

STANDARDS RESEARCH

Deployment of Health Care Facility Digital Infrastructure in Canada

A Framework for Standard-Based Solutions

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Executive Summary

Health care facility digital infrastructure plays a pivotal role in delivering today's health care services. Digital infrastructure has evolved rapidly in recent years to meet business demands from many market sectors, while growth in connected devices, data-driven insights, integrated system automation and workflows in health care create greater demands and complexity. Today's health care stakeholders are looking for scalable, secure, and future-proofed digital infrastructure to meet ongoing and future business needs. For the purposes of this report, health care facility digital infrastructure is defined as the hardware, software, networks, physical facilities, applications, and systems that are required to develop, deliver, monitor, control, or support digital services as well as the supporting skillsets and processes.

The objectives of this research report are to understand the current health care facility digital infrastructure landscape in Canada, identify gaps, and determine how standards-based solutions could better support the planning, implementation, intersystem communication, and life-cycle management of health care facility digital infrastructure. The research methodologies employed included a literature review, consultative interviews and a validation process. In total, over 550 records were identified from a large scope of sources, 14 interviews were conducted, and 20 subject matter experts were consulted to validate the proposed recommendations.

This report identifies several of the gaps between the health care facility's needs and today's available digital infrastructure standards, guidelines, and industry practices, and provides subsequent recommendations for standards-based solutions to help bridge these gaps.

Interview findings show that stakeholders are seeking to achieve maintainable, consistent, interconnected, networked/partnered, planned, and future-proofed health care facility digital infrastructure. While there is a large roster of standards available from several standards development organizations that can be referenced to assist with planning, designing, and implementing health care facility digital infrastructure, there are gaps between today's health care facility digital infrastructure requirements and the in-use tools that are currently available and that support the industry. Despite this obstacle, health care facilities remain resilient by adapting their internal tools, resources, and processes as they creatively seek solutions to meet their business goals.

This case-by-case approach has led to a lack of standardization between organizations and across provinces and territories, resulting in a lack of transparency and a greater risk that smaller, less resourced and less experienced organizations will be vulnerable when implementing health care facility digital infrastructure that is not future-ready and may not have the capability to achieve the full functionality from the end-devices, software, and systems. Overall, this leads to inconsistent patient experiences from organization to organization and may also lead to less equitable and accessible care.

To address the gaps found through the research report, 12 recommendations have been identified for development of an overarching health care facility digital infrastructure standard or guidance document. The recommendations target three broad categories: people and processes; system integration and intersystem communication; and continuous improvements.

These recommendations include:

1. Develop common definitions;
2. Develop a digital health vision and strategy;
3. Complete workflow mapping;
4. Develop use cases and an integration matrix;
5. Plan equipment in tandem with systems;
6. Instil privacy and security by design;
7. Complete risk identification – from new to existing;
8. Develop a responsibility matrix;
9. Design flexible and scalable digital infrastructure spaces;
10. Develop commissioning documents;
11. Institute a master system integrator; and
12. Ensure ongoing training.

Through the consultative process, many interviewees expressed concern that standardization in the area of health care facility digital infrastructure may hamper the ability to achieve innovation, that recommendations may not be achievable by all, or that the standards may fail to stay up to date with changing needs in health care delivery. When developing a digital infrastructure standard, consideration needs to be given to the variances in funding, skillsets, and resourcing between health care facilities and provincial regulatory body processes.



"Health care facility digital infrastructure plays a pivotal role in delivering today's health care services."

1 Introduction

Canada has a publicly funded health care system that provides universal access to hospital and physician services [1]. This system is funded through 13 provincial and territorial tax-funded public insurance plans. A health care facility (HCF) is a place that is dedicated to giving medical care [2].

HCF digital infrastructure plays a pivotal role in delivering today's health care services. Digital infrastructure has evolved rapidly in recent years to meet business demands from many market sectors, while growth in connected devices, data-driven insights, integrated system automation and workflows in health care create greater demands and complexity. Today's health care stakeholders are looking for scalable, secure, and future-proofed infrastructure to meet ongoing and future business needs.

As a result of this growth, the requirements for HCF digital infrastructure are rapidly changing and a greater reliance is being placed on digital infrastructure. This creates challenges beyond just the physical infrastructure, affecting people and processes, system integration and intersystem communication, and continuous improvements. Codes, standards, guidelines, specifications, and other documents address specific aspects of HCF digital infrastructure. These documents typically specify particular rules that must be filled in order for the named system to be safe and to function according to the industry best practices. These documents are used during the specification and procurement process; however, they generally do not cover all factors that impact the system, including planning, implementation, and operations.

To overcome the gaps that exist between currently available standards and the technology challenges reported by facilities, a majority of the HCF leaders and decision-makers engaged in the consultative process relied on internally developed processes and documents to guide the planning, implementation, intersystem communication, and life-cycle management of their digital health solutions. While these organization-led documents and methods may fill a void in the supporting guidance, they often lack validity and are not available to the greater health care system.

1.1 What is Digital Infrastructure

Digital infrastructure is the hardware, software, networks, facilities, applications, and systems that are required to develop, deliver, monitor, control, or support digital services. This infrastructure is supported by the surrounding people and processes [3].

1.2 Objective

The objectives of this research report are to understand the current HCF digital infrastructure landscape in Canada, identify gaps, and determine how standards-based solutions could better support the planning, implementation, intersystem communication, and life-cycle management of HCF digital infrastructure. This research study and subsequent report involved a

two-part process that included a literature review and consultative process, inclusive of interviews with key stakeholders, a gap analysis, and validation by subject matter experts. The overall study aims to answer the following questions:

1. What are the key systems, personnel, capital processes, and improvements that have led to the successful implementation of digital infrastructure?
2. What are the key factors that indicate implementation success?
3. What standards are currently used and what are the barriers to their use?
4. What strategies are used when implementing digital systems in a hospital environment?

By answering these questions, the end goal of this report is to provide recommendations to inform the development of an HCF digital infrastructure standard. By developing a standard or guideline, health care facilities would have a resource that could be used to guide major construction/capital projects or to inform leading practices that may be applied to smaller digital infrastructure projects.

2 Methodology

2.1 Literature Review

This phase of research involved a comprehensive literature review with a focus on published standards, guidelines, best practices, and peer-reviewed literature from Canadian, Australian, European, and some United States sources. The timeframe for the literature review encompassed material published from 2017 onwards (2015 onwards based on exception). This literature review provides an in-depth summary of the state of the industry, and in conducting the review it helped to finalize the list of stakeholders and questions to be asked during the consultation phase of the project.

This literature review aimed to answer the following questions:

1. Are there any existing and accepted statements that clearly indicate what an HCF "should"[1] or "shall"[2] do to implement digital infrastructure and technologies affecting the infrastructure?
2. How are other countries approaching health care digital facility infrastructure planning and implementation?
3. What are the recommended activities for ensuring success in each subsection (i.e., systems integration and intersystem communication, people and processes, and continuous improvements)?

To ensure that a thorough review of existing literature was conducted, Table 1 was created and reviewed with the project team in order to define domains of search and search terms.

This literature review examined three key areas of focus: system integration and intersystem communication; people and processes; and continuous improvements. While there are evident differences between many of the European countries, Australia, and Canada, there are also key similarities such as the presence of a publicly funded health care system and a movement towards public–private partnerships. Therefore, these jurisdictions were included in the literature review. Over 550 records were identified from a large scope of sources. These records were reviewed and the selection of documents that appear in this literature review were identified as being relevant to the research questions.

2.2 Consultative Process

Phase 2 of research is the consultative process. This involved a series of interviews, a gap analysis, and validation by subject matter experts.

2.2.1 Interviews

Interviews were conducted for the purpose of gathering insights into the current state, challenges, and opportunities as they pertain to HCF digital infrastructure. In total, 14 stakeholder sites participated

1 "Should" expresses a recommendation that is advised but not required.
2 "Shall" expresses a requirement that the user is obliged to satisfy in order to comply with the document.

Table 1: Domains of Research and Search Terms – Literature Review Research Plan

Domain	Terms		
Standards & Guidelines	ANSI, BICSI, CSA Group, IEC, ISO, NEMA, TIA		
Peer-Reviewed Literature	PubMed, JAMIA, JAMA, BMJ, Nature, arXiv, IEEE		
Agencies	MoH, Health Canada, Canada Health Infoway		
Industry Publications	HIMSS, Longwoods, Digital Health Canada, Health Canada		
Key Search Terms	Digital Infrastructure, ICT, ICAT, Health Care Data, Hospital, User Interface, Human Factor, Support Service, Use Cases	Future-Proofing, Governance, Medical Devices, Clinical Equipment, Interoperability, Integration, System Life-Cycle, User Experience, eHealth	Networks, Command Centre, Data Centre, Automation, Security, Artificial Intelligence, RTLS, Real-time Locating System

from across Canada from the following categories of stakeholder involvement:

- Hospital (5 organizations)
- Industry (4 organizations)
- Regulatory (5 organizations)

Participants were asked to respond to a number of open-ended questions that differed based on their stakeholder category and role. Interview questions were developed for the purpose of filling gaps that were identified from the literature review (see Appendix A for the list of interview questions asked).

2.2.2 Gap Analysis

A gap analysis was conducted to compare stakeholder needs identified through the interviews against the current state of existing documentation as outlined in the literature review. Recommendations were then developed to address the identified gaps.

2.2.3 Validation

The last phase of the study involved validating the recommendations that were developed in the gap analysis. The validation approach involved the distribution of a SurveyMonkey questionnaire to 26 cross-industry subject matter experts across Canada. This survey aimed to:

1. Determine if each recommendation was applicable at a national-level;
2. Determine the subject matter experts' agreement or disagreement with the recommendation; and
3. Gather additional comments to help inform the recommendation.

In total, 13 individuals responded to the survey. There was an overall 86% level of agreement with the recommendations. Survey questions asked can be found in Appendix B.

3 Literature Review

3.1 Digital Infrastructure Standards and Guidelines

Several standards and guidelines were found across multiple countries that can currently help health care facilities define what they should or shall do when implementing digital infrastructure. The existing standards and guidelines can be found in Appendix C.

3.2 Global Landscape

3.2.1 Canada

Canada has a publicly funded health care system known as Medicare, which provides relatively universal access to hospital and physician services [1]. Access to care is based on equity and need, as opposed to ability to pay [1], [4]. This includes availability of services but also quality of care [4]. This system is funded through 13 provincial and territorial tax-funded public insurance plans. Canada's publicly funded health care system

does face challenges, specifically related to Canada's aging population, fiscal constraints, and immense geographical landscape [2].

Related to the planning, design, and development of new health care facilities, Canada has a strong focus on public-private partnerships (P3s). This type of procurement model has been successfully used for an ever-increasing number of large infrastructure projects, including public hospitals [5]. Since 2003, more than 50 hospitals, valued at a total of over $18 billion, have been procured, constructed, and put into operation through the use of the P3 model. SaskBuilds, Alberta Infrastructure, Partnerships British Columbia, New Brunswick Department of Transportation and Infrastructure, Infrastructure Ontario, and Société Québécoise des infrastructures are the provincial government departments/agencies that oversee P3-related projects in Canada [1].

In Canada there are two main organizations, both not-for-profit, that focus on digital health. The first is Canada Health Infoway, which works with partners to accelerate the adoption of digital health solutions, focusing on quality, access, and efficiency in the delivery of care [6]. The second is Digital Health Canada, which is a professional association with a focus on connecting, inspiring, and educating digital health professionals within Canada [7].

3.2.2 Europe

Across Europe, public resources allocated to health services range between 3% and 9.4% of the GDP. While a majority of European health systems provide coverage for a comprehensive set of health care benefits, there are countries in which upwards of 20% of the residents are not covered by the health system. This causes variances in the amount of funding that is cost shared by the patient, as well as the availability and quality of services [8]. Out-of-pocket patient payments for medicine, dental care, and mental health care are primary concerns [8].

Regarding the capital planning process, there are significant differences amongst European countries. This can be exemplified by the dissimilarities in capital financing. While the French hospital sector is primarily self-financing or funded through private finance loans with some P3s [8], in comparison, Sweden's decentralized government system's funding for large capital investments comes from the regional government, with hospitals having little to no role in the capital development planning process [8].

Similar to Canada, Europe has agencies and organizations tasked with moving their digital health agenda forward. One of the primary agencies supporting this is Digital Health Europe, which is funded under the Horizon 2020 Programme. This agency has an aim to support the deployment of digital solutions, specifically those that address person-centred, integrated care. They do so through the identification, analysis, and replication of best practices and stakeholder mobilization [9]. Another organization focused on a similar agenda is MedTech Europe, which has a mission to create sustainable health systems while making innovative medical technology available to more people. It does so through advocating for policies, innovation, stakeholder engagement, research and data, communications, industry events, and training sessions [10].

3.2.3 Australia

State, territory, and local governments share the responsibility for running Australia's health system [11]. Australia, similar to Canada, has a public hospital system called Medicare that provides free or low-cost access for most health care services. Access to private sector services are available through private health insurance [11]. Australia's health system faces increased demands and challenges as a result of an aging population, increasing rates of chronic disease, high costs of medical research and innovations, and indecision on how to make the best use of emerging health technologies [11].

Most public health care procurement in Australia is undertaken by the states. No central body coordinates state procurement in the interests of efficiency and quality. Public service administrators and industry stakeholders acknowledge major opportunities to improve costs and efficiency; however, efforts to maximize value remain hampered by transactional issues, high tendering costs, arbitrary funding cycles, and overly restrictive specifications designed to minimize risk and "future-proof" purchasing decisions [12].

The Australian government has an agency called the Digital Health Agency that is tasked with improving health outcomes for Australians through a national digital health strategy and the delivery of digital health care systems. This agency focuses primarily on engagement, innovation, clinical quality, and safety [11]. Furthering this, the Australian government has invested significant funding into what is known as the Digital Health Cooperative Research Centre. This research centre aims to improve quality of health care through evidence. To do so, it is developing a multidisciplinary task force focused on bringing together collective expertise in research and development for data, information, and telecommunication technologies [13].

3.3 Achieving Success

3.3.1 System Integration and Intersystem Communication

Findings from the literature have been grouped into four different areas of focus: system selection, clinical equipment, interoperability, and device regulations. Appendix C provides a listing of the standards identified through this literature review by country, along with their potential relevance to this subsection. In total there are 42 standards that include information relevant to this topic.

3.3.1.1 System Selection

Limited literature related to ensuring interoperability and communication for system selection was found and this concept will be further explored in the consultative interview phase.

3.3.1.2 Clinical Equipment

While a listing of clinical equipment was not located, it was identified that physicians are often given freedom to choose which equipment or supplies they prefer to use, and which can drive up costs and reduce standardization [14]. Different strategies can be used in order to allow maximization of cost savings, flexibility, and standardization while not completely restricting choice. An example of strategies are the formulary model and the payment-cap model.

3.3.1.3 Interoperability

This literature review revealed that there are existing frameworks in place to support the interoperability of systems and to ensure that data can be shared seamlessly within organizations and between partners. These frameworks include HL7 FHIR [15] and SNOMED CT [16], both of which aim to solve technical and semantic interoperability. Another way of circumventing the semantic interoperability of trying to make multiple producers create data that are understood by multiple consumer systems is that information can be stored in a centralized repository [17].

