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The Requirements for Smart Cancer Hospitals: An Overview

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ABSTRACT

Background: The increasing complexity of cancer care and rapid advancements in digital technologies have led to the emergence of smart cancer hospitals as innovative solutions to contemporary healthcare challenges.
Objective: This review aims to provide a comprehensive overview of the essential architectural, technological, and operational requirements for designing and operating smart cancer hospitals.
Methods: A synthesis of recent literature and global case studies was conducted to identify core elements defining smart cancer hospitals, focusing on technology integration, adaptable architectural design, environmental considerations, IT infrastructure, and multidisciplinary care.
Results: Smart cancer hospitals incorporate advanced technologies such as artificial intelligence, the Internet of Things (IoT), big data analytics, and telemedicine to enhance diagnostic accuracy, treatment efficiency, and patient experience. Modular and adaptable designs enable rapid technological updates and spatial flexibility. Sustainable architectural elements contribute to improved patient outcomes and staff well-being. Robust IT infrastructure ensures secure, interoperable clinical data exchange. Integration of multidisciplinary collaboration areas, palliative care, and psychosocial support fosters holistic, patient-centered care.
Conclusion: This review outlines critical components necessary for creating future-ready smart cancer hospitals that combine technological advancement with human-centered care. These insights aim to assist architects, healthcare providers, and policymakers in developing oncology facilities responsive to evolving cancer care needs.

Keywords: Smart Hospitals; Cancer Care; Healthcare Architecture; Digital Health Technologies; Internet of Things IoT

INTRODUCTION:

Hospitals and healthcare centres are considered fundamental infrastructure projects in every country. Their key role in a nation's healthcare system significantly impacts economic, cultural, and social policies—both at micro and macro levels. This level of influence underlines the pressing need to enhance the efficiency of such healthcare construction projects [1]. One effective strategy to improve productivity during both the construction and operational phases of hospitals is the integration of advanced technologies and the upgrade of technical systems used in these projects. These technologies are aimed at integrating healthcare data, facilitating access to clinical information for patients and physicians, and improving the efficiency of administrative and clinical processes [2]. Furthermore, they contribute to greater flexibility in service delivery and reduce the time and cost associated with information exchange across different levels of healthcare providers [3]. The concept of the smart hospital emerged from the process of digital transformation and is now viewed as a forward-thinking approach to healthcare delivery [4]. In smart hospitals, advanced information and communications technologies (ICT) are integrated with clinical and logistical systems to automate and optimize routine healthcare processes. Moreover, the use of big data analytics and artificial intelligence (AI) algorithms enables the prediction of disease progression, early detection of complications, and personalized treatment planning. One of the core infrastructures of smart hospitals is the IoT, a network of smart devices and sensors connected to central systems via the internet. These sensors can continuously monitor patients' vital signs, control temperature and humidity in operating rooms and intensive care units, and track the real-time location and condition of medical equipment [5]. This real-time data collection and smart alerting significantly enhance clinical care safety and quality [4, 6].

Cancer care, due to its diagnostic complexity and the need for continuous monitoring, benefits more than any other field from smart hospital innovations. IoT technology, by integrating data and clinical histories, enables the creation of personalized treatment pathways. This personalized approach is essential for improving the quality of life of cancer patients by increasing treatment effectiveness and reducing adverse effects [5, 7, 8].

The purpose of this study was to review the architectural and structural requirements of a smart cancer hospital. In this study, we first aimed to establish a precise definition of a smart hospital by reviewing various studies. Next, we reviewed the standards for a specialized cancer hospital, and by combining these two components, we summarized the requirements of a specialized smart cancer hospital through various studies.

Smart Hospital

The design and construction of smart hospitals is a complex and multifaceted process aimed at developing advanced medical centres through the integration of innovative technologies and optimized spatial planning. These hospitals incorporate technologies such as the IoT, AI, smart building management systems, and environmental sensors to collect and analyse real-time data. This integration enhances the accuracy and speed of medical services. Therefore, building a smart hospital goes beyond the physical structure and requires coordinated collaboration between the construction industry, IT sectors, and healthcare services [4, 9].

Definition of Smart Hospital

The concept of a smart hospital is the result of widespread advancements in ICTs, alongside the evolving demands of modern healthcare systems over recent decades. This trend began in the 2000s with the emergence of the "digital hospital," where institutions gradually transitioned from traditional paper-based systems to electronic health records. With the development of IoT, real-time tracking of equipment and patients through sensors became possible, allowing more precise and intelligent management of medical processes. Over time, technologies such as AI, robotics, and big data analytics were also introduced, leading to more personalized care and automated clinical workflows [9]. A summary of definitions for smart hospitals is provided in Table 1.

