Planning Considerations for Migration to Hospital Intelligent Technology Infrastructure

by Graeme Robertson

Executive summary

Around the world, hospitals are struggling to meet the demands for quality patient care and efficiencies across the organization. Healthcare engineers and technicians need to facilitate efficiency improvement by addressing new and emerging functional requirements for patients and staff. This paper reviews best practices for development of a logical design and deployment of a hospital intelligent technology infrastructure.

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Introduction

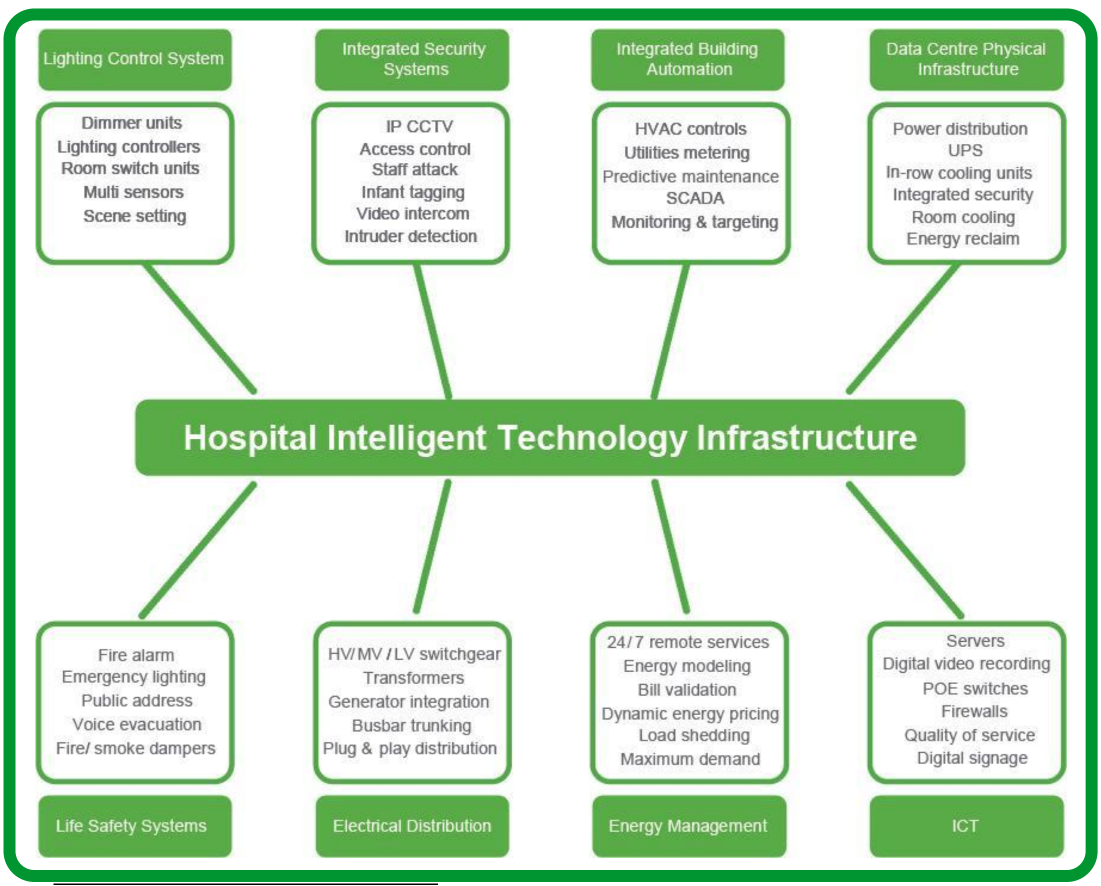
A “hospital intelligent technology infrastructure” is necessary to survive and remain competitive in today’s healthcare industry. Such an infrastructure implies the progressive integration of information systems with physical infrastructure systems (i.e., power, HVAC, lighting). An intelligent technology infrastructure acts as a central nervous system for the hospital and integrates disparate systems such as power, building management, security, and IT. This enables faster and more accurate communication, as well as real-time monitoring, optimization, and automation. When hospital systems can “talk” with each other, the infrastructure as a whole is strengthened and builds intelligence, thereby improving resource efficiencies across the healthcare organization.