3.3.1.4 Device Regulations

There are challenges that exist as digital technology is a grey area between consumer products and medical devices. The U.S. Food and Drug Administration (FDA) is currently modernizing its 510(k) program, which deals with the approval of device updates that differ from versions that were previously approved [18]. While this will cover the use of consumer devices for medical purposes, at present these devices are only covered ad hoc. As an example, in the case of a medical device being used as an ophthalmic instrument, the FDA regulatory requirement called Optical Radiation Safety Testing becomes relevant [19]. Similarly in Canada, Health Canada is working to adapt and keep pace with innovation in digital health. Through its Regulatory Review of Drugs and Devices initiative, Health Canada is establishing a new division within the Therapeutic Products Directorate's Medical Devices Bureau, which will focus on the pre-market review of digital health technologies. Key areas of focus will include wireless medical devices, mobile medical apps, telemedicine, software as a medical device (SaMD), artificial intelligence, cybersecurity, and medical device interoperability [20].

In Canada, Health Canada provides guidance on what defines an SaMD. The term SaMD is defined as "software intended to be used for one or more medical purposes that perform these purposes without being part of a hardware medical device" [21]. Medical purposes are classified as either being "intended to acquire, process, or analyze a medical image, or a

signal from an in vitro diagnostic device or a pattern/signal from a signal acquisition system or imaging device" or "intended for the purpose of supporting or providing recommendations to health care professionals, patients or non-health care professional caregivers about prevention, diagnosis, treatment, or mitigation of a disease or condition" [21]. An SaMD falls under Health Canada's current regulatory framework for medical devices and as such is subject to the requirements governing the sale, importation, and advertisement of medical devices in Canada [21].

This literature clearly identified that Canada is currently addressing gaps related to its digital device regulations. This work should be closely monitored and reviewed again as progress is made.

3.3.2 People and Processes

Findings from the literature have been grouped into seven different areas of focus: personnel resource requirements; governance and organizational structure; guiding criteria for infrastructure investment; guiding principles for deploying technology; partnerships and collaboration; clinical and operational workflows; and user engagement. Appendix C provides a listing of the standards identified through this literature review by country along with their potential relevance to this subsection. There is a total of 23 standards that include information relevant to this topic.

3.3.2.1 Personal Resource Requirements

3.3.2.1.1 Human Evaluation and Responsiveness

The human factor of digital technology is important to explore as it requires upfront consideration for how staff engage with and interpret data, the level of oversight needed, and real-time communication requirements between staff and patients, particularly for portable devices that allow real-time communication to flow between patients and staff [19].

Aligned with the human evaluation component of this section is the need to evaluate and ensure that user interface design principles are considered. Canada Health Infoway has established 5 user interface guidelines to support the development and selection of a user-friendly interfaces and experiences with platforms [22]. These include:

- Limit the number of concepts presented to the user;
- Use plain language in the user interface;
- Use headings and avoid repetition when displaying encoded and unencoded information;
- Avoid truncation whenever possible; and
- Use graphical methods to ease comprehension.

Addressing the human factors of usability are Nielsen's 10 usability heuristics for user interface design. These heuristics act as a rule of thumb [23]. There is a significant amount of literature related to best practices for usability and user-friendly interface design.

3.3.2.1.2 Evaluating the Appropriateness of Use Cases

The Agency for Healthcare Research and Quality defines use case as a "set of instructions that an individual in a process completes to go through one single step in that process. It describes what the user does to interact with a system" [24]. The purpose of use cases is to better understand how a user is supported by a system during the completion of a task [24].

Limited documents related to the selection of appropriate use cases were found. Of those that were identified, the primary focus was on vendors, which posed a risk of bias and therefore were not included in this review. For those use cases that were included in this review, the primary focus was on artificial intelligence (AI) and real-time locating systems (RTLS).

In a care environment such as end-of-life care, where uncertainty is inherent, and ethical decision-making is complex, the appropriateness of using AI to make ethical decisions is questionable. When considering the implementation of clinical use cases for AI, needs should be informed by clinicians and their patients and gold standard AI protocols should be established to ensure AI decisions are understandable by health care professionals [25].

In a conference paper that highlighted the beginning works of a business case for a Canadian hospital that was considering the acquisition of an RTLS system, the following use cases were identified:



"Workforce skillsets and training are crucial to the planning, implementation, and ongoing success of digital health solutions."

- Patient Abduction/Wandering
- Staff Safety
- Equipment Location

It was recommended that hospitals wishing to implement an RTLS system establish an interdisciplinary team to develop the use cases for RTLS. This will help hospitals better understand how RTLS will be used and what the intended performance of the system is [26].

3.3.2.1.3 Enhanced Training and Workforce Development

Workforce skillsets and training are crucial to the planning, implementation, and ongoing success of digital health solutions. It is recommended that organizations develop and deploy training and educational programs to support organizations, developers, clinicians, and consumers [27].

No broad overarching recommendations, guidelines, or best practices related to education and training as it pertains to digital health infrastructure were found in this literature review. This aligns with findings from the 2017 Senate report that set out recommendations for the application of robotics, AI, and 3D printing in health care. One of the key issues raised was the need for education and training requirements [28] .

However, specific criteria that should be taken into consideration for the use of AI were found [28]. Such criteria include engagement from a multidisciplinary team made up of key stakeholders such as AI developers, implementers, health care system leadership, frontline clinical teams, ethicists, humanists, patients, and caregivers. Engaging a multidisciplinary team such as this allows each group member to bring forth unique perspectives, requirements, and expertise [27].

To support AI, it is recommended that a data science curriculum be developed, which would include teaching about the importance of engaging diverse development teams and ethical considerations such as equity, inclusion, and potential unintended consequences, (how to use AI products and services and how to assess its appropriateness [27]). Lastly, to inform consumers about consent, privacy, and health care, AI consumer health educational programs should be developed and should target all educational levels [27].

3.3.2.1.4 Modernized Skillsets

Much of the literature that was identified for this section focused on genomics, data, and AI; however, no broad overarching recommendations for skillsets as it pertains to HCF digital infrastructure were identified.

Information and communication technology specialists have been shown to make up only 1% of the health care workforce, and upwards of 70% of health professionals do not use digital solutions as a result of knowledge gaps, specifically those that are related to data analytics. It is recommended that health care organizations build up digital knowledge and skills among clinicians [29]. In a review that sought expert opinion from across the U.K. and overseas, the impact that technological innovation had on the National Health Service workforce was explored. Recommendations from this report target three areas:

the citizen and the patient, health care professionals, and the health system itself [30].

The citizen and the patient should be engaged and should receive education about genomics and digital health technologies if needs were identified. Programs should be developed by trusted sources and co-designed with patient and carer organizations, and delivered through existing patient support avenues [30].

Several recommendations were made in regards to skillsets for health care professionals. For example, having organizations provide health care professionals with access to literacy training and continuing digital health education, with a specific focus on health data procurement, curation, integration, governance, and ethics of autonomous systems such as AI, critical appraisal, and interpretation of AI and robotics.

3.3.2.1.5 Change Management

Historically, innovative digital health solutions have shown success at a pilot level but, unfortunately, have faced challenges when deployed at scale. This same challenge has been exhibited when a successful solution is implemented within a different region and highlights that one size does not fit all when implementing digital health solutions [31]. These challenges can be partially attributed to change management, whereby a successful deployment requires significant changes to workflows and organizational relationships [31].

This is especially important when looking at the translation of evidence into clinical practice. Research has shown that approximately half of evidence-based practices ever reach patients in a clinical setting. The cause of this has been discussed and is thought to be due to the habitual nature of humans and the lengthy, at times months long, process to engage and sustain intentional change. When implementing digital solutions, the routines of patients, physicians, and nurses, as well as internal organizational processes, must change. To overcome the challenges in sustaining these changes, they need to be embedded in the culture of the organization itself [32].

A comprehensive approach needs to be taken when deploying these changes to ensure that governance and leadership are clearly established, stakeholders are identified, communication channels and messages are clear, and that workflow, education, and training are considered. To support this change, Canada Health Infoway has consolidated best practices and published a framework for change management [33].

3.3.2.2 Governance and Organizational Structure

3.3.2.2.1 Data Governance

Data governance faces several challenges, specifically related to understanding where data lives, how to access the data, process implementation for data security and access, and the development of the right skillsets and resources to support and manage health care data [34]. To overcome these challenges, a strong data and analytics strategy can be developed with a focus on ensuring there is alignment between analytics initiatives and the organization's strategy, improving evidence-based culture, taking a lead from the top, engaging in the early philosophy, and having a successful execution [35]. It is recommended that this strategy answer the following questions [35]:

- What are my clinical or business objectives? How will data help address them?
- What data assets do we have now, and which ones will we need in the future to meet our objectives?
- How do we ensure our data are stored in a way that promotes durable, secure access for analysis that is compliant with standards when we use the data?
- How will our data be governed?
- How will our data be packaged to enable use and reuse?
- How can we improve data interoperability to "connect the dots" across clinical and operational data?

Governance remains a key challenge across the digital health infrastructure. This literature review revealed limited best practices or recommendations for governance.

3.3.2.2.2 Policies and Procedures

In European countries, the COVID-19 pandemic has highlighted the lack of investment in and adoption of digital health solutions and has raised the awareness that their data are inaccessible or unusable and, in this

current form, increases the vulnerability of their health care facilities. Critical steps to improve the digital resilience of European health systems have been developed with a specific focus on the development of a code of conduct for the processing of genetic, biometric, or health data. These steps in developing the code of conduct include gathering public interest to determine legal requirements and specifically to develop a common interpretation for what accounts for public interest. The purpose of this code is to determine exactly what the public considers to be unjust in terms of data sharing and usage and to negate the restrictive prevention of data sharing between health care facilities, particularly when the sharing of data does not align with the public's interest or is critical to the outcomes of the patient [29].

To ensure confidentiality, a relative anonymization model could be used to allow for traceability without subjecting the public to identification. In addition, an opt-out model could be used by the public to consent to secondary use of data in research [29].

Lastly, guidelines should be established to support patients, physicians, health care managers, and industry in mitigating risks and developing a common understanding for the control, use, and sharing of data, and for achieving the potential benefits of using health care data appropriately [29].

3.3.2.3 Guiding Criteria for Infrastructure Investment

3.3.2.3.1 Flexibility in Design

Hospitals should no longer be considered "complete" when they are first built; their infrastructures are complex and dynamic and should be constructed in a flexible manner to support future growth. The building and the infrastructure need to be able to respond to changing needs, requirements, and changes from different drivers such as new technologies or national policies. There was limited literature related to how to future-proof and provide flexibility in digital infrastructure. It was, however, identified that building information modelling (BIM) technologies can help support the construction of a future-proofed infrastructure investment in both new and existing buildings [36], [37]. Using BIM technologies on health care projects has become mandatory in the U.K. and is becoming an industry standard in Canada as well.

3.3.2.3.2 Prioritizing Investments

Currently there is not a well-accepted guideline for prioritizing investments in technologies and their supporting infrastructure. There are, however, several standards and guideline development organizations which support various technologies throughout their work, but the main driver of prioritization is currently left up to the individual HCF. Examples of these types of guidelines include EMRAM [38] and INFRAM [39].

There is some guidance on what should be considered when prioritizing investments such as conducting a health-economic impact analysis (encompassing cost effectiveness and long-term savings for regulatory and payer approval) [40], but there is no single activity recommended for achieving success.

With a more specific focus, the World Health Organization (WHO) has guidelines regarding the prioritization of digital health interventions that should be available via mobile devices. This guideline does not sufficiently cover all investments that would need to be made for an HCF digital infrastructure, however the guideline is meant to gradually expand to include a broader set of digital health solutions. A list of current minimum recommendations for provider and/or patient mobile devices within the health care setting have been developed. Examples include targeted client communication, provider-to-provider telemedicine, and client-to-provider telemedicine [41].

It has also been identified that prioritizing investments in infrastructure to support telehealth initiatives could help save money and improve care, particularly in rural areas. The recommendations in the literature are for Europe and outline several key considerations [29] with the following that would apply to Canada:

- Connectivity is critical for telehealth to help address doctor shortages in remote communities;
- Digital infrastructure for health must be built quickly; and
- Telemonitoring of chronic diseases, telecare, virtual conference tools, and AI chatbots can be used to reduce pressure on hospitals and the entire health care system.

These sources provide initial steps into the prioritization of digital health infrastructure; however, they are very solution focused and highlight that a gap in an overall strategy for prioritizing investments are at an organizational level.

3.3.2.4 Guiding Principles for Deploying Technology

3.3.2.4.1 Balancing Risks of Rapid and Bottom-up Deployment

Bottom-up rather than top-down health innovations provide many benefits when they are designed by the people using the systems, but they also suffer from some pitfalls as a consequence of being custom developed for specific organizations or uses [42]. These technologies often shadow information technology and fall under the radar of governing organizations that control privacy, information technology, and risk [42].

Organizations need to invest in fostering bottom-up innovations and providing structure while removing some of the barriers to getting an initiative up and running, but they also need to effectively manage patient safety risks. To do this the organizations need to focus on organizational learning, proactive risk management, and making risk management decisions transparent and explicit [42]. Newer technologies that are more capable of rapid implementation can be harder to govern and to ensure that the risks remain low. Mobile apps in particular can be created quickly without going through robust engineering requirements and development which can lead to less documentation and more difficulty in determining risks and ability to govern [43]. Research institutes such as Women's College Hospital Institute for Health System Solutions and Virtual Care (WIHV) [44] or the NICE standard [45], [46] can be used to evaluate clinical applications and tools that may fall into this category of rapid development to ensure that they are clinically valid and appropriate for implementation in the hospital setting. This is particularly important for health facilities that do not have the internal expertise in evaluating applications or other fast-paced technologies.

3.3.2.4.2 Partnerships and Collaboration

Partnerships are required to overcome challenges in digital health. As an example, the National Health Service recommends that partnerships with relevant regulatory bodies are needed to establish a clear, robust framework for use of genomic data by health care providers. These frameworks should place focus on patient confidentiality with an aim to garner confidence by the community [30].

Further to this, the literature points to many different barriers affecting partnerships, such as innovators and technology companies partnering inconsistently and facing challenges with gaining HCF and clinician interest for their products and services [47]. This has a direct impact on the relevance and appropriateness of their technologies. To overcome these challenges there are several strategies that can facilitate the implementation of innovative solutions. One recommendation is to form partnerships early and engage patients and clinicians [47]. A collaborative, trusting, information-sharing, time-concise, and cost-considerate environment should be established by leveraging tools that support stakeholders in understanding one another's roles [47].

3.3.2.5 Clinical and Operational Workflows

Research currently related to how workflows impact integration and communication between systems is mainly focused on note-taking and data input. A big challenge in interoperability is that clinical notes are taken in an unstructured way [48]. One recommendation from the literature for achieving success was increasing the usability or user-friendliness of a system and making sure that the system or technique itself is motivating users to input data in a structured way [49].

This literature review identified additional challenges related to integrating digital solutions into health care delivery and workflows. Contributing to this is the notion that model developers and data scientists do not sufficiently consider how their models will be integrated into health care delivery [50]. It is suggested that algorithms should be designed by considering implementation, first asking what the intent of the solution is and providing a link between artificial intelligence and clinical and operational capabilities [50]. Concepts of ethics, equity, inclusion, and bias should be incorporated into clear goals when deploying or developing technological solutions for clinical settings [32].

3.3.2.6 User Engagement

User engagement as it relates to digital health, recognizes that engagement is a process inclusive of people's interactions with digital tools, and that the degree of engagement is driven by an

individual's investment to interact with the solution. While behavioural measures account for one way of measuring engagement, there are remaining gaps. Research suggests that further work needs to be done to define and measure engagement. In doing so, solutions such as machine learning can be implemented in ways that support stakeholder engagement and quality care. Canada Health Infoway has developed a process for engaging stakeholders that offers a proven approach to stakeholder engagement. This four-stage process includes [51]:

- Identify Stakeholders: Whereby persons impacted by the project are identified.
- Analyze, Segment and Prioritize Stakeholders: Whereby stakeholder needs and concerns are evaluated.
- Understand Stakeholder Perspectives: Whereby stakeholder's questions and desired level of responsibility and involvement are understood.
- Incorporate Stakeholder Perspectives: Whereby it is determined what level of input from stakeholder's perspectives are included in the project.