Key Features of Smart Hospitals

One of the key features in constructing smart hospitals is their flexible and future-oriented design, which allows rapid adaptation to technological changes and emerging healthcare demands. The use of advanced materials and prefabricated construction systems, alongside digital technologies in the building process, enhances both the speed and quality of construction

Table 1. Summary of definitions for smart cancer hospitals

Researcher	Year	Key Objective	Definition
European Union Agency for Network and Information Security [10]	2016	Automating processes and data collection	A hospital that enhances patient treatment through the IoT, optimizes asset management by creating an ICT environment connected to internal assets, and uses business process automation.
Frost & Sullivan [11]	2017	Reducing treatment costs and medical errors	A hospital that uses integrated ICT-based solutions to reduce patients' additional costs and prevent medical incidents.
Karen Taylor [12]	2017	Improving treatment performance and updating innovative functions	A hospital that aims to improve existing treatment methods and introduce new functions by optimizing the ICT environment and implementing automated processes.
Korea Embedded Software and System Industry Association [13]	2018	Integrated hospital management and patient monitoring	A hospital that creates an integrated management system using ICT for various hospital resources such as medical staff, equipment, information, and facilities to ensure patient safety and effective hospital management.
Seoul Asan Hospital Innovation Design Center [2]	2020	Improving the quality of medical services	A next-generation hospital that overcomes the limitations of existing hospitals in care quality, patient safety, patient experience, and efficiency using technologies related to the Fourth Industrial Revolution.
Ministry of Health and Welfare [2]	2020	Cost reduction and enhanced patient safety	A hospital that applies ICT technologies such as IoT to enhance medical services, aiming to improve patient safety, diagnostic and treatment quality, and reduce costs.
Mohammadzadeh et al. [14]	2023	Automation of treatment processes	A hospital that automates and optimizes treatment processes using modern technologies.
Rajaei et al. [15]	2024	Optimization of treatment and healthcare services	A hospital that optimizes treatment processes and enhances healthcare services through modern ICT technologies.
Anthopoulos et al. [16]	2024	Integration of healthcare service processes	A hospital that delivers healthcare services in an integrated and efficient manner using advanced technologies.

while also reducing maintenance and energy costs. Furthermore, particular attention to environmental hygiene, intelligent ventilation, natural lighting, and efficient flow management of patients and personnel is among the core design principles of these hospitals [17].

Architectural Frame of Smart Hospital

1. Modular and Prefabricated Design: Reducing construction cost and time in smart hospitals is facilitated through prefabrication methods and innovative technologies. Besides accelerating hospital commissioning, this approach minimizes environmental pollution around the site—such as dust, noise, and construction waste—resulting in sustainable and eco-friendly construction practices [17, 18]

2.Building Information Modelling (BIM) and Smart Monitoring: A robust infrastructure for IoT and building control systems enables integrated, intelligent, and real-time monitoring of healthcare spaces during the operational phase. This plays a critical role in optimizing energy use, enhancing safety, and increasing operational efficiency in smart hospitals [19-21].

3. Sustainable Design and Energy Efficiency: Enhancing environmental comfort through smart lighting, ventilation, acoustics, and internal temperature design improves the patient and visitor experience. Durable materials and controllable systems contribute to the long-term sustainability of the facility by extending its

lifespan and reducing costly maintenance needs [22].
4. Design Flexibility: Adaptable design enables smart hospitals to respond quickly to emergencies—such as healthcare crises—or the integration of new technologies. This functional flexibility ensures diverse healthcare demands are met over time [23].

