabilisation techniques. Native vegetation was planted, and energy-efficient structures were designed to minimise ecological impact.

Opened to the public in 2006, the centre now serves as a model of sustainable architecture and education in a fragile mountain ecosystem. Its exhibits on *Biodiversity*, *Renewable Energy*, and *Disaster Preparedness* highlight the interconnectedness of human activity and nature. The transformation from a dumping site into a hub of environmental awareness demonstrates how science-led redevelopment can combine education, ecology, and community participation. Through its outreach initiatives and eco-science camps, the centre continues to inspire citizens to embrace sustainability and resilience.

Together, the Science City in Kolkata, Nehru Science Centre in Mumbai, and Sikkim Science Centre in Gangtok embody a shared national vision: transforming neglected or polluted spaces into beacons of learning, sustainability, and social innovation. Each case illustrates how science centres can serve as both educational platforms and agents of ecological regeneration, aligning perfectly with India's broader mission of creating smart, sustainable, and inclusive urban futures.

The following curated workshops reflect how science centers contribute to the vision of smart cities by fostering scientific literacy, technical skills, and inclusive community engagement across diverse age groups.

*Others - This segment includes sectors like innovation, environment, health, digital skills, inclusive education, and civic engagement—supporting Smart City goals through technology, sustainability, public awareness, and capacity building.

Total Number of Workshops (all categories combined):

2022: 477

2023: 925

2024: 1193

Sector	Workshop Type	Exact Count	Examples
Workshop for Common Public	Hands-on experience	22	-Foldscope making -Mushroom culture workshop -Science Toy Making Workshop
	Literature/ General	37	-Popular Science Lectures on Water, Biodiversity -Fire Safety Awareness - Film Shows - Forest Conservation Lecture
Workshop for School students	Hands-on experience	27	- Robotics and Arduino Programming -Aeromodelling & Water Rocket Launch -Creative Science Camps -Astronomy with Telescope
	Literature/ General	53	-Science Quizzes -Poster and Essay Competitions -Awareness Sessions on Health, Environment
Workshop for scientists, researchers and teachers	Hands-on experience	32	-Artificial Intelligence Bootcamp -Biotechnology Lab Sessions -Orientation on STEM Projects - Tinkering & 3D Design
	Literature/ General	46	-Symposium on Emerging Technologies -Teacher Training on NEP - Seminars on Scientific Pedagogy - Geoscience Lecture
Others	Hands-on experience	138	-Workshop on Green Chemistry for Sustainable Tomorrow -Workshop on 'Waste to Wealth' -Workshop on 'Hand Washing & Sanitization'
	Literature/ General	184	-Workshop for New National Policy of Education -Workshop on 'Nature Trail & Herbarium Techniques' -Workshop on 'Nature Trail & Herbarium Techniques'

6. REAL-LIFE CASE STUDY

Students: As part of Singapore's Smart School Lab Initiative, high school students worked hands-on to construct smart home models using sensors and the Internet of Things where students participate in hands-on workshops involving IoT devices, coding, and AI. One such program allowed high school students to build simple smart home models using sensors and microcontrollers. This hands-on experience improved STEM comprehension and sparked interest in tech-related professions.

Reasearchers: Researchers at Amsterdam's Urban Living Lab worked with locals to create intelligent transportation solutions. In one project, researchers engaged with residents to co- develop a smart mobility system using real-time traffic data. The workshops allowed researchers to test prototypes in real settings, gather user feedback, and refine their innovations.

Public: In Pune, India, community workshops on to renewable energy and IoT technologies- taught locals how to use air quality sensors and construct solar lamps. The public was given the opportunity to take part in sustainable projects and better understanding of environmental challenges. These initiate sustainability projects or engage with local governance, showing how workshops can turn everyday citizens into active contributors to smart city development (Singapore Ministry of Education, 2023).

7. Conclusion and Recommendations

Relying solely on classroom teaching or segregated learning groups cannot cultivate the depth of understanding that modern technology demands. Genuine technological literacy develops when people of different ages and backgrounds collaborate in open, hands-on learning spaces. Science centres create exactly these opportunities. They bring together students, professionals, and curious citizens in workshops that encourage experimentation, creativity, and practical problem-solving.