3.3.3 Continuous Improvements

Findings from the literature have been grouped into four different areas of focus: new and existing buildings, specific-building technologies, system life-cycle management, and future-ready technological systems.

Appendix C provides a listing of the standards identified through this literature review by country along with their potential relevance to this subsection. There are four standards that include information relevant to this topic.

3.3.3.1 New and Existing Buildings

Scalability is key when designing new infrastructure in new and existing buildings. This allows facilities to make continuous improvements to the infrastructure and add new systems that use the infrastructure without undergoing a complete infrastructure construction project. The literature around designing an HCF digital infrastructure is limited; however, some support and basic information can be extrapolated from other industries. One area where there is sufficient consensus is privacy and security, which should be by-design in all newly implemented systems and not left up to users to ensure privacy and security of organizational or patient data [52].

3.3.3.2 Specific Building Technologies

For specific building technologies there are standards and research on how to correctly implement these across industries. For instance, one technology that appears to provide adequate coverage is the use of wireless local area networks (WLANs) to support the expansion and reliability of telemetry [53]. However, there is a general gap in the literature on how to achieve success in implementing building technologies.

3.3.3.3 System Life-Cycle Management

It is noted that there was limited research found related to the life cycle (i.e., moving through the phases of concept, project, transition, operation, and retirement) for HCF infrastructure. The importance of life-cycle management has been addressed in Section 3.3.2.2, Governance and Organizational Structure.

3.3.3.3.1 Data

Governance of data requires attention throughout the life cycle of data from creation to maintenance, depreciation, archiving, and finally deletion. The step that is often missed even in research frameworks is deletion [54], which causes data to end up being "eternal" [55]. Although there is knowledge within the industry about the importance of data governance, especially with the advent of artificial intelligence and genomics, there currently is no standard or guideline for this topic.

3.3.3.3.2 Technologies

The management of life cycles for technologies in health care or the planning surrounding technologies was a topic area of focus for the literature review; however, the review did not find relevant articles on this topic.

3.3.3.3.3 Infrastructure

Although there is knowledge within the industry about general life spans of specific infrastructure elements, no current published literature was found on the life cycles or longevity of infrastructure in health care.



"Planning for a future-ready technological system is about collecting high-quality data in large quantities."

3.3.3.4 Future-Ready Technological Systems

Planning for a future-ready technological system is about collecting high-quality data in large quantities. The other important part of being future-ready is ensuring intersystem communication and having the correct people and processes in place to evaluate and implement new technologies [56]. From the literature review, it was noted that there was no common consensus or leading framework for system (hardware and software) planning, as such no documents were found for the creation or planning approach for a future-ready technology system.

3.3.3.4.1 Artificial Intelligence/Learning Health System

The current obstacles for implementing machine learning in health care is the availability of high-quality data in large quantities [56] and interpretable models [57]. In order to have high-quality data, the structure of data sets is of the utmost importance and there needs to be great care taken in not only the quality but also the comparability of datasets in order to ensure that the information extracted is not completely trivial and driven by the composition of the data [25]. Organizational architecture that facilitates community formation must include communities of patients, families, and clinicians and researchers that all work together to produce and use big data [56]. The second item is ensuring that the models are interpretable. To do this the implementation of artificial intelligence algorithms needs to take in to account the users, human understandable algorithms need to be used, and the outputs must be displayed in a human-understandable manner [25].

3.3.3.4.2 Big Data

The recommendations around big data are similar to other technologies in that planning needs to be done before implementation. Standardization and best practices for metadata are required in order to capture precise descriptions and data types [55].

An important step in implementing any standardization in selection is incorporating physicians and other users in the decision-making around the standards to improve acceptance and adoption [58]. These decisions also need to be made with appropriate data that can inform and enhance the decision-making process. This data can be from systems within the hospital and their performance or performance measurement data based on previous decisions of the purchasing group to improve efficiency of purchasing decisions [59].

Unique device identifiers (UDIs) are key to tracking devices across multiple health care settings. A standard has been implemented in the United States, however Canada does not have a similar standard for its devices. An appropriate standard would help ensure that the UDI is integrated into electronic health information systems and is human-readable and automatically captured [60].

3.4 Summary

This literature review sought to find existing literature, standards, and guidelines and identified the following key items:

1. There is a limited number of existing and accepted statements that would indicate to an HCF what should or shall be done to implement digital infrastructure in its facilities or technologies affecting the infrastructure. Although a number of standards and guidelines were gathered from different organizations, many standards and guidelines fell into one or more of the following categories: sole focus on one part of the digital infrastructure (i.e., real-time locating system); sole focus on one of the subsections of systems integration and intersystem communication, people and processes, or sole focus on continuous improvement or lack of specificity relating to the Canadian health care system. There is insufficient coverage of standardization or guidelines to support HCF digital infrastructure and technologies.
2. Europe and Australia, which share a similar health care system to Canada, also have a lack of standards or guidelines that thoroughly address the planning and implementation of health care digital facility infrastructure.
3. There is a small amount of research on recommended activities for achieving success in the categories of systems integration and intersystem communication, people and processes, and continuous improvements. However, this research does not cover the full spectrum of activities needed to support success, and there is a lack of consensus on recommended activities. Specifically, there is a lack of published research on how to design infrastructure in new and existing buildings in order to support continuous improvements.
4. Digital solution implementation does not follow a one-size-fits-all approach and recommendations made within one system may not directly translate to success within another. This highlights a potential challenge that will need to be closely considered when developing a standard.

These gaps identified through the literature review were used to develop the interview questions outlined in Appendix A.

4 Current Landscape

It is important to note that unless otherwise referenced in this document, the findings for the remaining sections of the report (i.e., Sections 4, 5, 6, and 7) are a summary of the input received from stakeholders through the consultative process. Further research was conducted as needed to explore concepts brought up in the consultative process.

4.1 Health Care Facility Digital Infrastructure Framework

The diagram in Figure 1 summarizes many of the components that make up HCF digital Infrastructure for the purposes of this report. These various components have been gathered through the consultative process. The HCF digital infrastructure components provide the foundation upon which end-devices, software, and systems operate and interconnect. An example of this is depicted in Figure 2 in Appendix D, which also contains the descriptions of the components.

Together the components of this framework make up a smart hospital that is powered by an integrated, intelligent, autonomous and sensor-rich environment that securely shares information. The outcomes of achieving increased intelligence and automation include:

- Improved patient experience;
- Efficient workflows;
- Operational efficiency;
- Cost savings;
- Improved patient outcomes; and
- Improved collaboration.

In a smart hospital, if digital health is insufficiently planned, the outcomes of poor implementations range from wasted capital dollars, loss of buy-in from clinicians, and additional costs to manage new systems. To ensure success in delivering on these outcomes, health care facilities must invest in people and processes, system integration, and intersystem communication and continuous improvements. Many of the end-use devices and software systems that people interface with on a daily basis are highly dependent on

the supporting HCF digital infrastructure components, which include the wired and wireless networks, telecommunication spaces, radio connectivity, cellular connectivity, data centres, and security. While the focus of the findings is on HCF digital infrastructure, the operational drivers are equally important to manage and oversee.

4.2 Opportunities

The following sections provide an overview of Canada's competencies and areas of opportunity with regards to HCF digital infrastructure and the elements that support it.

4.2.1 Governance

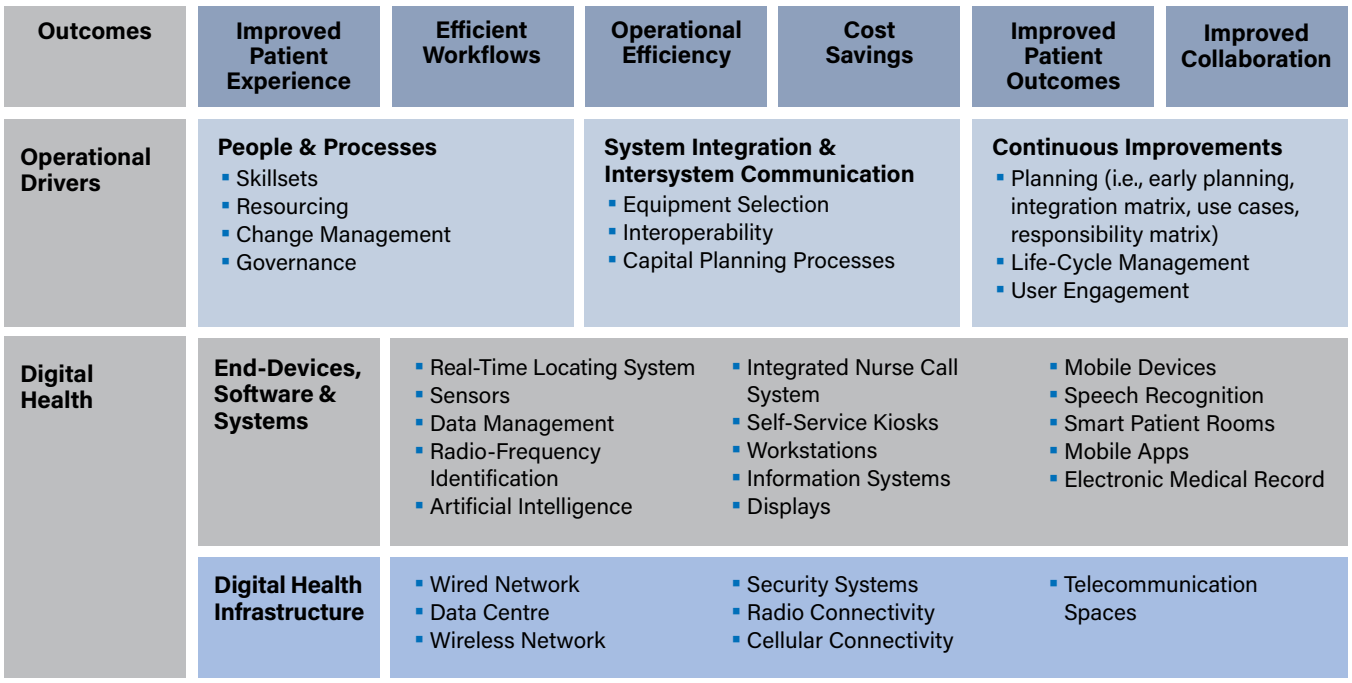
Canada has a publicly funded health care system known as Medicare that provides universal access to hospital and physician services [1]. Access to care is based on equity and need, rather than an individual's ability to pay [1], [4]. This system is funded through 13 provincial and territorial tax-funded public insurance plans.

As it pertains to the planning, design, and development of new health care facilities, Canada has a strong focus on public-private partnerships (P3s) for delivering large capital projects. P3 models share governance for digital infrastructure between the HCF, regional health authorities, and private sector delivery teams across decision-making, procurement, payment, implementation, and ownership. This model underscores the need for upfront planning.

Accreditation Canada provides accreditation for health care facilities across Canada through the use of standards, most of which are developed by the Health Standards Organization (HSO). HSO has 120 customizable health standards that are aimed at improving the quality of health care and social services globally for patients and their families [61]. As identified through the consultative process, Accreditation Canada does not look at HCF digital health applications nor digital health infrastructure during the accreditation process.

In addition to accreditation, HCFs are also responsible for reporting data on health quality [62]. Organizations such as Health Quality Ontario track and measure health system performance through a standard set of indicators [6]. These indicators are primarily focused on system performance and patient outcomes.

Figure 1: HCF Digital Infrastructure Framework



4.2.2 Health Care Guidance Organizations

In Canada there are two main organizations that focus on providing information and guidance to the health care community in the digital health domain. These organizations are predominantly focused on electronic health records. Canada Health Infoway works with partners to accelerate the adoption of digital health solutions, focusing on quality, access, and efficiency in the delivery of care [63]. The second organization is Digital Health Canada, which is a professional association with a focus on connecting, inspiring, and educating digital health professionals within Canada [64].

At a provincial and territorial level, guidance organizations exist that provide support to digital health, as shown in Table 2.

Table 2: Provincial and Territorial Governing Organizations

Province	Overarching Ministry/Authority	eHealth Guidance
Alberta	Alberta Health	Alberta Health and Alberta Health Services are jointly responsible for many of the eHealth systems that comprise the Alberta EHR [65], [66].
British Columbia	Ministry of Health	The Digital Health Strategy Initiatives Office is responsible for the development of IM/IT strategies to address all aspects of the health system, both for clinical and non-clinical support [67].
Manitoba	Manitoba Health and Manitoba Healthy Living, Seniors and Consumer Affairs	Manitoba Shared Health supports provincial digital strategies, the integration of health systems and manages digital assets [68].
New Brunswick	Ministry of Health	The Government of New Brunswick's Innovations and eHealth Services branch is responsible for overall alignment and integration of innovative eHealth and Digital Health services to achieve optimal health system performance.
Newfoundland & Labrador	Department of Health and Community Services	The Newfoundland and Labrador Centre for Health Information supports the development of data and technical standards and the delivery of information technology and eHealth services [69].
Northwest Territories	Department of Health and Social Services	No eHealth-related governing body.
Nova Scotia	Department of Health and Wellness	No eHealth-related governing body
Nunavut	Department of Health	No eHealth-related governing body.
Ontario	Ministry of Health and Ministry of Long-Term Care [70]	eHealth Ontario is the agency tasked with facilitating the development of Ontario's proposed public Electronic Health Record system [71]. Ontario Telemedicine Network which is now part of Ontario Health, is the largest telemedicine network in Canada. Using a cloud architecture, HCFs have access to a secure video network [72].
Prince Edward Island	Department of Health and Wellness	No eHealth-related governing body.
Quebec	Ministry of Health and Social Services/Ministère de la Santé et des Services sociaux	Quebec has no eHealth-related governing body. The electronic record that was implemented in 2008 was overseen by the Agence de la santé et des services sociaux (ASSS) de la Capitale-Nationale [73].
Saskatchewan	Ministry of Health	eHealth Saskatchewan has a mandate to lead electronic health record (EHR) planning, strategy, implementation/management, and data stewardship [74].
Yukon	Department of Health and Social Services	No eHealth-related governing body [75].

As demonstrated in Table 2, of the 13 provinces and territories in Canada, eight have an eHealth guidance organization. The remaining five have no specific guidance organization. This highlights that there is a variance in provincial focus on digital health across Canada and has to be taken into account in order to better ensure that the recommendations of this report are applicable at the national level.

4.2.3 Available Resources

There are several standards and guidelines developed by various organizations pertaining to designing digital infrastructure and information, communication, and automation technology (ICAT) systems for health care facilities. The main organizations in the digital health care industry that focus on standards and guidelines are listed in Table 3.

In HCF projects, specifiers (those who develop the specifications) usually look both to the standards that are provided by the organizations list in Table 3 and also specific sections within standards that are related to other Master Format divisions, such as electrical or mechanical. A non-exhaustive list of standards that specifiers use are included in Appendix E. Many HCFs seek information on standards that may be applicable to their needs and, as a result, may develop a unique set of guidance documents specific to their organization. Given technology's changing pace, it can be a challenge to maintain a set of standards that remain relevant.

4.2.3.1 Codes, Laws, Practices

In Canada, there are codes and policies that govern building design. Building regulations in Canada are under the jurisdictional authority of the provinces and territories as well as some local governments. Federally, there are policies and model codes that the provincial governments can adopt as they are written, or they can choose to develop their own codes to enforce.