However a number of significant barriers must be overcome to achieve this goal of an intelligent infrastructure. Constrained budgets, process inefficiencies, and an ageing infrastructure all contribute to a high degree of waste. In fact, a World Health Organisation’s (WHO) report estimates that 20–40% of resources spent on healthcare are wasted.[1] It is also estimated that in the United States alone $335 billion a year is wasted in healthcare due to the lack of interoperability of information systems.[2]

How can engineers, technicians, and facilities personnel introduce change that will produce real efficiency results? First the organisation must realize that architectural and engineering design and services play a key role in achieving improved health outcomes. Engineers and technicians are the ones who understand the steps that need to be taken to create an overall system design model that integrates separate sub-systems into a single intelligent infrastructure (see **Figure 1**). This white paper shares best practices for identifying functional requirements, mapping out a logical design, and maintaining an efficient network.

Figure 1

Components that make up an intelligent technology infrastructure



[1] WHO. “World Health Report 2010: Health Systems Financing: The Path to Universal Coverage.”

[2] Bradley Sokol, Fast Track Technologies, Ltd. “RFID & Emerging Technolgies Market Guide to Healthcare.”

Benefits and desired outcomes

A hospital intelligent technology infrastructure should be designed with the following goals in mind to best serve the needs of the patients, staff, and healthcare organisation:

- Provide maximum system uptime, high levels of resilience, and intelligence distribution
- Improve energy efficiency by closely monitoring and controlling energy sources
- Improve patient and staff safety through integrated video surveillance, access control systems, and protection systems
- Improve patient comfort through lighting and environmental controls, as well as nurse call services in patient rooms

The technology infrastructures covered in this paper focus on the principle of an intelligent technology infrastructure, which facilitates applications that improve staff efficiency and the patient experience. This type of communications infrastructure is often referred to as a "hospital grade network" and is designed to achieve the following benefits:

"The reliability of the electrical power infrastructure, cooling, and physical security systems that support the information technology equipment is of equal importance to achieve the required levels of resilience."

- **Security** – Hospital data is sensitive and must be safeguarded. Considerations such as remote access by clinicians, data security of the equipment, and compliance with applicable local data regulations and laws should be built into the design.
- **Performance** – High speeds of data entry and retrieval, 7 x 24 uptime, flexibility, and serviceability are characteristic of what an intelligent hospital network strives to deliver. Consistently high levels of performance are required for data, voice, video, and biomedical applications which require wireless communications in order to provide maximum benefit.
- **Resilience** – A six sigma compliant network design is required to deliver 99.999% availability, which roughly equates to 5 minutes down time per year. The server room or data centre physical infrastructure design is also a critical aspect of network reliability. (See Schneider Electric white paper *"Data Center Physical Infrastructure: Optimizing Business Value")*. The reliability of the electrical power infrastructure, cooling, and physical security systems that support the information technology equipment is of equal importance to achieve the required levels of resilience.
- C**apacity** – Modular, scalable systems allow for investment in sufficient capacity to handle both current and visible future needs without high up- front investment. This is essential to achieve a full return on investment in the medium and longer term. Networks must be designed to support real-time location system (RTLS) migration, where asset location management can be achieved for potentially hundreds of thousands of devices.