Technologies Used in Leading Smart Hospitals

According to a 2025 report by Newsweek, the trend toward hospital digitalization is regarded as a key indicator of transformation in global healthcare systems. Findings indicate that smart hospitals have significantly improved the quality of health services by employing advanced technologies like AI, IoT, integrated health information systems, and digital infrastructure. Performance evaluations of these hospitals are based on criteria such as the level of digital transformation, patient experience quality, and the integration of technological systems—highlighting the crucial role of innovation in improving efficiency, safety, and personalized care delivery [24]. Some of these technologies are briefly outlined below:
1. AI: As a transformative technology, AI plays a fundamental role in the architecture of smart hospitals by enhancing the quality of care at every level. Leveraging high processing power and deep learning algorithms, AI enables the simultaneous analysis of vast amounts of medical data—including diagnostic images, treatment records, and biological data. It facilitates accurate and rapid disease diagnosis, minimizes human errors, and accelerates clinical response times. Additionally, AI's predictive capabilities and personalized treatment suggestions improve patient satisfaction while reducing the workload of healthcare staff. It also optimizes administrative and operational processes, leading to cost savings and improved hospital efficiency [25, 26].
2. IoT: As a cornerstone of smart hospitals, IoT plays a significant role in integrating clinical and support processes. By creating a smart network between medical devices, monitoring sensors, and support systems, IoT ensures continuous, real-time monitoring of patient conditions and hospital assets. Wireless connectivity allows critical patient data to be instantly transmitted to medical teams, facilitating faster and more accurate decision-making. Additionally, IoT enables efficient resource management, reduces energy waste, improves operational productivity, and enhances hospital safety. This technology supports a flexible infrastructure adaptable to future needs and contributes to improved care quality and patient experience [27, 28].
3. Digital Imaging: The integration of digital imaging technologies such as CT, MRI computed tomography scan(CT Scan), magnetic resonance imaging(MRI), and radiology with AI has revolutionized the analysis and interpretation of medical data. AI-powered algorithms can process vast volumes of imaging data faster and more accurately than human capabilities, enabling early disease detection and precise identification of affected areas. Furthermore, it allows for the design of personalized and optimized treatment plans, enhancing treatment effectiveness and reducing side effects—thereby significantly improving healthcare quality [29].
4. Robotics: The use of robots in clinical environments—ranging from precision surgeries to hospital logistics—reduces human error, increases procedural efficiency, and lessens staff fatigue. Robotics enhances precision in medical interventions and facilitates automated transport of medication and equipment, significantly improving hospital safety and effectiveness [30, 31].
5. Telemedicine: This technology enables the delivery of healthcare services remotely, making specialized care accessible in underserved and remote areas. It minimizes the need for physical visits, thereby improving the overall efficiency of healthcare systems. Telemedicine plays a vital role in chronic care management and follow-up services, improving the quality of care and patient satisfaction. As such, it represents a practical solution to access challenges and contributes to a better patient experience [32].

Requirements for Building Cancer Hospitals

According to the WHO and IAEA framework, cancer centres—including specialized cancer hospitals—are established in alignment with national cancer control objectives. The core pillars of these institutions include education, clinical guideline development, human resource capacity building, and effective service delivery model design. These centres function beyond clinical roles and hold multidimensional significance within the healthcare system. Accordingly, their development framework must be evidence-based, patient-centred, multidisciplinary, and well-organized [33].
A multidisciplinary cancer hospital requires expert clinical teams, oncology nursing staff, and support professionals. The primary units of these hospitals, as outlined by World Health Organization (WHO) and International Atomic Energy Agency (IAEA), are detailed in Table 2.

Table 2. Requirements of a cancer hospital based on A WHO–IAEA Framework [33]

Requirement	Description
Diagnostic Departments	Laboratory, pathology, blood bank, medical imaging, nuclear medicine, and pharmacy.
Therapeutic Departments	Surgical oncology, medical oncology, radiation oncology, oncology nursing, and paediatric oncology.
Palliative Care Departments	Palliative medicine, supportive care, nutritional therapy, rehabilitation, and cancer survivorship care.
Prevention Department	Includes cancer prevention and screening programs.
Education and Research	Continuous staff training, skills enhancement, and conducting clinical research.
Medical Information and Cancer Registry	Health information management systems and cancer patient databases.
Hospital Management	Includes effective administrative and financial management

1.Main Facilities and Infrastructure:

The main facilities and infrastructure of specialized cancer hospitals must provide the necessary capacity to deliver safe, efficient, and patient-centred medical services. These infrastructures should be flexible technically, functionally, and spatially to support specialized care, smooth workflows, and adequate access. The design of these sections should align with principles of performance optimization, service quality enhancement, and responsiveness to the future needs of the healthcare system. Some of these infrastructures include:

- Diagnostic and imaging services: including advanced radiology, ultrasound, nuclear medicine, endoscopy, and specialized laboratories (biochemistry, haematology, pathology).
- Inpatient and outpatient services: with dedicated inpatient wards for cancer patients (at least 30 beds), an intensive care unit (ICU), and outpatient clinics for consultation and chemotherapy.
- Surgical, medical, and radiation oncology: facilities for surgery, chemotherapy, and radiotherapy with centralized preparation of cytotoxic drugs.
- Palliative and supportive care: dedicated units for palliative care, pain management, psychological support, and rehabilitation.