There are national codes for many building systems such as plumbing, energy or fire, including CSA C22.1 Canadian Electrical Code. These codes do not have strong coverage of digital infrastructure, especially pertaining to HCFs. With respect to privacy and security, several acts govern the flow of data and personal information. In the case of personal health information, there is the Personal Health Information Protection Act (PHIPA) in Ontario, which is a piece of legislation that deals with the complexities of sending, sharing, and storing information and data that relates to personal health [76]. Another act governing this space is the Privacy Act, which sets out the rights that citizens have with respect to the information that the government collects, uses, and discloses about

Table 3: Non-Exhaustive List of Organizations Developing ICAT Standards and Guidelines

Organizations	Headquarters Location
American National Standards Institute (ANSI)	USA
Building Industry Consulting Services International (BICSI)	USA
CSA Group	Canada
Institute of Electrical and Electronics Engineers (IEEE)	USA
International Electrotechnical Commission (IEC)	Switzerland
International Organization for Standardization (ISO)	Switzerland
National Electronics Manufacturers Association (NEMA)	USA
Telecommunication Industry Association (TIA)	USA
Underwriters Laboratories (UL)	USA
Underwriters Laboratories of Canada (ULC)	Canada

them [77]. Provinces and territories also have similar regulations that govern the freedom of information and the protection of data [77].

The Personal Information Protection and Electronic Documents Act (PIPEDA) governs personal information by commercial organizations. In 2012, PIPEDA was declared as substantially similar to PHIPA, meaning that the acts do not need to be applied simultaneously to custodian personal health information [78]. On November 13, 2020, the federal Privacy Commissioner announced changes to PIPEDA. These changes will lead to the creation of two new acts – the Consumer Privacy Protection Act and the Data Protection Act [79]. These new acts are expected to focus on meaningful consent, data mobility, disposal of personal information, algorithmic transparency, and de-identified information [79]. There are currently no federal, provincial, or territorial codes that protect HCF digital infrastructure from cybersecurity threats.

Overall, there are many references to digital infrastructure systems found within various standards at federal and at provincial levels. This makes designing and implementing digital infrastructure technologies more difficult and unclear.

4.2.3.2 Standards

Standards contain specific rule sets to follow and generally set out a comprehensive set of requirements for digital infrastructure components relating to their technical specifications and safety features. Standards often address specific objectives such as base level performance, safety, regulatory requirements, and interoperability. This allows the specifier to choose from several manufacturer components or equipment options while still being able to comply with the intent.

There are many standards, as detailed in Appendix C and Appendix E and summarized in Table 4, that are used across industries that address systems contained within the umbrella of digital infrastructure. Many of these standards are also well established, such as those addressing wiring standards and wireless protocols. Specifiers have their choice between several different standards and documents to reference depending on the use and environment they are designing.

The introduction of smart connected technologies, as well as the rapid growth in algorithms and software, leads to concerns over existing standards. Some organizations are working to update standards to apply to these new technologies, but new standards are also

Table 4: Topic Coverage of Commonly Used Digital Infrastructure Standards

System	Design	Selection	Installation	Testing	Privacy	Security	Operation and Performance	Lifecycle	Interoperability
Wired Network	✓	✓	✓	✓		✓	✓		
Wireless Network	✓	✓	✓	✓		✓	✓		
Telecommunication Spaces	✓	✓	✓	✓			✓		
Radio Connectivity	✓	✓	✓	✓		✓	✓		✓
Cellular Connectivity	✓	✓	✓	✓		✓	✓		
Data Centre	✓	✓	✓	✓		✓	✓		
Security Systems	✓	✓	✓	✓		✓	✓		
End-Devices, Software, and Systems			✓	✓					



"Health care facilities (HCF) have many stakeholders, both internal and external that interact with their digital infrastructure in different capacities."

needed in order to cover all systems currently being implemented in hospitals.

Construction work on new and existing buildings follow specifications that are generally based on National Research Council Canada's National Master Construction Specification (NMS) [80]. These are meant to cover all aspects of construction work for all disciplines, from landscaping to technologies.

Digital infrastructure systems for capital builds generally follow the NMS, which has a series of sections that address specifications; more specifically, this information can be found under Division 27 – Communications and Division 28 – Electronic Safety and Security. Division 25 – Integrated Automation is another area of focus, which typically falls within the mechanical scope, however, this section also includes the Building Automation System/Building Management System, which is increasingly recognized as an HCF digital infrastructure system given the growth in the Internet of Things (IoT) and its role in creating smarter building environments. Division 26 – Electrical is also included as it contains lighting controls and metering sections that play an important role in the technology-driven smart building environment. Governing organizations within different jurisdictions can choose to accept different specification formats, but they typically use the NMS or are based off of it.

Specifications are also used to procure technology solutions and capital infrastructure. These specifications can be created within or outside of a construction or capital project and are used to support the selection, implementation, and testing methods.

4.2.3.3 Guidelines

Guidelines are not requirements but are intended to lay out best practices or to give a better understanding of the use of specific components or systems. There are no prominent and commonly used guidelines that describe best practices specifically for digital infrastructure in HCFs.

In the absence of an applicable standard or guideline, HCFs would usually rely on manufacturers' recommendations for design and installation and apply the practices in place at the facility for implementation and operations.

4.2.4 People and Processes

There are many stakeholders that interface in some capacity with HCF digital infrastructure in Canada. These stakeholders have differing subject matter expertise that impacts digital infrastructure to varying degrees. This section of the report provides an overview of how these stakeholders interact with HCF digital infrastructure and the roles they have in the planning, design, implementation, and continuous improvements of HCF digital infrastructure.

4.2.4.1 Stakeholders

4.2.4.1.1 Health Care Facilities

Health care facilities (HCF) have many stakeholders, both internal and external that interact with their digital infrastructure in different capacities. These include:

- **Health care leaders –** provide guidance, establish a vision, and develop a strategy for the delivery of

care within their organization. Depending on each individual organization, the role of digital technology in the overall vision, and resources to achieve the vision, can vary significantly.

- **Health informatics professionals –** informatics staff retrieve, compile, construct, format, and extract electronic data from information systems.
- **Information technology professionals –** manage HCF software, hardware, and related processes.
- **Users –** users refer to the end users who directly use devices that are connected end-devices or rely on HCF digital infrastructure. Users' workflows and processes are impacted by these devices and the overall performance of HCF digital infrastructure.
- **Patients and family –** patients engage with digital infrastructure through a variety of avenues which differ between HCFs. Interactions can occur at home, when patients access their health care information through patient portals or virtual care. When inside the HCF, they may interact with digital infrastructure by using systems such as kiosks or bedside devices; or they may indirectly interact with technology by relying on it for their care provision.
- **Capital planning teams –** when new hospitals are developed, capital planning teams facilitate and manage the planning of HCF digital infrastructure, including overseeing the development of technical output specifications and contract documentation.

4.2.4.1.2 Industry

Contractors have a growing responsibility to deliver constantly advancing infrastructure to meet the ongoing and future requirements specified by the HCF's stakeholders through the capital planning process or other construction-related projects. For large capital projects, the ministries involved may decide to manage the projects through various different procurement models. Depending on the model used, consortiums delivering the project will include general contractors for design-build (DB); design-build-finance (DBF); stipulated sum; or design-build-finance-maintain (DBFM) projects. Each model will vary to the extent that the HCF, as owner, can specify requirements or whether technologies will be selected by the third-party contractor. Contractors are required to understand the nuanced technology specifications for each unique capital project, and translate, incorporate or integrate the technologies into the design and build of HCFs. Working with consultants, contractors must deliver the hospitals intended functionality as specified in the technical output specifications, while balancing the costs of HCF digital infrastructure.

4.2.4.1.3 Consultants

Consultants have varying roles with HCF digital infrastructure. They support and provide subject matter expertise across all domains of design, planning, construction, commissioning, and post-occupancy support of the digital infrastructure, including end devices, systems, and software. Their involvement, level of support, and roles vary between projects and provinces.

4.2.4.1.4 Suppliers and Manufacturers

Suppliers and manufacturers are those who make or supply the products or services used for HCF digital infrastructure. With the evolution of digital health, there are many vendors in the market that provide a wide range of products and services.

4.2.4.1.5 Integrators

Integrators are generally defined as the group or team responsible for the implementation of digital infrastructure components and systems. As system integration and the associated use cases continually evolve in health care, integrators are becoming an essential stakeholder in HCFs. Integrators ensure functionality and interoperability between systems. These individuals can be an independent entity or can be an entity of an HCF, contractor, supplier, or consultants.

4.2.4.1.6 Telecommunicatoins Service Providers

Telecommunications service providers supply the connections between the HCF and the outside world via the Internet. As outlined in Appendix D, these connections are typically provided through underground fibre infrastructure into building entrance facilities but can be provided in alternative manners depending on the remoteness of a particular location. The data and voice services provided by telecommunications service providers are critical to the operation and functionality of HCF digital infrastructure.

4.2.4.1.7 Regulators

Regulators include those organizations with national, provincial/territorial, and regional governance that administer the delivery of publicly funded health care services to their constituents. The provincial governing organizations have the primary jurisdiction over the delivery of these services. They stipulate provincial laws and regulations of which the delegated regional organizations, HCFs, and health care professionals follow in order to provide health care services. A list of health care regulators can be found in Table 2 in the Overarching Ministry/Authority column.

4.2.4.2 Resource Requirements

4.2.4.2.1 Change Management

The implementation of end devices, software, systems, or new use cases has the potential to significantly change the way care is delivered or how business is conducted, and could influence daily routines and the workflow of staff. In a health care environment that is complex and heavily focused on patient care, change can be a challenge and organizations can be faced with resistance and fear. In order to achieve innovation and leverage digital health solutions to their full capacity, HCFs have processes in place to train, educate, communicate, and staff as to support change and to achieve successful adoption. Canada Health Infoway provides a Change Management Toolkit and a National Change Management Framework [33] as a guide that organizations can use. The resources developed by Canada Health Infoway were referenced in several of the interviews and acknowledged as being useful and comprehensive.

4.2.4.2.2 Communicatons, Education, and Training

An important part of the adoption of digital health is communication, training, and education. These are core components of Canada Health Infoway's National Change Management Framework [33]. Onboarding, in-service, preceptor/mentorship, and just-in-time training are four ways in which training related to digital health is delivered in HCFs. Training and education aim to transfer knowledge and skills, promoting adoption and integration of technology into users' everyday workflows. Training is typically delivered by suppliers and contractors based on requirements specified in the contract documentation. In addition, specific onboard, in-service, support material and just-in-time education can be developed and delivered to users by the HCF. Those delivering the training may include deployment teams, informatics staff, information services personnel, certified trainers, educators, and unit personnel.

4.2.4.2.3 Governance and Organizational Structure

Governance organizations provide the mechanisms that guide, steer, or regulate HCF digital infrastructure, including specifying the reporting relationships, roles, responsibilities, and relationships among the stakeholders. They set a direction on the processes related to procurement, decision-making, information sharing, and escalations. A list of governance organizations can be found in Table 2.

4.2.4.2.4 Guiding Criteria for Infrastructure Investments

Several guiding principles related to the design, planning, and implementation of HCF digital infrastructure were identified through the consultative process. These include:

- **Planned:** Whereby there should be a general understanding of the desired functionality of a system and use cases to support it.
- **Strategic:** Whereby infrastructure is designed, planned, and implemented based on an overall digital strategy that accounts for both short term and long term technology goals and use cases.
- **Interconnected:** Whereby there are connections between systems and buildings that drive efficiencies in processes and workflows.
- **Networked/partnered:** Whereby innovation is driven through partnerships with vendors, industry, and other HCFs.
- **Maintainable:** Whereby systems can be maintained without a significant investment in resources and operational costs.
- **Consistent:** Whereby HCF digital infrastructure is standardized and consistent across buildings and environments.
- **Future-proofed:** Whereby infrastructure is scalable and flexible to support future changes to end devices and service delivery.

- **Project managed:** Whereby leading practices in management sciences support the governance, deployment, and adoption of technology.

Many Canadian HCFs look for resources from other countries or global organizations to support their information needs. A common guideline that has been referenced is the HIMSS INFRAM model [39]. INFRAM provides a framework that details different levels of infrastructure maturity that HCF leaders use to assess and map out their infrastructure, benchmark with other facilities across the industry, and help prioritize digital infrastructure investments.

4.2.4.2.5 Guiding Prinicples for Deploying Technology

Currently in HCFs technology requires significant planning and consideration for many constraints, including budgets, access to resources, internal skillsets, and competing priorities. Some HCFs that were included in the consultative process reported prioritizing and road mapping (illustrating digital initiatives and deadlines) digital solutions as a way of mitigating these constraints.

- **Prioritization:** Whereby specific criteria are set by HCFs, prioritization criteria may be selected based on how well solutions align with an organization's strategic goals and overall budgetary requirements. Prioritization must also account for solutions that require bypass of the annual process if there is a defined urgent issue that needs to be addressed.
- **Road mapping:** Whereby solutions are sequenced and implemented over a timeline that accounts for dependencies, construction requirements, responsibilities, resourcing, change management, and budgetary requirements.
- **Managed:** Whereby HCF digital infrastructure deployment acknowledges that leading practices should be in place to support the successful design, deployment, transition, and operations of HCF digital infrastructure. These leading practices include management sciences such as project management, change management, and resources. These may include recommended practices from established industry organizations, such as the Project Management Institute or Canada Health, which publish proven practices and certify personnel in proven methods.

Evaluating the successful deployment of technology requires the development of metrics. The specific metrics chosen are dependent on the technology being implemented, its deployment location, and the HCFs' resourcing capabilities. Lean methodologies encourage the continuous evaluation of implemented technologies so that continuous improvements can be made. In addition, a transparent reporting process enables front-line users to report any challenges post-implementation. This is particularly critical when technology impacts service delivery and patient care. To minimize risk, HCFs establish risk assessments and develop risk-mitigation plans prior to implementation. An excellent example of risk mitigation can be observed by the routine practice of downtime procedures for health information systems. Clear procedures, roles, and responsibilities are identified and made transparent across the organization. During downtimes, additional resources are brought in to support front-line staff.

4.2.4.2.6 User Experience

In HCFs there are many stakeholders that interact with technology. A high consideration is given to the usability of end devices and software interfaces. Literacy, language, equity, and accessibility are key principles that HCFs take into account when considering the usability of digital health solutions.

When implementing new use cases or digital health solutions, HCFs must take into account the impacts they will have on workflows and processes. Redundant or duplications of tasks are associated with a negative experience amongst staff, whereas streamlined workflows and efficiencies are associated with a positive experience. One standard that targets usability is the ISO 9241-11:2018 Ergonomics of Human-System Interaction – Part 11: Usability. This covers the application of usability to interactive systems, including systems, products, and services [81].

There is also a significant amount of literature related to the user experience and user interface design principles. This literature is leveraged to assist HCFs in targeting the user experience. Organizations that provide resources that support the user experience include usability.gov and various academic organizations such as Boston University [82], [83].



"Integration and interoperability of systems can have a large impact on the workflows within an HCF."

4.2.5 System Integration and Intersystem Communication

HCFs are continuously working towards improved interoperability and integration between systems and sites with varying levels of success. The following section discusses the current state of system integration and intersystem communication at HCFs.