Providing a common intelligent network allows traditionally disparate systems within a hospital to communicate with each other and send targeted information to different users. By integrating building systems into a single network, healthcare organizations can realize the following capital expense (CapEx) and operational expense (OpEx) benefits:

CapEx benefits – Less cabling and construction, fewer devices

- A single infrastructure base avoids the extra cost of having to wire individual subsystems with custom cabling and sockets for different applications. By standardizing to CAT6 or 7 twisted pair cabling and universal network sockets (RJ-45), both the number and average length of cables are reduced. The reduction of cabling and the use of a standardised, repeatable method also reduce the labour cost associated with the cable installation.
- An intelligent technology infrastructure network reduces time spent on commissioning the systems, which leads to reductions in required construction labour.

The number of active network devices is also reduced in an information technology network. Each separate system doesn't require its own switches or network equipment. In addition, the switch capacity can be optimized, which leads to cost reduction.

OpEx benefits – Improved network operating resilience

"System availability can be better managed from a single network than from many separate networks."

- System availability can be better managed from a single network than from many separate networks. High availability design improves network uptime and reliability.
- Network management and diagnostics can be integrated into the systems to indicate whether the point of failure is in the network or in the equipment. This improves failure detection and shortens reaction time. For example, an inactive network switch port can lead to a camera being silent. The first reaction would be to investigate the camera, but with network diagnostics, the point of failure can be detected in the network switch and the problem can easily be fixed.
- Network security can be improved with firewalls and this prevents unauthorized access to network resources that may cause costly downtime.
- Remote access can be built with secure solutions (such as VPN tunnels and one-time passwords), allowing remote access to only certain parts of the network. For example, building maintenance staff can use building management systems (BMS) remotely, but might not be allowed access to video security or access control.
- Openness and flexibility allows future technological developments, such as wireless ZigBee and RTLS tagging, to be easily adapted to standard Ethernet/IP communications. Relocating and reconfiguring equipment using standard IP communication and wireless technologies is easier and more cost effective than discrete technologies.
- Facilities management wireless connectivity allows mobile working whilst in continuous connection to the integrated system. For example, facilities maintenance staff can test system operations by connecting to a WLAN using the management system, while standing next to the field equipment to observe correct system behaviour.
- Power over Ethernet (PoE) techniques reduce maintenance and reconfiguration costs. PoE-powered devices can be relocated to any network socket without having to install new electrical cabling.
- Remote access to the systems reduces duty calls and results in faster problem resolution. For example, the system can check to see if an alarm requires immediate action remotely from a BMS or from video surveillance feeds.
- Targeted monitoring and control offers views to different management tasks. HVAC, video surveillance, access control, electrical, energy efficiency, data centre, and network can all be set up as different dashboards. Also, collective integrated dashboard can offer views for total facility management.

An intelligent technology infrastructure can also improve a patient's journey through the healthcare system, as well as provide additional efficiencies through improved staff productivity. For more information, see Schneider Electric white paper entitled *"Effect of Intelligent Technology Infrastructure on Hospital Operating Costs and Patient Care"*.

Design guidelines

When designing an intelligent technology infrastructure, functional, logical, and maintenance requirements need to be gathered at the outset. The logical and functional requirements are derived from network safety requirements, availability requirements, building(s) layouts, and cabling requirements. The functional requirements are the most important because the network must meet the needs of the end users (patients and staff), as well as the needs of the technical systems and the applications they support.

Below is a list of variables that influence the overall efficiency of the design:

1. **Departmental adjacencies** – This influences the efficiency of patient flow, which will impact the patient's personal experience at the hospital.

2. **Single versus double rooms** – This affects infection control and recovery rates, as well as reduction of patient falls and medication errors.

3. **Windows versus no windows** – This determines the level of natural light, which is linked to recovery rate and reduction of sensory deprivation, anxiety, and depression for both patients and staff.

4. **Floor and wall surfaces** – This is important for infection control, where surfaces should be impervious and smooth without cracks and crevices at the top and bottom edges. Aseptic paint with antibacterial properties may also be used.