2.Multidisciplinary and Team-Based Care:

Multidisciplinary and team-based care in cancer hospitals emphasizes structured collaboration among different specialties. This approach aims to improve treatment coordination, facilitate clinical decision-making, and enhance the patient experience. The team structure should be designed based on continuous collaboration, effective communication, and shared responsibility to deliver coherent services focused on individual patient needs. Some examples include:

- Multidisciplinary teams: coordinated cooperation of oncologists, surgeons, radiologists, pathologists, nurses, and other healthcare staff to provide comprehensive and coordinated care.
- Tumour Board meetings: regular meetings for group decision-making about personalized patient treatment.

3. Key and Support Services:

Key and support services in cancer hospitals play a fundamental role in ensuring treatment efficiency and sustainable operation of the facility. These services must be cohesively and integrally designed to enable rapid, precise, and safe support for diagnostic, treatment, and care processes. The structure of these sections should focus on facilitating processes, improving service quality, and minimizing disruptions in the patient treatment pathway.

- Equipped pharmacy and laboratory: providing rapid diagnostic and effective therapeutic services.
- Cancer registry and electronic medical records: comprehensive cancer database and electronic record system for follow-up and research.
- Quality control and safety: continuous monitoring of service quality and adherence to clinical standards.
- Patient navigation services: support services

to guide patients within the healthcare system and reduce confusion.

4. Research, Education, and Human Resource Training:

Research, education, and human resource development in cancer hospitals should be defined as an inseparable part of the organizational structure. This area aims to enhance specialized knowledge, improve professional skills, and develop the scientific capacity of the institution. The design of this section should facilitate scientific growth, knowledge production, and effective transfer of training to staff and future generations, while simultaneously improving treatment quality and contributing to scientific advances in oncology.

- Clinical research: appropriate infrastructure for clinical trials and applied research.
- Educational programs: continuous training for staff and specialized programs for students, residents, and support personnel.

5. Management Structure, Accreditation, and Social Interaction:

The management structure, accreditation, and social engagement in cancer hospitals should be based on transparency, accountability, and adherence to recognized national and international standards. These sections aim to ensure service quality, effective resource management, and increased public trust. The management framework should enable efficient decision-making, continuous supervision, and ongoing improvement, while also fostering active community engagement for education, prevention, and public health promotion.

- Transparent governance structure: structured management with defined administrative and financial departments.
- Accreditation and quality standards: compliance with national or international standards such as JCI, OECI, Joint Commission International(JCI), Organization of European Cancer Institutes(OECI) or Commission on Cancer.
- Community relations: programs for cancer prevention, early detection, and public education.

Adapting Smart Hospital Requirements to Cancer Patient Needs

In recent years, these healthcare centres have sought to improve patient experience, increase safety, and optimize resource efficiency by integrating advanced technologies such as high-speed 5G networks, medical robots, and sophisticated data management systems. Beyond technological aspects, smart hospitals require flexible architectural designs and integrated management systems capable of rapid adaptation to technological advances and therapeutic needs. Major functional requirements considered essential in building smart cancer hospitals include:

- Biophilic Design: Creating visual and physical connections with nature in waiting areas and chemotherapy spaces, as an effective health-based architectural approach, can significantly reduce stress, anxiety, and fatigue in cancer patients. Use of natural elements such as healing gardens, green walls, and aquariums not only provides a calming and pleasant environment but also stimulates patients' senses, enhancing psychological well-being and satisfaction during treatment cycles. Such design reduces monotony and stress typical of clinical settings and positively impacts the quality of experience for patients and companions. Additionally, these spaces offer higher quality, more pleasant environments for healthcare staff due to visual variety and mental rest [34].
- Modular and Flexible Spaces: Utilizing prefabricated components in the design of cancer hospitals, especially in high-traffic areas like chemotherapy and radiotherapy units, enhances the functional flexibility of the spaces. This approach enables rapid redesign or expansion of sections with minimal disruption to overall hospital operations. Prefabricated parts also reduce construction time, minimize environmental pollution during building, and limit interference with patient care processes. This system supports the creation of scalable, optimized therapeutic environments and facilitates response to future changes in treatment needs [18].
- BIM for IoT: Employing Building Information Modelling in the design and construction of smart hospitals, particularly cancer centres, enables precise and integrated planning for sensor placement, wireless networks, and IoT-connected medical equipment. This ensures that all smart infrastructure is properly embedded in the physical building structure from early design stages, preventing functional inconsistencies during operation. BIM's simulation and detailed virtual analysis improve control and communication system efficiency, facilitate access to real-time data, and simplify future maintenance and upgrades at lower costs [20, 35].