4.2.5.1 Clinical and Operational Workflows

Integration and interoperability of systems can have a large impact on the workflows within an HCF. Lean methodologies are a recognized approach for developing efficient workflows. There is a shared understanding that technology deployment should consider the workflows of end users. Based on the interviews, this has been neglected, which has resulted in systems that have not been adopted and, in some organizations, has left a negative undertone towards future technology implementations. In these situations, significant change management is required. Real-time location systems were the most common frustration noted amongst HCFs. When probed, it was evident that these were systems that lacked an accessible user interface or utilized technology that failed to provide a reliable and accurate location.

4.2.5.2 System Selection and Procurement

System selection and procurement in HCFs is complex and differs depending on the capital planning process or technology project, as well as the jurisdiction in which the project is located. The typical models employed include the following:

- Public Sector, Private Sector Partnership (P3)
- Design-Build (non-P3)
- Design-Bid-Build
- Sole Sourcing / Direct Award

In P3 or non-P3 models, procurement documents are developed to differing degrees (including drawings and specifications) that are packaged within Request for Proposals (RFPs) and released for public bid. In this model the design-build team select systems based on requirements in the procurement documents developed by the owner, the owner's advisor, or the planning, design, and conformance (PDC) team.

The other typical model in which systems are selected in HCFs is through sole sourcing /direct award, whereby contracting involves purchasing goods or services directly from a supplier. The use of this model is usually limited due to the governing body procurement restrictions for most HCFs.

4.2.5.3 Fixtures, Furniture, and Equipment (including IT peripherals)

When a new or existing building project is undertaken, generally consultants are hired to conduct the planning of the furniture and equipment that will go into the new space. The equipment ranges from macerators to MRIs to barcode scanners. These pieces of equipment

are planned in consultation with users on a room-by-room basis in order to produce a list that contains all of the equipment that will be purchased or relocated to the space and to generate the budget for furniture and equipment. These pieces of equipment are then defined by specifications and purchased by the design-build team or commissioned by the hospital.

4.2.5.4 Interoperability

Interoperability is the backbone of system integration and intersystem communication. There are numerous existing frameworks in place to support the interoperability of systems and to ensure that data can be shared seamlessly between systems within an organization, across the enterprise, between partnering organizations, and across the province. Canada Health Infoway provides a summary of the Canadian standards and guidelines for terminology and communications [84]; these standards can be grouped into the following broad categories:

- **Content:** These standards focus on data structure and organization; some examples include Health Level 7 Version 3, Clinical Document Architecture (HL7) [15], Nursing Data Standards.
- **Exchange:** These standards focus on the flow of messages to and from and address the format of messages; some examples include HL7 Fast Healthcare Interoperability Resources (FHIR) [15], and Digital Imaging and Communications in Medicine (DICOM) [85].
- **Terminology:** These standards focus on clarity of information so that it is unambiguous; some examples include International Statistical Classification of Diseases and Related Health Problems (ICD), SNOMED CT [16], and Logical Observation Identifiers Names and Codes (LOINC®) [86]. These solutions are working to solve technical and semantic interoperability.
- Other standards focus on privacy and security or specific standards set in each jurisdiction to support organizations to connect to provincial systems. ISO/TC 215 Health Informatics and SC1 standards [87] and initiatives cover many of these areas, including information security codes, medication management, among others.

While these standards cover clinical integration, there is a desire by HCFs for more data exchange between business, building, and clinical systems such as patient records, real-time locating systems, nurse call, telephones, and mobile devices. Integration platforms are often leveraged in HCFs as a way of connecting systems within a facility. Due to a lack of a guidance document, HCF staff and consultants often rely on subject matter expertise and experience in order to develop use cases. Hospital-developed interoperability matrixes are also leveraged and specify system-to-system integrations.

4.2.6 Continuous Improvements

Continuous improvements refer to the actions taken to maintain, upgrade, or replace HCF digital infrastructure.

4.2.6.1 New and Existing Buildings

4.2.6.1.1 New Buildings

In new facilities being developed through all procurement models (i.e., DB, DBF, DBFM), HCF digital infrastructure is selected based on a schedule of requirements. Hospitals often leverage expertise from consultants to develop these requirements in consultation with end users and provincial or regional governing organizations that provide decisions on project funding. Typically, internally developed responsibility matrices are developed that show the system and who is responsible for system selection, deployment, integration, handover, and maintenance.

4.2.6.1.2 Existing Buildings

In existing buildings, when a system is being replaced or a new system is being added, hospitals either independently or in collaboration with other government agencies, engage consultants to help develop specifications and RFP documentation to procure and implement a new system. These requirements are developed through industry standards, facility operational needs, and subject matter expertise.

Maintenance is provided both by suppliers and hospital-trained staff. This approach differs between organizations and is dependent on the system being maintained.

4.2.7 System Life-Cycle Management

System life-cycle management is currently done on a system-by-system basis or a component-by-component basis. For ICAT systems, there is very little guidance as to the lifetime of a particular system. It is a common occurrence that systems will not be replaced until they have reached a critical end-of-life state. This was reported as being a result of financial constraints.

Future-ready infrastructure should support the end devices, software, and systems for a number of years into the future. With the evolving nature of technology, future-proofing can be a challenge. There are two guiding principles for future-ready digital infrastructure that were identified in the literature review and that are further explored in the consultative process:

- **Scalability:** An approach taken when planning and designing digital infrastructure. Scalability allows facilities to make continuous improvements to the infrastructure and add new systems onto the infrastructure without undergoing a complete infrastructure replacement or upgrade.
- **Flexibility:** An approach taken to future proof HCF digital infrastructure. Hospitals are no longer being considered complete or static when they open; rather, they must be able to respond to changing needs and requirements from different drivers such as new technologies, policies, or service delivery changes.

To achieve scalability and flexibility in HCF digital infrastructure, many organizations develop digital health strategies to think outwards, up to 20 plus years out. Forecasting what technologies and use cases will be implemented requires research, benchmarking, and projecting how these devices, software, or systems will rely on HCF digital infrastructure in the future. HCF digital infrastructure is then designed to accommodate these future requirements, either through full implementation or through designing space for future growth. There are currently no standards or guidelines in place that provide guidance to this. It is heavily reliant on hospitals' and consultants' subject matter expertise and experiences.

5 Gaps

HCF digital infrastructure is evolving and expanding at a rapid pace. The once relatively simple provision of systems is more complex, and the data requirements are increasing exponentially. Today's market is demanding safe and reliable data to be transmitted in near real-time from all systems. Achieving this has been fragmented and lacks standardization between organizations and across provinces. This section highlights the challenges associated with the current processes and where challenges with HCF digital infrastructure are present.

A general gap that should be noted is that there is a lack of information related to the use of digital infrastructure in home, community, and long-term care settings. This was determined based on a thorough literature review that returned minimal information related to technology in these settings. In addition, those who were interviewed had minimal insight into the current state, challenges, or gaps within these HCFs.

5.1 People and Processes

5.1.1 Lack of Standard Digital Infrastructure Governance

Governance over digital health and its associated infrastructure has been identified as a challenge amongst many HCFs. Specifically, challenges related to the reporting relationships between leaders, committees and groups, and end users have been noted. This has resulted in technology procurement occurring in siloes, leading to integration challenges, lack of standardization in workflows between departments, and cost impacts. If roles and responsibilities for selection, integration, handover, and maintenance of HCF digital infrastructure are not clearly established at the onset, there is a potential that systems will not function or have the life cycle as was intended.

5.1.2 Inconsistency of Technology

Users, including patients, visitors, and staff, may also experience challenges when interacting with different devices during their interaction with the health care

system. Staff typically invest a considerable amount of time and effort in learning and identifying with current technology, so mixing in a completely different manufacturer into a facility when staff are already trying to learn new spaces and workflow can add an exceptional amount of stress to their day-to-day work life. Additionally, patient and family members who move throughout the facility in their short stay may be reluctant or confused when presented with different types of software or devices (i.e., kiosks) that do essentially the same thing from one location to the next.

5.2 System Integration and Intersystem Communication

5.2.1 Workflow Duplication

Most HCFs do not complete comprehensive workflow mapping or redesign exercises to ensure that their digital health solutions bring value and are implemented in ways that achieve workflow and process efficiencies. This has resulted in the implementation of solutions that cause redundant and duplicate tasks for end users, and impacts the user experience significantly.

5.2.2 Siloed Equipment Planning

The process for planning and purchasing new pieces of equipment or technology is often conducted in isolation from the specifications that are written for systems or digital infrastructure components. This can lead to many issues, particularly when the consultants conducting equipment planning are not experts in HCF digital infrastructure and do not have experience with the overall equipment planning process for digital technology. Issues have arisen in past construction projects where the output specifications and the equipment lists do not align and have led to an excess of change orders during the construction phase.

5.2.3 Procurement Challenges

Procurement also provides its own challenges, as vendors do not always satisfy the client's requirements. Lack of care when writing specifications, evaluating vendors, and monitoring the installation or implementation can lead to ineffective procurement.

Without taking appropriate care and engaging the correct stakeholders, the procured equipment is at a risk of not satisfying the needs of the facility or integrating properly within the infrastructure or the workflows.

5.2.4 Lack of Standards Coverage

The coverage of standards that are commonly used for digital infrastructure are included in Appendix E. As outlined in Section 4.2.3.2 many digital infrastructure systems have standards coverage across design, selection, installation, privacy, security, life cycle, and interoperability. However, the majority of these standards are not health care specific and during construction projects require cross-referencing of several sections within the National Research Council Canada's NMS specification divisions. This provides an opportunity for specification requirements to be missed when planning, designing, implementing, and commissioning systems or to not be updated uniformly throughout all divisions during their development.

With the rapidly changing industry of smart, connected technologies, standards and guidelines cannot keep up with specific requirements or best practices for each individual component or system. There is no overall guidance for end-devices, software, and systems that are helpful for HCFs looking to implement technologies that do not have their own standards. Overarching guidance for the implementation of new technologies within this category is lacking. With respect to end-devices, software, and systems, there are standards for many technologies that are health care specific such as nurse call systems; however, many new systems such as real-time locating systems are being implemented in hospitals and do not have specific HCF requirements.

5.2.5 Privacy and Security Risks

HCFs are at high risk of being targeted in cybersecurity attacks due to the nature of the data that they store. PHIPA is an act in place that lays out the requirements to protect personal health information [88]. There is no act or standard that specifically addresses the security of digital infrastructure in HCFs and no guidance provided on how to design sufficiently private and secure systems in order to support both the interchange of information as well as keep access to networks and information out of malicious hands.

5.2.6 Lack of Lifecycle Management

A complete digital facility infrastructure is made up physical building infrastructure, the network, and many end-devices, software, and systems that integrate and are interoperable with one another. Managing the versions and life cycles of each system while keeping in mind the compatible versions for its integrations can be a confusing process. There are currently no guidance documents or best practices that stakeholders can look to for managing the life cycle of these systems nor their integrations. This often leads to "Frankenstein-systems" and integrations that have been hospital-developed to work around these incompatibility issues. These workarounds often pose privacy and security risks.

Within the lifetime of the physical infrastructure components, the network and the end-devices, software, and systems may go through three or four different iterations. It is important that the life cycle of all of these different components be considered when procuring capital or undergoing a redevelopment or renovation.

5.2.7 Lack of Use Case Templates

It was identified that the implementation of planned interoperability use cases falls short on delivering what was envisioned by the HCF. A confusion between integrations and use cases is also a common problem. Due to the lack of a publicly available template or shared use case library, hospitals resort to developing use cases in-house, placing a heavy reliance on hospital staff and consultants to have experience with the desired integration use cases.

5.3 Continuous Improvements

5.3.1 Variance in Jurisdictional Responsibilities

Capital planning and overall focus on digital health vary amongst provinces, making it a challenge to develop or implement standards that can be achieved by all. There are variances in regulatory body funding approvals that can lead to related challenges to an organization's ability to obtain and resource digital health systems. This also causes variances in the overall planning process and associated roles and responsibilities.

Even within P3 projects, roles and levels of responsibility vary across jurisdictions. As an example, in Ontario, the individual hospital and its contracted consultants heavily guide the early capital planning process. These individuals are responsible for developing the equipment lists, functional planning, and developing the schedule of requirements. In contrast, in Nova Scotia, the Provincial Health Authority takes on a greater role in these tasks, leading to less reliance on external consultants. As another example, Partnerships BC gives more latitude to specify equipment and solutions, whereas projects run with Infrastructure Ontario require more open RFPs.

5.3.2 Lack of Organizational Digital Strategy

While many HCFs develop and use a digital strategy to guide their planning and design of their digital infrastructure, not all do. This can create an inability to achieve full potential from digital infrastructure, misalignment in priorities across the organization and with stakeholders, and productivity challenges as a result of not having an end goal to work towards.

5.3.3 Challenges with Retrofits and Renovations

Retrofits and integrations of HCF digital infrastructure within existing buildings produces a different set of challenges and needs. These include both technological and resource challenges, which must be considered to provide a successful integration between new and old spaces. Different technologies and systems (such as two nurse call systems from different vendors) installed on campus can produce issues in administrative, maintenance, and user experience. Different technologies will require separate Service Level Agreements, additional inventory of key components, separate administrative and management consoles, additional integration points, and additional training. Capital savings can quickly be nullified by escalating operational and support costs. Users, patients, visitors, and staff may also experience challenges with different devices provided doing the same thing during their interaction with the health system. Operational and support staff have already invested considerable amounts of time and effort in learning and identifying with current technology. When a completely different manufacturer solution is factored into a situation where they are already



"Numerous organizations across Canada have adapted care delivery and service models by leveraging digital health tools."

trying to learn new spaces and workflow, it can add an exceptional amount of stress to their day-to-day work lives. Additionally, patient and family members that move throughout the facility in their short stay may be reluctant or confused when presented with various different devices doing essentially the same thing from one location to the next.

5.3.4 Lack of Future Consideration in Telecommunication Spaces Design

Planning and design of HCF digital infrastructures carries unique challenges; from the time the design is initiated to the time the equipment is being installed, systems, workflows, and technology tend to go through several cycles and changes. Pathways, spaces, and networks can be flexible but, in order to grow, space needs to be included in the initial design. This however tends to get prioritized below clinical and architectural mandates and requirements, and therefore cannot always be achieved. Workflow and technology advancements are more challenging to anticipate but, if the telecommunication spaces and pathways have been designed properly and sized to accommodate future technology, most technology advancements and workflow changes can be accommodated without wholesale changes or additional space requirements. An example of where this has been a challenge is with the installation of new nurse call systems. Most new nurse call systems are now internet protocol based and, as a result, there are cabinet and cooling requirements that were not previously required with legacy systems. These new infrastructure requirements have created a challenge for existing hospitals with telecommunication spaces and infrastructure that are at capacity. This has required the construction of new telecommunication spaces, which can be a challenge due to fiscal and resource constraints.

6 Success Stories

Numerous organizations across Canada have adapted care delivery and service models by leveraging digital health tools. These success stories were identified in the consultation process and are highlighted in this report for reference. There are lessons to be learned from these institutions related to key systems, personnel, and capital planning processes. Concepts from these success stories have been incorporated into the 12 recommendations in Section 7.

6.1 Humber River Hospital – North York, ON

Due to fiscal constraints and available skillsets, many HCFs implement new technologies as stand-alone projects during capital projects, with little to no integration or overarching strategy to guide the implementation towards full functionality to achieve the desired health care system outcome. Humber River Hospital took a different approach by which the hospital leadership developed an enterprise-wide digital strategy early on in the planning process that had a clear focus on supporting patient care and efficient workflow throughout the hospital. This was carried through into the design of the new facility,

where "digital" was placed as a core pillar. Digital was broken down into four core objectives: digital information; mobile and connected; mission-critical; and interoperability. Placing these as a centre focus of the capital project provided clear direction from the outset. Patients and staff are now supported by technologies that enable them to deliver care rather than hinder them.