5. **Acoustic design** – In coordination with engineering services design, a combination of sterile and washable sound-dampening surfaces, improved noise attenuation in ventilation systems, and automatic noise monitoring systems encourages staff to make less noise. In addition, a range of practical measures like providing patients headsets to use when watching television can result in significant noise reduction. Reduction of high noise levels in hospitals can lead to improved health outcomes for patients due to less stress, better sleep, decreased blood pressure, optimized environment for wound healing, reduced staff errors, and "alarm fatigue".

"It is estimated that in the United States alone $335 billion a year is wasted in healthcare due to the lack of interoperability of information systems."

- WHO, 2010

6. **Unified services** – These are designed to provide an ideal healing environment through the efficient management of heating, ventilation, lighting, air conditioning, and bed services, and are aimed at improving recovery rates and geared toward a patient-centric networked model of care.

7. **Infection control** – Measures such as automated hand hygiene compliance monitoring, air filtration, contamination monitoring, and automatic water flushing systems can prevent micro-bacterial contamination.

8. **Electrical power infrastructure** – Essential for any healthcare facility to function, reliable power is needed for critical medical equipment and services, as well as server rooms and computer equipment containing electronic medical records, X-rays, and other crucial medical data.

9. **Medical engineering** – Services such as integrated bed-head units, which when equipped with the latest technology, provide the patient with the therapeutic benefit of being able to keep in touch with friends and family, order meals, activate nurse call, and control their physical environment. It also enables medical staff to directly input notes and / or records and use an inbuilt spotlight for examinations.

10. **Safety and security** – Active electronic systems such as video surveillance, access control, staff attack, intercom, fire detection and suppression systems, as well as real time location systems (RTLS) for patient and infant tracking, provide a secure environment for patients, visitors, and staff.

Functional requirements of a communications network in a hospital can be derived from the functional requirements of the system integration design. **Figure 2** demonstrates how the network is essential in all the levels of functional requirement.

The integrated communications network encompasses information technology systems and technical systems such as BMS, security, safety, and power monitoring. Medical systems can have a separate ICT network because of patient confidentiality issues if desired, although both of the networks can be built on the same core fibre-optic cabling utilizing different fibres.