- Environmental Comfort Control: Careful and sensitive design of building envelope and HVAC Heating, ventilation, and air conditioning(HVAC) systems in cancer hospitals, especially in sensitive areas like chemotherapy and radiotherapy rooms, plays a key role in improving the quality of the treatment environment. The design should ensure controlled natural lighting, provision of healthy and adjustable airflow, and maintenance of temperature and humidity within optimal ranges. Such conditions improve thermal comfort, reduce patient stress, increase treatment effectiveness, and enhance environmental sustainability by lowering reliance on energy-intensive systems [21, 22, 36].
- Radiation Shielding and Protection: Walls and radiotherapy rooms must be designed using specialized protective materials and precise layout to ensure complete safety of patients and staff against harmful radiation exposure. The design should comply with radiation protection standards while providing rapid and easy access to emergency areas in critical situations. This approach maintains radiation safety while enabling swift emergency responses and reducing risks from potential accidents, thus supporting the functional resilience of high-risk hospital units [37, 38].
- Palliative Care Spaces: Palliative care units should be designed to create a calm and supportive environment with soft lighting, access to private courtyards, and multisensory elements like natural sounds and calming scents to enhance quality of life for end-stage cancer patients. These spaces provide feelings of security, mental peace, and anxiety reduction, creating a more humane and pleasant treatment experience for patients and their families, and significantly improving psychological and physical well-being in final days [36, 39, 40].
- Safe Paths for Patients and Visitors: Dedicated corridors for cancer patients should be designed following safety and comfort standards, including non-slip flooring, proper lighting, and clear directional signage. This design reduces aimless patient movement, eases navigation, prevents accidents, and by separating traffic routes, minimizes infection transmission risks in treatment areas, thereby improving the hospital's environmental health [38, 41].
- Integration of Rapid Diagnostic Technology: Advanced diagnostic rooms must be designed with full infrastructure ready for installation of modern equipment such as CT and MRI scanners and bedside laboratory devices. This facilitates faster, more efficient diagnostic processes, minimizes patient waiting times, and improves clinical decision-making speed and accuracy through immediate access to test results. Such designs enhance care quality and optimize treatment workflow [42].

Study's strengths and limitations

To the best of our knowledge, this is a comprehensive study that reviewed the requirements of a smart cancer hospital with a focus on its architectural aspects. However, the study had some limitations. One key limitation is the limited number of articles available on this subject, which resulted in a scarcity of relevant studies to draw upon. In addition, while we concentrated on infrastructure, architecture, and IoT, some important areas—such as financial considerations, workforce training, challenges of technology integration and interoperability, and patient acceptance or adaptation—were not addressed. These limitations highlight opportunities for future research to expand the scope and provide a more holistic understanding of smart cancer hospital development.

Conclusion:

The rising global incidence of cancer and the complexities of cancer treatment are among the main reasons for establishing specialized cancer hospitals. Considering the growing use of advanced technologies, establishing smart cancer hospitals is a priority. The establishment of smart cancer hospitals necessitates a multifaceted approach that integrates advanced technological infrastructures, patient-centred care models, and adaptive operational frameworks. Furthermore, flexibility in both technical and spatial infrastructure is essential to accommodate rapid advancements in oncology treatment modalities and evolving patient needs.

Implementing smart cancer hospitals requires careful consideration of ethical, regulatory, and organizational challenges to ensure data security, privacy, and compliance with healthcare standards. By addressing these comprehensive requirements, smart cancer hospitals can transform oncology care by improving clinical effectiveness, optimizing resource utilization, and enhancing patient satisfaction.

Future research should focus on developing

standardized evaluation metrics for smart cancer hospitals, conducting studies on their long-term clinical and operational impacts, and designing strategies to ensure equitable access to smart healthcare innovations across diverse populations.

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