The success of Humber's leadership and strategic approach can be observed through their Command Centre. When faced with capacity challenges shortly after opening day, Humber leveraged its "digital first" mentality and transitioned its library, a flexible space, into a 4,500-square-foot Command Centre. In partnership with GE Health Care Partners, Humber leveraged its existing infrastructure, which placed a strong focus on interoperability between disparate information systems, in concert with GE's Analytics Platform. This allowed real-time information to be presented in a meaningful way that optimized patient flow and turnaround. The implementation of the large-scale analytics program gave Humber staff the ability to proactively monitor and manage the flow of patients. This has resulted in the creation of 34 virtual beds, significantly increasing Humber's existing capacity of 656 beds [89].

6.2 Michael Garron Hospital – East York, ON

The Michael Garron Hospital planned to develop a new Patient Care tower with leading-edge patient-centric technology. The hospital was planning to achieve the Electronic Medical Record Adoption Model (EMRAM) level 7, the highest level in becoming a paperless and digital facility [38]. (Note: EMRAM is a guidance tool for digital health care that was released in the United States.) It sought out opportunities for automation opportunities to become a smarter hospital. The hospital leadership team collaborated to imagine what patient care would look like in 10, 15, and 20 years. User groups with front-line staff were engaged to understand the current operations and therefore identify gaps between the current state and the future vision. In further planning, Michael Garron Hospital undertook an extensive consultation process with clinical users when developing the interoperability use cases. In doing so, the hospital was able to be very specific with the requirements of various system inputs and outputs to achieve each use case. The details of these use cases were very helpful in reducing risk and clarifying scope for the contractor.

6.3 Ontario Shores Centre for Mental Health Sciences – Whitby, ON

Ontario Shores Centre for Mental Health Sciences designed a video wall and audio-visual (AV) system for a new public lounge. Taking a unique approach on the project, the audio-visual installer was included as part of the design phase, which allowed for close coordination of requirements and capabilities. In the end, the owner (HCF) received a system that met its requirements. This approach also streamlined the design process as options were able to be directly discussed with the installer, resulting in a low-cost, functional solution.

6.4 Royal Columbian Hospital – New Westminster, BC

At Royal Columbian Hospital, it was crucial to ensure that the infrastructure and IT services were deployed seamlessly from both the existing facilities and the newly built facility. End-user engagement was sought out to understand the current and future workflows. This allowed the design team to understand the complete scope of digital services required for the hospital and plan strategically for the implementation. Guiding the system design with clinical functional requirements ensured that the specifications carried the correct intent and supported the procurement process. Additionally, in order to clarify the specifications for the proponent teams, the design team developed the integration design and matrix between hospital and building ICAT systems, which were included in the RFP documents. The design team then attended the proponent design meetings to evaluate the understanding of use cases as defined by the user groups.

It was decided to involve the relevant decision makers for the ICAT planning, including end users, hospital IT services (who ultimately own and maintain the systems), senior leadership (who support the costs for upkeep and integration to other key hospital owned systems), and the redevelopment team (who

are responsible for successful delivery of the project). Additionally, ICAT impacts the architectural design and the electrical/mechanical design, so identifying these key issues early in the process and working as an integrated team is key to creating output specifications that deliver on the end-user's goals.

6.5 University Health Network – Toronto, ON

The University Health Network gradually implemented a meshed hypercube network infrastructure using layer-three switches that exploited the concept of distributed intelligence (i.e., Ethernet fabric). The configuration and destination information were distributed across each switch within the Ethernet fabric. Switches within that fabric were seen and managed as if they were a single logical chassis, which significantly reduced network management and latency on the network. This allowed many latency-sensitive applications to converge on a single and robust infrastructure.

6.6 Health Sciences Centre – New Women's Hospital – Winnipeg, MB

The New Women's Hospital development in Winnipeg began in 2010. The hospital was faced with a challenge in that its current clinical systems and building systems would change throughout the design-build process and by the time the building opened. Discussions were held early in the process to determine how the physical built environment, work patterns, and digital tools could mitigate this risk.

7 Recommendations

There are gaps between today's HCF digital infrastructure and the needs of the industry. This report has outlined the existing documentation as well as the gaps between current documentation and industry requirements. These gaps were determined by reviewing standards and best practices literature, and by conducting interviews with industry stakeholders. The recommendations to fill these gaps were determined through the interviews, validation process, and in alignment with the approaches taken at HCFs that led to successful digital infrastructure projects. Components of digital health infrastructure identified in Figure 1 through the consultative process were also carried through the recommendations ensuring the outcomes remained at the forefront of the recommendations being made. These recommendations, presented in Table 5, are organized into three groups: people and process, system integration, and continuous improvements.

7.1 Recommendation 1: Develop Common Definitions

It is recommended that common definitions for digital health be defined and used Canada-wide, across all sectors of health care. These definitions should include but are not limited to virtual care, virtual hospital, artificial intelligence, predictive analytics, staff duress, nurse call, and real-time locating.

7.2 Recommendation 2: Develop a Digital Health Vision & Strategy Development

It is recommended that a digital health vision and strategy be developed and maintained for all HCFs regardless of whether they are actively involved in a construction project or technology deployment. If actively involved in a capital planning process, a strategy should be developed prior to technical specification development. This will guide the detailed planning of digital infrastructure in later stages. A digital health vision and strategy should align with the organization's overall strategy and identify technology and infrastructure capabilities for the future. This strategy needs to be developed with senior management or be given their endorsement. Without this there will be budgetary constraints during execution.

7.3 Recommendation 3: Complete Workflow Mapping

It is recommended that prior to designing or deploying end-devices, software, or systems, the workflows of those impacted by the implementation be mapped. This will allow any waste (inefficient use of resources) – such as long wait times, overprocessing, chaos, and redundant tasks – to be identified and reimagined

as an ideal future state process prior to design and implementation. Workflow mapping should be conducted in consultation with the stakeholders of the areas impacted by the workflow changes. Through the lens of the seven flows of health care (patients, families, providers, medications, supplies, information, and equipment), stakeholders may identify steps that are manual, paper based, require interactions with other team members, and require repetition or waits. Meetings can be conducted along with site walkthroughs, which may help to identify extra work steps, to determine the desired and most efficient processes in each area. The engagement of end-user stakeholders will also support the long-term adoption of the digital implementation.

Table 5: Recommendations Summary

Recommendations	Lack of Digital Infrastructure Governance	Inconsistency of Technology	Workflow Duplication	Siloed Equipment Planning	Procurement Challenges	Lack of Standards Coverage	Privacy & Security Risks	Lack of Life-Cycle Management	Lack of Use Case Templates	Variance in Jurisdictional Responsibilities	Lack of Organizational Digital Health Strategy	Challenges with Retrofits and Renovations	Lack of Future Consideration in Telecom Design
Develop Common Definitions					✓	✓							
Digital Health Vision & Strategy Development											✓		
Workflow Mapping		✓	✓				✓					✓	
Use Cases & Integration			✓	✓					✓				
Planning Equipment in Tandem with Systems			✓	✓	✓		✓					✓	✓
Privacy and Security by Design		✓					✓	✓				✓	✓
Risk Identification – New to Existing		✓	✓									✓	
Develop Responsibility Matrix	✓	✓	✓	✓	✓			✓			✓	✓	
Design Flexible and Scalable Digital Infrastructure Spaces												✓	✓
Develop Commissioning Documents for New and Existing Buildings	✓		✓	✓								✓	
Master Systems Integrator	✓	✓			✓								
Ongoing Training			✓						✓			✓	✓



"As hospitals have become more connected, integration requirements between systems have become complex and critical to hospital operations."

7.4 Recommendation 4: Develop Use Cases and Integration Matrix

As hospitals have become more connected, integration requirements between systems have become complex and critical to hospital operations.

It is recommended that an integration matrix template be made available and identify which systems will be integrated, whether these integrations will occur on opening day or in the future, and who is responsible for the integration (contractor versus hospital or both). These roles and responsibilities will need to be clearly defined as there will be a "grey" area when connecting systems that are owned, implemented, and needed by different stakeholder parties. For example, the roles and responsibilities for integration of clinical systems often falls under the HCFs responsibility while the contractor is typically responsible for the integration of building systems. However, the responsibility for integrating a clinical system (e.g., electronic medical records) with a building system (e.g., nurse call system) can be considered as a grey area that should be clarified for each project.

Use cases describing the outcomes and intent of the system integrations should be included within the contract documentation. These use cases need to focus on what is to be accomplished, not necessarily the specific systems or vendors that need to be integrated. Use cases should be validated with a group or a committee that has a clear understanding of the workflows associated with the deployment area. Use cases are an essential component to include within performance requirement documents to achieve an intelligent digital infrastructure platform that allows various discrete technologies to speak to one another. Use Cases can be accompanied by assisting detailed documentation, including interface mapping and integration network architecture once designs are further developed.

7.5 Recommendation 5: Instil Privacy and Security by Design

Because of the critical nature of the information being shared within an HCF, special care needs to be taken to protect the privacy and security of the facility's data and systems. Therefore, it is recommended that privacy and security be designed into the system rather than left up to user responsibility. This becomes increasingly critical when working with intelligent systems like machine learning algorithms.

Privacy and security design and operation criteria should be included in guidelines and specifications for all systems. The guidelines should include system-specific privacy and security design information as well as respected best practices in privacy and security. Some of these best practices have been laid out by the Ontario Privacy Commissioner in the seven privacy and security by design principles [90]:

1. Proactive not Reactive; Preventative not Remedial
2. Privacy as the Default Setting
3. Privacy Embedded into Design
4. Full Functionality – Positive-sum, not Zero-sum

5. End-to-End Security – Full Lifecycle Protection
6. Visibility and Transparency – Keep it Open
7. Respect for User Privacy – Keep it User Centric

The above principles are excellent guiding criteria for the design of private and secure systems. These principles and similar principles developed by other organizations could be an excellent guide for developing specific criteria for the health care industry systems and for industry-specific privacy and security systems. These would be the most beneficial to guide HCFs in implementing their digital infrastructure.

7.6 Recommendation 6: Plan Equipment in Tandem with Systems

IT equipment and any equipment relating to or affecting systems that are considered as part of the digital infrastructure should be planned in tandem with the planning for digital infrastructure, systems, and software. The equipment list that is generated as part of construction projects should be created in consultation with the ICAT specifiers and experts in ICAT equipment as well as stakeholders of the area using the equipment. The specification for the pieces of equipment needs to be written in a way that allows for advancements to technology that might arise between planning and implementation of the project.

New IT equipment, whether procured for a redevelopment, renovation, or simply a renewal of systems, should only be decided upon with reflection and review of the digital infrastructure. This should be decided upon with a task force that includes membership from all stakeholders concerned, including the information technology group and the innovation and digital health groups within the HCF.

This will not only help the viability of these new pieces of equipment but will also help with managing the capacity of the digital infrastructure.

7.7 Recommendation 7: Complete Risk Identification – New to Existing

It is recommended that HCF construction projects conduct a comprehensive risk identification exercise associated with procuring a new system that differs from systems within the existing facility, particularly if there is no intent to implement and replace the legacy system facility-wide. This recommendation stems from the challenges associated with retrofits and integrations with existing buildings. This risk identification needs to be conducted early on in the planning phase to ensure that risks are mitigated and specifiers are not asking for technically impossible systems and solutions. HCFs should carefully consider their procurement option using a risk-based approach, as in some models (for example the P3 model), contractors have the discretion to select systems and to ensure a competitive bid process, meaning that an HCF is then limited in its ability to mandate a specific system that patches its existing buildings.

7.8 Recommendation 8: Develop a Responsibility Matrix

The purpose of a responsibility matrix is to provide an overview of the systems' roles and responsibilities between the contractor and the owner, and does not override specific requirements noted in the schedule of requirements. A responsibility matrix template should include:

- Categorization of systems, grouped by divisions;
- Subcategories that identify the role and responsibility associated with approvals (design and construction and commissioning and start-up), identification, specification, selection, procurement, purchase, freight and tariff, coordination, storage, power and communications, set-up, system integration, installation, commissioning, operation (control and monitor), training, maintenance, renewals, and replacements.

The capital planning process is complex and when planning, designing, and implementing HCF digital infrastructure, it is critical that stakeholder's roles are clearly established at the outset. The responsibility matrix allows the planner to fully understand various skillsets of stakeholders. A responsibility matrix template for capital planning will track these roles and ensure they are carried throughout the project.

7.9 Recommendation 9: Design Flexible and Scalable Digital Infrastructure Spaces

It is recommended that all telecommunication spaces be designed from the outset with enough growth space (e.g., at minimum one future full-sized cabinet for expansion and growth) to accommodate future technology advancements and life-cycle updates in the near future. By suggesting physical requirements such as one additional cabinet (versus a percentage increase) there is additional floor space made available for future growth. Workflow and technology advancements are more challenging to anticipate, but if the telecommunication spaces and pathways have been designed properly with an eye to the future, most technology advancements and workflow changes can be accommodated without wholesale changes or additional space requirements.

7.10 Recommendation 10: Develop Commissioning Documents for New and Existing Buildings

As digital technologies within HCFs become more complicated and heavily integrated, it is recommended that new commissioning documents be developed. Complex and critical components such as the data centre already have guidelines, but it would be helpful to develop similar guidelines for other digital infrastructure systems. These documents would outline the expectations of these systems and components and address gaps and downfalls in different configurations of each system. Some of the examples of additional commissioning requirements may include:

- Device/component level failover testing, which ensures that when components of the system fail, ensures that all components have been properly configured and the configuration has been saved so when a power refresh happens the system returns to normal operation.
- Performance metrics for analysis and collection of data (it would be beneficial to understand how the system functions when many devices or components trigger an alarm or send info at the same time).

7.11 Recommendation 11: Institute a Master Systems Integrator

It is recommended that a master systems integrator be a defined and established role for all new organizations that are undergoing extensive capital planning with deployment of new health care technologies. The role of the master systems integrator is to make sure all systems communicate properly and collaborate with all stakeholders. This will help ensure that described use cases are executed as intended, which requires an understanding of the different systems involved, their implementation timelines, risk, and dependencies. The master systems integrator will be responsible for ensuring that all health care IT, clinical, and building systems coordinate, communicate, and seamlessly operate with one another, which requires as much technical knowledge as project management and leadership skills. The technical capability is considered to be the foundation and is required to be in place as systems continually evolve and software versions and compatibility continually change.

It is recommended that the master systems integrator have experience integrating a variety of systems in the health care environment, possess an understanding of the criticality of the health care environment, and be knowledgeable of clinical, business, and building systems, manufacturers, designs, and industry best practices/standards. While a smaller organization or smaller capital project may not justify a full-time resource assignment, a portion of a full-time equivalent should be dedicated to every digital implementation project.

7.12 Recommendation 12: Ensure Ongoing Training

Training is a key component in technology deployment, specifically when being introduced into a legacy facility. It is recommended that training with users start early in the construction project and continue during construction and post construction.

The responsibilities for this training are to be clearly outlined, detailing whether training for a new system will fall under the responsibility of the hospital, the contractor, or the vendor of the specific system.

8 Conclusion

As patients and visitors come to expect a hospital experience similar to what they would have in retail or hospitality services, health care staff similarly expect access to technologies in order to create efficiencies in their workflows. To support these needs, HCF digital infrastructure needs to be adaptable to support it. HCFs are in a unique position when it comes to the rapid expansion of digital infrastructure technologies. HCFs stand to both benefit immensely from the implementation of new technologies and face numerous challenges or risks that may be associated with the implementation of those new technologies. Further to that, pressures for resources coupled with the nature of the data and systems they are working with, present challenges for organizations to be up to date.