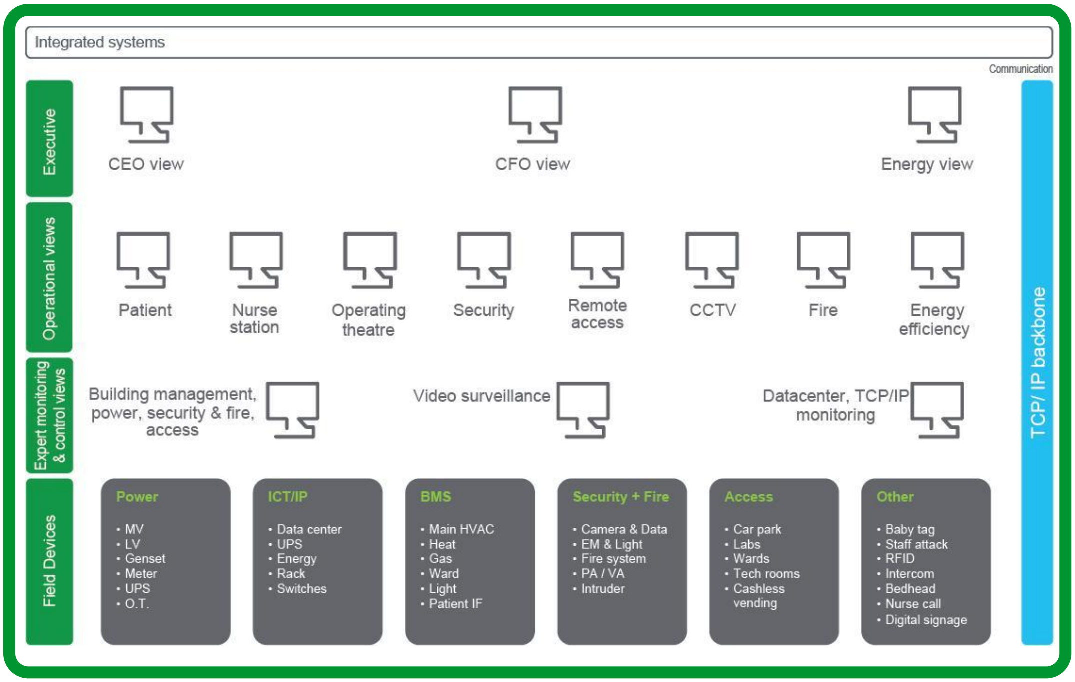


Figure 2
Hospital intelligent infrastructure functional design

To enable communication between the systems within a hospital intelligent technology infrastructure, the following key components should be considered when trying to achieve resilient network operation:

1. Graphical user interfaces for various users – nurse to facility manager to CEO
2. Portable user interfaces for laptops, PDAs and portable keypads
3. Network controllers
4. Direct Digital Control (DDC) system controllers housed in distributed enclosures
5. Frequency inverters
6. Motorised control valves and damper actuators
7. Sensors, switches, and other field-mounted control and monitoring devices

Operating and maintenance services must fit the required level of performance throughout the installation life cycle to support the analysis of:

1. 24-hour alarms
2. Repeated alarms
3. Duration from alarm acknowledgement to clearance
4. Unacknowledged alarm duration
5. Hardware point alarms
6. Alarm failure pattern
7. Alarms regarding mean time to repair and mean time between failures control-loop performance and usage
8. Optimizer performance at occupancy time

9. Access to system
10. Modified points and manual overrides on a per-user basis

The logical design derives its requirements from the functional requirements, and covers protocols, topology, and the safety of the network (see **Figure 3**). Although the physical design is the last step of the design process, the physical realities must be taken into account in the logical design.