The analysis in this study highlights that science centres are critical enablers of smart and sustainable urban growth. They serve not just as exhibition spaces but as living laboratories where innovation, public awareness, and social participation

converge. Through experiential education, community engagement, and the application of emerging technologies, science centres translate abstract concepts—such as artificial intelligence, climate resilience, and circular economy—into meaningful local actions.

Three key findings emerge. First, science centres advance scientific and digital literacy, equipping citizens with the knowledge to engage responsibly with technology. Second, they foster public participation and co-creation, empowering people to take part in addressing urban challenges. Third, their collaborative models with governments, industries, and universities position them as effective partners in achieving the Sustainable Development Goals (SDGs), particularly those related to education, climate action, and sustainable cities.

Building on these findings, several recommendations are proposed:

1. Integrate science centres into city planning frameworks so their educational and civic functions directly support sustainability policies.
2. Strengthen institutional collaborations across public, private, and academic sectors to promote innovation and shared problem-solving.
3. Prioritise inclusive access by designing programmes that reach underrepresented communities and bridge the digital divide
4. Maintain technological relevance through regular updates of exhibits, staff training, and incorporation of cutting-edge tools such as IoT, AI, and renewable-energy demonstrators.
5. Encourage citizen science initiatives that collect local data and translate it into actionable insights for municipal decision-making.

Ultimately, a city becomes “smart” not through technology alone but through the collective intelligence of its citizens. Science centres cultivate this intelligence by nurturing curiosity, critical thinking, and shared responsibility. When fully integrated into the smart-city ecosystem, they transform technological progress into human progress—helping urban societies grow more informed, equitable, and sustainable.

8. Challenges and Future Directions

The potential of science centres as education, community engagement, and behaviour change levers in smart cities is enormous, but several factors can prevent them from living up to their potential and stall in the process. One of the most pressing issues is funding and resource constraints. Smart cities must keep moving forward, and science centre are one of the centres that encourage public learning. While it's exciting to see current innovations coming, keeping interactive exhibits and technology fresh and new programmes at the cutting edge takes much time and money. And if resources are slow to become available or resources are unavailable altogether, then science centres may struggle to stay in business, providing outdated information, few visits, and a diminished role in the design of smart city initiatives.

Another big challenge is always having to meet the demands of these rapidly evolving technologies. As smart cities get smarter, they grow faster than ever, with advanced things like artificial intelligence, big data, and automation already built into everything you do. The science centres face that challenge head-on. They need to keep up, but the technology at play in their exhibits and how people learn is changing at an equally fast pace. If they don't maintain those changes, they will begin to feel outdated, hindering their mission of teaching citizens about the very things that are shaping their urban environment. And, most importantly, the changes also require professional staff, who may not always be available or affordable.

Other important barriers are geographical attainment and accessibility. While smart cities encourage a seamless, accessible experience, science centres often have cultural or logistical challenges in attracting and engaging populations with limited mobility. High-tech exhibits and educational opportunities are likely built to accommodate a broad range of demographics—such as those of the disabled, the ageing population, or participants from economically disadvantaged backgrounds. If a science centre is not attentive to and willing to make its content accessible to all members of the community, it may fail to be an educational community, reinforcing existing knowledge gaps rather than bridging them.

Finally, these challenges reveal the dangers of a lack of science centres in smart cities: without sufficient funding, the ability to adapt to technological change, and a strong emphasis on reaching out to all segments of the population, science centres could struggle to maximise their potential for education and engagement with citizens. And this could undermine their role as tools for scientific literacy, community engagement, and long-term behavioural change—all of which are the cornerstones of ensuring that investments in smart cities yield real improvements in urban living. To solve them, it is critical to step forward and tackle these challenges ahead of time so science centres don't just turn into recreational outposts that are less than effective levers in transforming cities.

Science centres are critical to a smart sustainable city by helping to prepare individuals to contribute towards urban sustainability and through their education, innovation, and community engagement, they help society to achieve its Sustainable development goal In the age of complex urban challenges, science centres will only become more important. Policymakers, educators, and urban planners must recognise and support these institutions to ensure their continued success in shaping a sustainable future.

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