This study revealed that currently a majority of stakeholders rely on hospital-developed documents and processes to guide their digital health solutions as well as standards for infrastructure that are not specifically geared towards HCFs. While these hospital-developed documents may fill the gaps for these facilities, they have typically not been validated or vetted externally, and they are missing the benefit of shared experience across the Canadian health care system. Further to this, these actions are repeated in many organizations and jurisdictions across the country, leading to siloed processes and practices.

Twelve recommendations are laid out in this document to support the deployment of HCF digital infrastructure. It is suggested that these recommendations be incorporated into an overarching guidance document for the planning, design, implementation, intersystem communication, and life-cycle management of HCF digital infrastructure. As there are already commonly accepted standards that cover the design, implementation, installation, and testing of the base digital infrastructure systems, it would be important for this guidance document to focus on HCFs and how to achieve a future-ready digital infrastructure through specific requirements, methods, and practices.

Many interviewees expressed concern that standardization in the area of HCF digital infrastructure may hamper the ability to achieve innovation, that recommendations may not be achievable by all, or that the standards may fail to stay up to date with changing health care delivery. When developing an HCF digital infrastructure standard, consideration should be given to the variances in funding, skillsets, and resourcing between HCF organizations and provincial regulatory body processes. In order to not impede innovation and to stay in sync with industry changes, process guidance and decision-making criteria should be used and dictated solutions should be avoided.

To address the interconnectedness of health care, some of this guidance will need to focus on processes for implementing systems that are not covered in individual standards. This is especially critical to support the rapid transformation in health care service delivery from what was traditionally brick-and-mortar service provided in person to the health care services being provided beyond the walls of the hospital. These transformations in health care delivery are possible through an interconnected ecosystem of end-devices, systems, and software that may outpace the traditional timelines it takes to develop standards individually for components.

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Appendix A – Interview Questions

This appendix provides a list of the interview questions asked during the consultative process. The questions were developed based on the stakeholder group being interviewed and include:

A.1 Hospital

1. When considering the selection of digital health solutions, how important is integration and intersystem communication?
2. In the past, what issues have you experienced with integration and intersystem communication between systems?
3. Where is your biggest challenge as it relates to interoperability? Do you have any insights into how this could have been avoided in the initial planning and implementation phases?
4. What types of clinical equipment would you classify as mandatory for your organization?
5. Are there any gaps in your workforce that have impeded your ability to plan, implement, scale, or maintain your digital health systems?
6. When you have implemented digital health systems in the past, how did you decide on which use cases to implement?
7. Does your organization face any challenges with the usability of your digital health systems?
8. When implementing a new digital health solution, how does your organization train users?
9. What types of skillsets do you think are necessary to support these emerging systems such as AI, augmented reality, and digital twins?
10. When implementing a digital health solution in a way that changes workflows/processes, what is the process your organization takes to update or develop new policies and procedures?
11. Linking back to our previous conversation around internal skillsets, do you think there is an opportunity to stay ahead and be innovative through partnerships versus primarily focusing on in-house skills and knowledge?
12. Does your organization face any challenges or barriers with governance of your digital health systems?
13. How do you track the life cycle (upgrade, retirement) of your digital health systems at your organization?
14. Have you ever had an experience in which you were involved in the scaling of a digital health solution?
15. How do you prepare your digital health infrastructure to be future-ready for emerging technologies and use cases?
16. Do you have any feedback on how we can improve upon the interview process?

A.2 Industry

1. Do you think that health care facilities have the digital expertise required to manage their digital integration needs?
2. Where do you see the most gaps? What do you see as the key reasons for those gaps?
3. Which types of organizations do you see the most gaps in (e.g., acute, community, long-term)?
4. What resources or approaches would you recommend to organizations to improve integration between their digital health systems?
5. What are the main gaps from a workforce perspective that you have observed that have impeded health care facilities' ability to plan, implement, scale, or maintain its digital health systems?
6. When thinking of the future, many organizations are concerned about how they can obtain the skillsets to plan, implement, maintain, and train staff on emerging digital health systems (e.g., AI, augmented reality and digital twins). Do you have any guidance on how organizations can achieve this?
7. What organizations have you observed that have been successful with digital health systems and what approaches have they employed that have contributed to their success?
8. What do you see as the biggest challenges health care facilities face when planning, designing, or implementing technologies?
9. What approaches (i.e., resources) have you seen employed that successful organizations have used to plan, design, and implement technologies?
10. When considering the selection of digital health solutions, how important is integration and intersystem communication?
11. In the past, what issues have you experienced with integration and intersystem communication between systems?
12. Where is your biggest challenge as it relates to interoperability? Do you have any insights into how this could have been avoided in the initial planning and implementation phases?
13. Are there any gaps in your workforce that have impeded your ability to plan, implement, scale, or maintain your digital health systems?
14. When you have implemented digital health systems in the past, how did you decide on which use cases to implement?
15. What types of skillsets do you think are necessary to support these emerging systems such as AI, augmented reality, and digital twins?
16. Do you have any feedback on how we can improve upon the interview process?

A.3 Regulatory

1. Do you think that health care facilities have the digital expertise required to manage their digital integration needs?
2. Where do you see the most gaps? What do you see as the key reasons for those gaps?
3. Which types of organizations do you see the most gaps in (e.g., acute, community, long-term)?
4. What resources or approaches would you recommend to organizations to improve integration between their digital health systems?
5. What are the main gaps from a workforce perspective that you have observed that have impeded a health care facilities' ability to plan, implement, scale, or maintain its digital health systems?
6. When thinking of the future, many organizations are concerned about how they can obtain the skillsets to plan, implement, maintain, and train staff on emerging digital health systems (e.g., AI, augmented reality and digital twins). Do you have any guidance on how organizations can achieve this?
7. What organizations have you observed that have been successful with digital health systems and what approaches have they employed that have contributed to their success?
8. What do you see as the biggest challenges health care facilities face when planning, designing, or implementing technologies?
9. What approaches (i.e., resources) have you seen employed that successful organizations have used to plan, design, and implement technologies?
10. How are you involved in the regulation of digital health solutions for new and existing buildings?
11. When considering the selection of digital health solutions, how important is integration and intersystem communication?
12. In the past, what issues have you experienced with integration and intersystem communication between systems?
13. Where is your biggest challenge as it relates to interoperability? Do you have any insights into how this could have been avoided in the initial planning and implementation phases?
14. What types of clinical equipment would you classify as mandatory for your organization?
15. Are there any gaps in your workforce that have impeded your ability to plan, implement, scale, or maintain your digital health systems?
16. When you have implemented digital health systems in the past, how did you decide on which use cases to implement?
17. Does your organization face any challenges with the usability of your digital health systems?
18. When implementing a new digital health solution, how does your organization train users?

19. What types of skillsets do you think are necessary to support these emerging systems such as AI, augmented reality, and digital twins?
20. When implementing a digital health solution in a way that changes workflows/processes, what is the process your organization takes to update or develop new policies and procedures?
21. Linking back to our previous conversation around internal skillsets, do you think there is an opportunity to stay ahead and be innovative through partnerships versus being primarily focused on in-house skills and knowledge?
22. Does your organization face any challenges or barriers with governance of your digital health systems?
23. How do you track the life cycle (upgrade, retirement) of your digital health systems at your organization?
24. Have you ever had an experience in which you were involved in the scaling of a digital health solution?
25. How do you prepare your digital health infrastructure to be future-ready for emerging technologies and use cases?
26. Do you have any feedback on how we can improve upon the interview process?

Appendix B – Survey Questions

This appendix provides a list of the survey questions. The questions were developed based on the stakeholder groups being surveyed and include:

B.1 General Questions

The following questions were asked of each interviewee:

1. Please enter your name.
2. Please enter your job role.
3. Please enter your organization.

B.2 Recommendation-Specific Questions

The following questions were asked in relation to each of the recommendations located in Section 7:

1. Is the above recommendation applicable at a national level?
2. Do you agree with recommendation #1?
3. We also welcome additional comments that will help inform the recommendation.

Appendix C – Literature Review of Existing Standards and Guidelines

This appendix provides a summary table of the existing standards and guidelines identified through the literature review and their relevance to the topic areas under Section 3.3 Achieving Success.

Table 6: Existing Standards and Other Relevant Documents

Country	Name of Standard/ Document	Organization	Reference Identifier	Relevance to		
				System Integration & Intersystem Communication	People & Processes	Continuous Process Improvement
AUS	Application Solution Guide	Victoria State Government	DH Standard			
AUS	CIS and EMR Application and Interoperability Standard	Victoria State Government	DH Standard	✓		
AUS	Governance and Use of National Health Service Directory Data	Victoria State Government	DH Standard		✓	
AUS	Medications Management Interface and Interface Workflow	Victoria State Government	DH Standard	✓		
AUS	Oncology System Requirements	Victoria State Government	DH Standard	✓		
AUS	Patient Administration System	Victoria State Government	DH Standard	✓		
AUS	Queue Management and Outpatient System Integration Principles	Victoria State Government	DH Standard	✓		
CA	Accessible Design for Self-Service Interactive Devices	CSA	B651.2-07 (R2017)		✓	
CA	Canadian Health Care Facilities (Occupational Health & Safety, Patient Safety, and Accessibility Provisions)	CSA	Z8000		✓	
CA	Commissioning of Health Care Facilities	CSA	Z8001-13 (R2018)		✓	
CA	Health Care Facilities Standard	CSA	Z8000		✓	✓
CA	Health Informatics – Directory Services for Security, Communications and Identification of Professionals and Patients – *Withdrawn*	CSA	Z21091-07		✓	

Country	Name of Standard/ Document	Organization	Reference Identifier	Relevance to		
				System Integration & Intersystem Communication	People & Processes	Continuous Process Improvement
CA	Health Informatics – Electronic Health Record – Definition, Scope and Context – *Withdrawn*	CSA	Z20514-07	✓	✓	✓
CA	Health Informatics – Guidelines on Data Protection to Facilitate Trans-Border Flows of Personal Health Information – *Withdrawn*	CSA	Z22857-06	✓	✓	
CA	Health Informatics – Health Indicators Conceptual Framework – *Withdrawn*	CSA-ISO	21667:06	✓	✓	
CA	Health Informatics – Health Informatics Profiling Framework – Withdrawn	CSA-ISO	17119-06	✓	✓	
CA	Health Informatics - Interoperability of Telehealth Systems and Networks – Part 1: Introduction and Definitions – *Withdrawn*	CSA-ISO	16056-1-05	✓	✓	
CA	Health Informatics – Interoperability of Telehealth Systems and Networks – Part 2: Real-Time Systems – *Withdrawn*	CSA-ISO	16056-2-05	✓	✓	
CA	Health Informatics – Interoperability of Telelearning Systems – *Withdrawn*	CSA-ISO	16058-05	✓	✓	
CA	Health Informatics – Messages and Communication – Web Access to DICOM Persistent Objects – *Withdrawn*	CSA-ISO	17432-06	✓	✓	
CA	Health Informatics – Public Key Infrastructure – Part 1: Framework and Overview – *Withdrawn*	CSA-ISO	17090-1-05	✓	✓	
CA	Health Informatics – Public Key Infrastructure – Part 2: Certificate Profile – *Withdrawn*	CSA-ISO	17090-2-05	✓	✓	
CA	Health Informatics – Public Key Infrastructure – Part 3: Policy Management of Certification Authority – *Withdrawn*	CSA-ISO	17090-3-05	✓	✓	

Country	Name of Standard/ Document	Organization	Reference Identifier	Relevance to		
				System Integration & Intersystem Communication	People & Processes	Continuous Process Improvement
CA	Health Informatics – Requirements for an Electronic Health Record Architecture – *Withdrawn*	CSA-ISO	18308-05	✓		
CA	Inclusive Design for an Aging Population	CSA	B659-08 (R2018)	✓		
CA	Infection Control During Construction, Renovation and Maintenance of Health Care Facilities	CSA	Z317.13-17			
CA	Information Technology – Real-Time Locating Systems – Test and Evaluation of Localization and Tracking Systems	CSA-ISO/IEC	18305:18	✓		
CA	Operation and Maintenance of Health Care Facilities	CSA	Z8002:19	✓	✓	
CA	Wayfinding for Health Care Facilities	CSA	Z317.14-17	✓	✓	
INTL	Additive Manufacturing	ISO	261	✓	✓	
INTL	Audio Standard for Nurse Call Systems	NEMA SB	10	✓	✓	
INTL	Automation systems and integration – Digital Twin framework for manufacturing (Under development)	ISO/DIS	23247-1	✓		
INTL	Domain Information and Service Model for Service-Oriented Point-of-Care Medical Device Communication	ISO/IEEE	10207	✓		
INTL	Ergonomics of Human-System Interaction – Part 11: Usability: Definitions and Concepts	ISO	9241-11	✓		
INTL	Information Technology – W3C Web Content Accessibility Guidelines	ISO/IEC	40500:2012	✓		
INTL	IT Applications in Health Care Technology	ISO	35.240.80	✓		
INTL	Standard for Biometric Open Protocol	IEEE	2410-2019	✓		
INTL	Standard for Hospital Signaling and Nurse Call Equipment	UL	1069	✓		
INTL	Information Technology – Security Techniques – Information Security Management Systems – Requirements	ISO/IEC	27001:2005	✓		✓

Country	Name of Standard/ Document	Organization	Reference Identifier	Relevance to		
				System Integration & Intersystem Communication	People & Processes	Continuous Process Improvement
INTL	Information Technology – Security Techniques – Code of Practice for Information Security Management	ISO/IEC	27002:2005	✓		
INTL	Health Informatics – Provisions for Health Applications on Mobile/ Smart Devices	ISO	17522:2015	✓		
INTL	Health Informatics – Dynamic On-Demand Virtual Private Network for Health Information Infrastructure	ISO	11636:2009	✓	✓	✓
INTL	Health Informatics – Deployment of a Clinical Data Warehouse	ISO	29585:2010	✓		
INTL	Health informatics – Personal Health Device Communication	ISO/IEE	11073	✓		
INTL	Basic Safety and Essential Performance of Electrical Medical Equipment and Electrical Medical Systems	IEC	60601-1	✓		
USA	Administration Standards for Telecommunications Infrastructure	TIA	606-C	✓	✓	
USA	Balanced Twisted-Pair Cabling Components	ANSI/TIA	568.2-D	✓		
USA	Basic Safety and Essential Performance of Electrical Medical Equipment and Electrical Medical Systems	IEC/EN	60601-2	✓		
USA	Cabling Installation	ANSI/NECA/ BICSI	568	✓		
USA	Commercial Building Telecommunications Cabling Standard	ANSI/TIA	568.1-D	✓		
USA	Commercial Building Telecommunications Wiring Standards	ANSI/TIA	568			
USA	Definitions/Characteristics of Artificial Intelligence in Health Care	ANSI/CTA	2089.1	✓		
USA	Distributed Antenna Systems (DAS)	ANSI/BICSI	006-2015		✓	
USA	Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises	TIA	607	✓		

Country	Name of Standard/ Document	Organization	Reference Identifier	Relevance to		
				System Integration & Intersystem Communication	People & Processes	Continuous Process Improvement
USA	Intelligent Building Systems	ANSI TIA	862	✓		
USA	Outside Plant	ANSI TIA	758	✓		
USA	PoE Installation	ANSI/BICSI	N2-17	✓		
USA	Product Definition for Additive Manufacturing	ASME	Y14.46 - 2017		✓	
USA	Safety Standard For Guided Industrial Vehicles	ANSI/ITSDF	B56.5-2019		✓	
USA	Telecommunications Infrastructure Standards for Data Centers	ANSI/TIA	942		✓	
USA	Telecommunications Pathways and Spaces Standard	ANSI/TIA	569		✓	✓
USA	Integrated Accessibility Standards	O. Reg.	191/11		✓	
USA	Telecommunications Infrastructure Standard for Healthcare Facilities	TIA	1179	✓	✓	✓

Table 7: Existing Guidelines

Country	Name of Guideline	Organization
Europe	The Topol Review – Preparing the Healthcare Workforce to Deliver the Digital Future	NHS
CA	User Interface Design Guidelines	Canada Health Infoway
CA	Virtual Care Toolkit	Accreditation Canada
INTL	Web Content Accessibility Guidelines 2.1	WAI
CA	Guide to Information Security for the Health Care Sector	eHealth Ontario
INTL	WHO Guideline: Recommendations on Digital Interventions for Health System Strengthening	World Health Organization
INTL	Classification of Digital Health Interventions v1.0: A Shared Language to Describe the Uses of Digital Technology for Health	World Health Organization
UK	Evidence Standards Framework for Digital Health Technologies	NICE
INTL	Electronic Medical Record Adoption Model (EMRAM)	HIMSS
INTL	Infrastructure Adoption Model (INFRAM)	HIMSS

Appendix D – Digital Infrastructure Components

This appendix describes each of the main components of the HCF digital infrastructure layer. The standards and guidelines that are typically used in HCF projects with respect to these components are listed in Appendix E. There are hundreds of standards that have been created by standards development organizations that specify reference when designing HCF digital infrastructure. Many of these standards were reviewed and examined for the purposes of this report. A selection of commonly used standards is included below for reference.