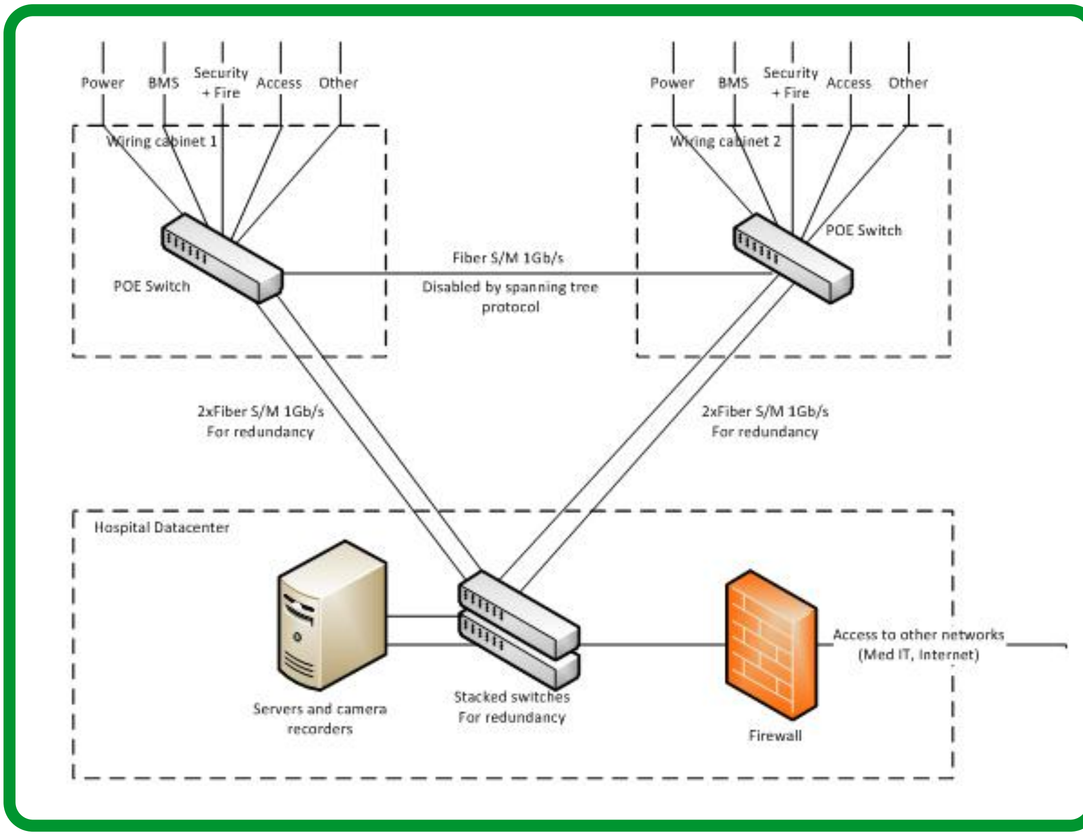


Figure 3
Simplified logical network design

The design in **Figure 3** shows the network devices, topology and safety elements. Ethernet switches are used to route the network traffic from wiring cabinets to a centralized hospital data centre. PoE switches are used to power TCP / IP cameras and other PoE devices. Resilience of the network is strengthened by adding failover backup switches in the data centre and doubling the network connections to servers and wiring cabinets. Network reliability is also increased by using extra fibre between wiring cabinets to create alternate routes for the traffic in case of cable failure. There are also many other techniques such as virtual LANs, load balancing and Quality of Service (QoS) that will be used to build a superior resilient and highly available network.