There are many components that go into the HCF digital infrastructure. Facilities with more advanced end-devices, systems, and software often have more advanced digital infrastructure and their infrastructure may contain more components. The main components that are seen across HCFs are detailed in the following sections.

D.1 Wired Network

A wired network includes a robust and reliable cabling backbone and network components that support the transfer and communication of information across a facility. The wired network forms the foundation of site communication and all other system for data, audio, and video. Specifically, a wired network includes backbone cabling, multimode fibre, single mode fibre, redundant and diverse paths, horizontal cabling, active equipment, dual core switches, and edge/distribution switches. At the time of writing this report, the latest standard for horizontal cabling is Category 6A unshielded twisted pair. Category 7 is not yet recognized by the Telecommunications Industry Association (TIA). However, this is evolving and is anticipated to change over time. Power over Ethernet (PoE) is an advancing technology requiring redundant and reliable power for field devices.

D.2 Wireless Network

Within HCFs, a wireless network enables increased mobility of staff and patients by providing a method for reliable and fast wireless exchange of information. In order to allow for seamless transition to the new standard by any legacy equipment and devices, it is recommended that this standard be applied with backwards compatibility for previous versions. Coverage area is at the discretion of the HCF and can cover up to 100% of all areas of the facility, including stairwells and elevators, as well as exterior spaces. Design of the wireless network is critical to ensure that interference to other wireless technologies is not produced, such as telemetry systems.

D.3 Telecommunication Spaces

Telecommunications spaces are physically enclosed, secured, and environmentally controlled areas of the building that support dedicated IT equipment and devices. In addition to the data centre, these spaces include telecommunications rooms, which are enclosed architectural spaces that accommodate structured cabling terminations, network equipment cabinets, and wall-mounted equipment panels/cabinets for ICAT, AV, communications, and integrated safety and security systems. Entrance facilities house incoming services equipment from external providers, for telecommunications providers and other managed private services, and serve as a separate, access-controlled space for systems not owned by the hospital. Telecommunication spaces need to be designed to accommodate the future growing needs of ICAT equipment in the HCF environment.

D.4 Data Centre

The data centre is an enclosed, secured, and environmentally controlled space that houses centralized servers and data storage and processing equipment. Geographic redundancy and diversity ensure that services remain operational even in the event of a catastrophic failure of environmental controls, power, or the physical space. There are typically two data centres: a primary data centre and a secondary data centre. In recent years, many facilities have been choosing to move the secondary data centre off-site or to the cloud. A secondary data centre accommodates redundant network core equipment. Both data centres and all supporting systems require redundancy and fault tolerance.

D.5 Security Systems

Security systems within HCFs include access controls, video surveillance, real-time locating system (including patient wandering and infant protection), panic duress systems (wired and wireless), and intrusion detection. These systems can function independently or under a common platform that supports information flow and automated alerts between systems, as well as insights based on trends and performance. Security systems are expected to cover the entire campus, including services spaces and external areas such as parking areas, courtyards, and walkways.

Cybersecurity is an important component of a hospitals security posture. Cybersecurity includes pieces of the network architecture such as the firewall, as well as traffic monitoring, authentication, and many other software components. These systems are intended to prevent malicious actors from accessing hospital networks and ensure the confidentiality, integrity, and availability of all hospital systems.

D.6 Cellular and Radio Connectivity

A distributed antenna system (DAS) boosts the cellular coverage throughout the entire facility and should support all major cell service providers in the area. Coverage area is dependent on the strategy depicted by each individual HCF but can include up to 100% coverage, which includes the interior of the facility, elevator cabs, mechanical and electrical spaces, service areas, stairwells, and indoor parking. The DAS supports both cellular voice and data requirements and should have built-in redundancy with respect to life safety and emergency services use. The DAS typically includes all local and provincial emergency services frequency bands, and all major cellular frequency bands, which in recent years includes a minimum 5G frequency compatibility. To support legacy frequencies such as 3G and 4G, a backwards compatibility can be included.

In addition to the DAS, there is typically a land mobile radio distributed antenna system (LMR-DAS), which is used to boost the UHF Radio signal coverage throughout the building. The LMR-DAS is a separate antenna system from the cellular DAS, and boosts the UHF radio coverage of the life safety and emergency services such as first responders and ambulances.

D.7 End-Devices, Systems and Software

End-devices and systems refer to the equipment, devices, and systems in an HCF that are reliant on the HCF digital infrastructure in order to achieve full functionality. This includes the provision of adequate power, wired network drops, and adequate wireless coverage. Examples of end-devices include but are not limited to:

- Mobile devices (i.e., smartphone, tablet)
- Desktop computers (i.e., fixed, on wheels)
- Business devices (i.e., phones, faxes, printers, scanners)

- Audiovisual
- Sensors (e.g., building)
- Augmented and virtual reality devices
- Nurse call devices
- Patient wandering and infant protection arm bands
- Staff duress badges

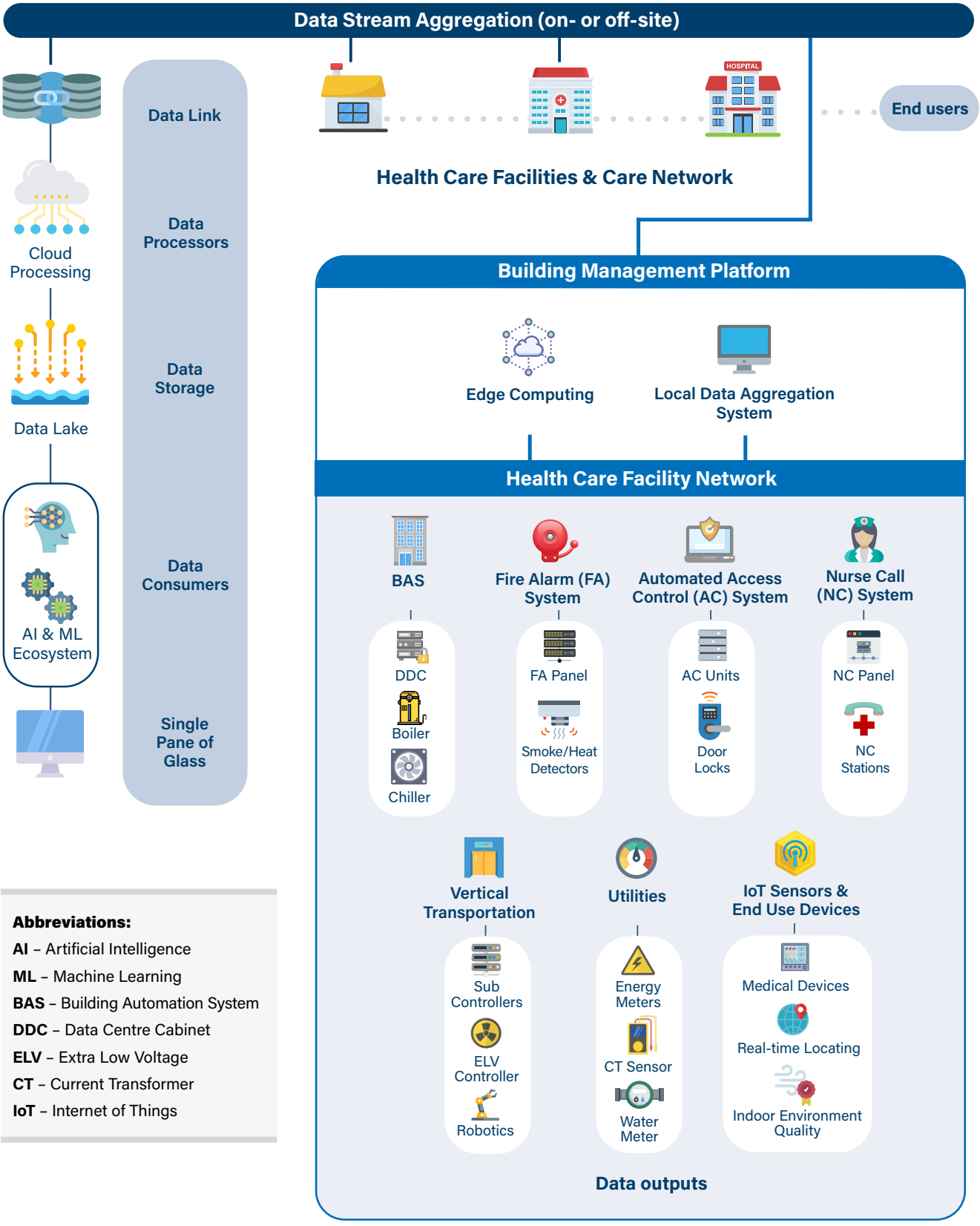
This report does not address medical equipment end-devices and their standards, although they can also rely on the digital infrastructure.

Software refers to those applications that provide the user interface and workflow component to many of the end-devices and systems. Software allows these items to be observed and controlled. Software is reliant on the digital infrastructure both directly (i.e., wired network) or indirectly (through end-device infrastructure requirements). Software in an HCF includes but is not limited to:

- Unified communications
- Decision support systems
- Electronic health records and accompanying clinical information systems
- Predictive analytics and artificial intelligence
- Administrative systems
- Real-time locating interfaces
- Nurse call interfaces
- Medication management
- Inventory management
- Facility management and flow management systems
- Management software is deployed throughout the facility to monitor and manage all systems including network, wireless, building, security, and clinical systems

In Figure 2, we depict how some of the end-devices, systems, and software are tied into the rest of the network. There are many systems that can tie into an HCF network, including systems not generally considered part of the digital infrastructure such as the fire alarm system and the building automation system, as these would also be connected to the network.

Figure 2: Example System Overview



Abbreviations:

AI – Artificial Intelligence
ML – Machine Learning
BAS – Building Automation System
DDC – Data Centre Cabinet
ELV – Extra Low Voltage
CT – Current Transformer
IoT – Internet of Things

Appendix E – Commonly Used Standards

There are hundreds of standards that have been created by standards development organizations that specifiers reference when designing HCF digital infrastructure. Many of these standards were reviewed and examined for the purposes of this report. A selection of commonly used standards are included below for reference.

Table 8: List of Common Digital Infrastructure Standards and Codes Used in HCFs

Topic	International	National
Networks (Wireless/ Wired)	ANSI/TIA-568.0-D Generic Telecommunications Cabling for Customer Premises	CSA C22.1 Canadian Electrical Code
	ANSI/TIA-568.1-D Commercial Building Telecommunications Cabling Standard	
	ANSI/TIA-568.2-D Balanced Twisted-Pair Cabling Components	
	ANSI/BICSI 008-2018 Wireless Local Area Network (WLAN)	
	ANSI/NECA/BISCI 568 Cabling Installation	
	TIA TSB-162-A Telecommunications Cabling Guidelines for Wireless Access Points	CSA T527 Bonding Requirements for Telecommunications in Commercial Buildings
	IEEE Standard 802.3an 10GBASE-T (10 Gb/s Ethernet Operations over Balanced Twisted-Pair Cabling)	
	ISO/IEC 14763-1:1999 Implementation and Operation of Customer Premises Cabling – Part 1: Administration	
	ANSI/TIA/EIA-862-A Building Automation Systems Cabling Standard for Commercial Buildings.	
	ANIS/TIA/EIA-568-C.0 Generic Telecommunications Cabling for Customer Premises	
	ANSI/TIA/EIA-606-A Administration Standard for Commercial Telecommunications Infrastructure	
	ANSI/TIA-607-C Generic Telecommunications Bonding And Grounding (Earthing) For Customer Premises	

Topic	International	National
Connectivity (Cellular, Radio)	EN 50310 Telecommunications Bonding Networks for Buildings and Other Structures	
	TIA-569.0-D Telecommunications Pathways and Spaces	
	ANSI/BICSI 006-2015 Distributed Antenna Systems (DAS)	
	ANSI/TIA-606-C Administration Standard for Telecommunications Infrastructure	
	TIA-222-H Structural Standard for Antenna Supporting Structures and Antennas	
	ANSI/TIA-758-B Customer-Owned Outside Plant Telecommunications Infrastructure Standard	
	BICSI Telecommunications Distribution Methods Manual (TDMM) – Latest Edition	
	ANSI/TIA-1179-2010 Telecommunications Infrastructure Standard for Healthcare Facility	
	EIA/ECA 310 Cabinets and Associated Equipment	
Connectivity (Cellular, Radio)	ANSI/TIA-942-A Telecommunications Infrastructure Standard for Data Centers	
	ANSI/BICSI 002-2014 Data Center Design	
	ANSI/BICSI 005-2016 Electronic Safety and Security (ESS)	
Security	BICSI Electronic Safety and Security Design Reference Manual	
	ANSI/BICSI 001-2017 Educational Facilities Design	
General ICT Infrastructure	NEMA VE2 Cable Tray Installation Guidelines	CSA C22.1 Canadian Electrical Code
	ANSI/BICSI 007-2017 Intelligent Buildings and Premises	
	BICSI G1-17 Outside Plan (OSP) – General BICSI Outside Plant Design Reference Manual (OSPDRM) – Latest Edition	
	ANSI/BISCI 004-2018 Healthcare	
	IEEE 602 IEEE Recommended Practice for Electric Systems in Health Care Facilities	
	ISO/TR 21730 Health Informatics – Use of Mobile Wireless Communication and Computing Technology in Healthcare Facilities	
	AC193 Mechanical Anchors in Concrete Elements	
	NEMA 250 Enclosures for Electrical Equipment (1,000V Maximum)	
	ANSI/BICSI 003-2014 Building Information Modeling (BIM)	

Topic	International	National
Other Technology	ANSI/BICSI N2-17 PoE Installation	
	ISO 11064, Parts 1–7 Ergonomic Design of Control Centres	
	BICSI Information Transport Systems Installation Manual (ITSIM) – Latest Edition	
	ISO 9241-11:2018 Ergonomics of Human-System Interaction — Part 11: Usability: Definitions and Concepts	
	NEMA SB 10 Audio Standard for Nurse Call Systems	

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

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