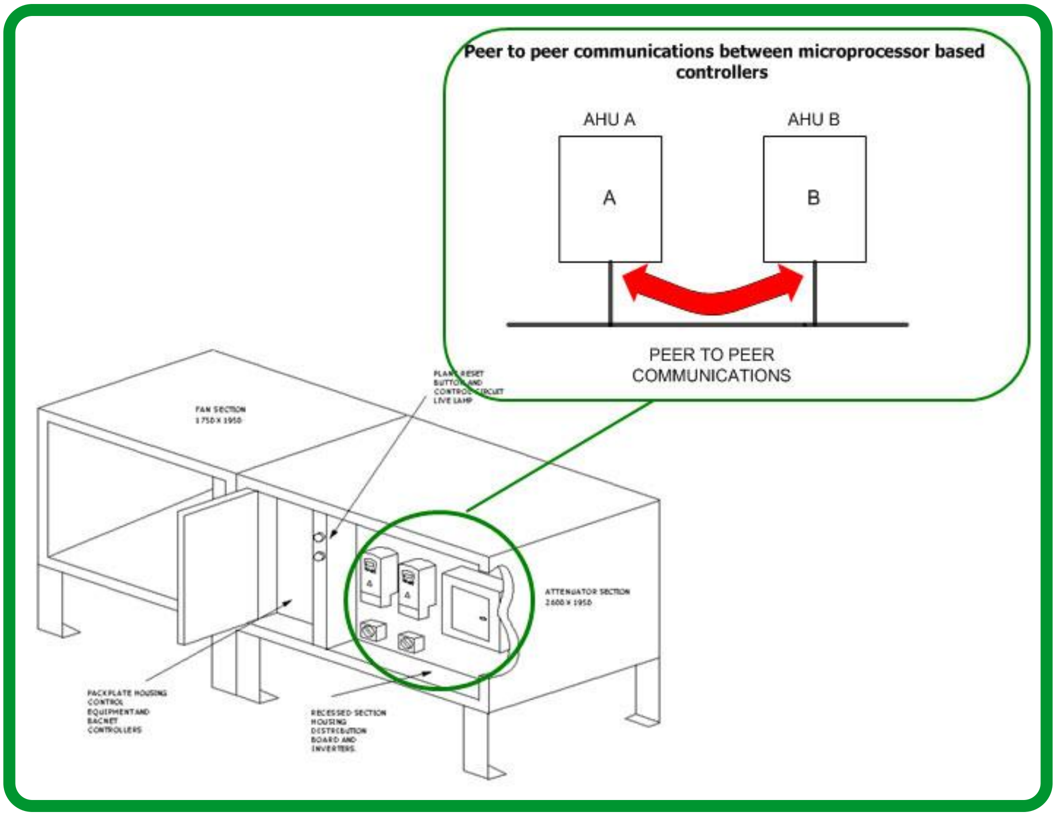
Distributed intelligence

The diagram in **Figure 4** illustrates the principle of distributed intelligence and power as applied to the hospital ventilation systems. The same principle applies equally to other systems, such as fluid power distribution systems.

The application of this principle reduces the capital cost of the installation as it allows HVAC systems to be pre-fabricated and tested at the factory, negating the requirement for custom manufactured motor control centres (MCCs). The commissioning phase of the project is also simplified due to the fact that commissioning taking place offsite. Once in operation, each unit is fully decentralized. This increases system resilience because the failure of one direct digital control (DDC) unit does not cause the failure of multiple plant components.

This type of distributed design also allows for the standardisation of control panel designs, software, and graphics to increase the level of familiarisation of the facilities staff. This advanced installation technique was used at in a major UK hospital and saved 22 weeks of site labour during the construction phase of the project.

Figure 4
Distributed intelligence and power in ventilation systems



Redesign process

The implementation of an intelligent technology infrastructure is highly scalable ranging from a single improvement in a single department of an existing hospital to a complete integrated technology infrastructure in a new hospital.

In order to carry out a technology redesign in existing hospitals, there are proven processes to initially determine the concentration and extent of waste. The main types of waste are identified as:

- Defects – drug prescription errors and incomplete surgical equipment
- Overproduction – inappropriate scheduling
- Transportation – distance between related departments
- Waiting – by patients or staff
- Inventory – excess stores that expire
- Motion – poor ergonomics
- Over processing – duplication of effort across different departments
- Human potential – not making the most of staff skills

The key stages involved in process efficiency redesign are illustrated in **Figure 5**. The advantages of small scale "pathway" redesign are speed and ease of implementation, but there is always a risk that an improvement in one part of the process will only lead to a longer delay at another, providing little or no overall benefit to the patient.

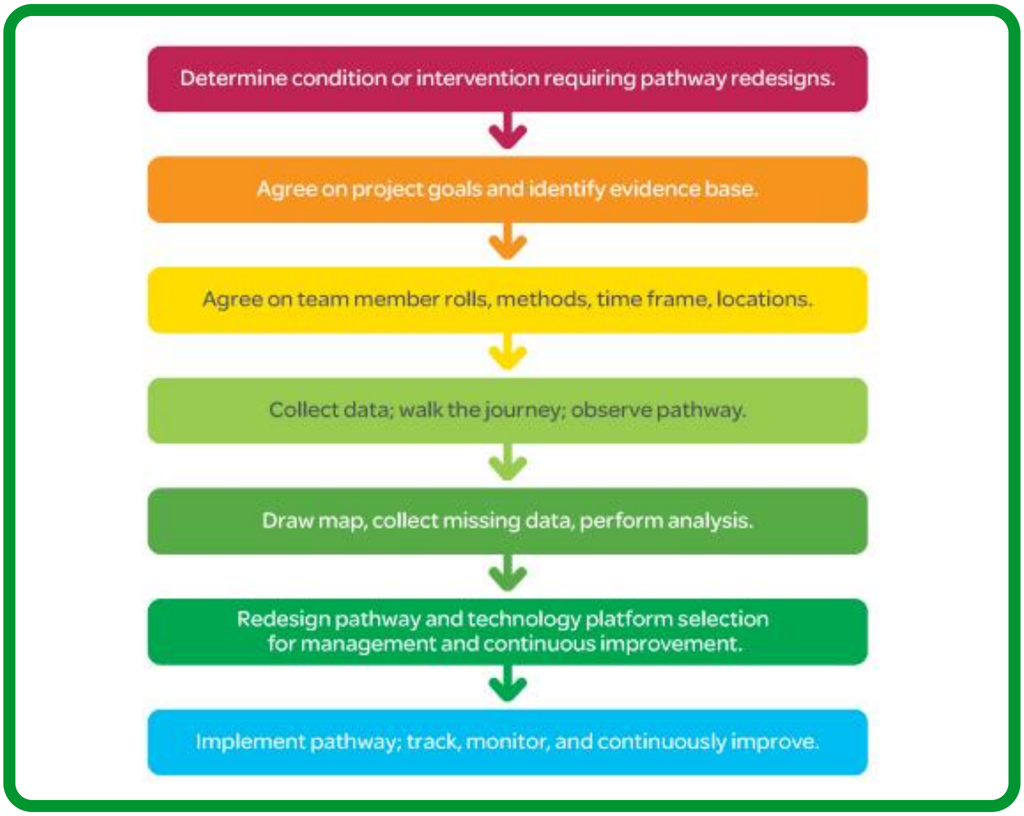


Figure 5
Key stages involved in pathway redesign

In new construction and redevelopment projects scenarios, or when considering patient journeys from a broader perspective, larger scale technology infrastructure designs can be considered, which aim to deliver major improvements in the end-to-end patient journey.

For more information on the benefits of a large-scale intelligent technology infrastructure, see Schneider Electric white paper entitled *"Effect of Intelligent Technology Infrastructure on Hospital Operating Costs and Patient Care".*

Maintenance and improvement

Servicing and maintenance of the equipment should take place in accordance with the manufacturer's recommendations. In cases where the delivery of healthcare services depends heavily on the correct functioning of the technology application, this obligation must be given the highest possible priority. The standard of maintenance in hospitals is generally poor. For example, an organisation such as the UK National Health Service (NHS) runs with a maintenance backlog estimated at £3.74 billion[3]. A different approach is needed to improve standards to gain full return on investment.

Some technology infrastructures can act as an enabler to smarter, more predictive maintenance regimes. One such example is condition-based monitoring, which uses a combination of advanced software and the data existing within hospital equipment to prioritise scheduled maintenance on equipment that needs it and reduce planned maintenance on

[3] "NHS faces £4bn maintenance backlog" – http://metro.co.uk/2007/10/24/nhs-faces-4bn-maintenance-backlog-379868/

equipment that doesn't. The data can also be extended to perform predictive maintenance, which uses software analysis to predict faults or possible failure conditions in advance of the event to allow corrective action to be taken before an issue arises.

Conclusion

Implementing a hospital intelligent technology infrastructure is one of several types of efficiency programs that are leading a new wave of conservation measures. The challenges are real, and the strategies and techniques suggested in this paper have been tested and proven at Schneider Electric healthcare customer sites. Infrastructure intelligence and efficiency is a largely untapped savings resource that aids in the effort to meet healthcare industry goals, ranging from improved patient care to sustainability, and improved financial health.

Prudent steps for launching an intelligent technology infrastructure in a hospital include the following:

- Identify a trusted energy partner and advisor with global deployment experience
- Assess existing processes for potential waste reduction and efficiency opportunities
- Solicit qualified contractors for best-value proposals

The development of an intelligent infrastructure incorporates technology pathways that improve the patient journey. When selecting pathways, healthcare organisations, planners, designers, and technology providers need to consider which pathways are best suited to the situation and provide the best return on investment.

About the author

Graeme Robertson is Global Business Development Director at Schneider Electric and has worked in the field of Intelligent Systems design for Hospitals for over 20 years. He holds a bachelors degree in Energy Engineering from Napier University in Edinburgh and is a member of the Institute of Energy. Graeme has worked on several award-winning hospital projects recognised by the International Academy for Design & Health and has published numerous papers in global journals and for industry conferences.