

C3 SYSTEM: AHEAD OF THE GAME



When the COVID-19 crisis struck Singapore, the lessons from SARS were still fresh and had since led to the country being more prepared, and the development of innovations that were critical to outbreaks.

An important factor in ensuring that patients get better care is the ability to optimise the management of resources such as beds, manpower and flow visibility, all this has been made possible with the Command, Control and Communications (C3) system.

The C3 system is a smart system that can sense, think and respond in order to optimise patient flow and care delivery, and acts as the “brain” of the hospital, in a concept similar to that of an airport control tower.

It provides real-time visibility, flow management and resource optimisation to enable Hospital Management to have a better appreciation of the COVID-19 ground situation, and coordinate, and make timely and effective decisions.

Conceptualised as early as 2013, the C3 system was the result of a collaboration between Tan Tock Seng Hospital (TTSH) and Integrated Health Information Systems (IHIS), with vendor ST Engineering, and was aimed at enabling better coordination and care for patients at a systemic level.

“Today, there is no such command and control centre in any healthcare facility worldwide. Traditional healthcare Command Centres typically focus on facility management or bed allocation,



while recently developed Command Centres are still predominantly inventory-centric and business Intelligence driven. Instead, ours would be a first of its kind in healthcare, with the primary focus to coordinate flow, by adopting a more holistic view to the hospital ecosystem," said Mr Albert Tan, Deputy Director, Resource Management.

"Evidence-based management decisions are vital in the healthcare system and IT projects such as C3 are the enablers to provide such evidence. C3 processes data from multiple source systems to present meaningful insights on a centralised video wall, and leverages artificial intelligence to predict potential choke points and identifies the most optimal resolution approach to ensure patients are timely discharged," said Mr Gurusamy Arul Prasath, C3 Project Manager at IHiS.

He added, "This way, hospital staff are able to make informed decisions to provide more efficient care."

One of the vendors eventually selected was ST Engineering. Bringing valuable experience in setting up the core platform, ST Engineering had built C3 systems for both defence and public institutions.

Ms Jas Sng, the project manager from ST Engineering, said that among the many C3 systems built, the Airport Operations Centre System was most similar to a hospital setting, whereby operations were constrained by fixed and limited resources, experienced peaks and troughs in demand and have the need to handle emergency situations.

Hence, that inspired them to use the same concept to build the C3 Smart Hospital System in providing real-time visibility of resources with automated workflows and contextual communication to manage operations proactively and derive efficiency.

Issue at Hand

TTSB was a busy hospital, with an average midnight bed occupancy rate of 91 percent in 2018, and an average Bed Waiting Time for admission of 3.9 hours. The demand for hospital/tertiary services was high partly because:

Often, healthcare partners do not have visibility of one another's situation. This delayed the efficiency of transfers across healthcare providers.

Optimisation occurs at a unit level, and individual providers are not cognisant of the impact of their work on others (eg: Polyclinics continued to refer patients to a tertiary hospital that was facing full occupancy).

The mindset was predominantly on inventory/stock management and not one of flow management. Within each healthcare operator, the management team might not have full real-time visibility of the ground operations, and any response was delayed, or blindsided by bottlenecks within the system.

With the increasing demand for healthcare, it was not sustainable to continue with the conventional ways of bed management, and there was a need to look at integration of care, both horizontally and vertically.

Vertical Integration

Vertical integration of care involved optimisation within the hospital's own resources. There was a need to be able to appreciate and predict patient flow, and quickly identify any choke points, ranging from shortage of manpower/supplies to prolonged turnaround time.

Sometimes, unnecessary delays could also be due to manual coordination, for example, when passing down information. As such, the C3 system also target to seamlessly trigger appropriate response plans via automated Standard Operating Procedures (SOPs).



The Minister for Health visiting the Operations Command Centre on the occasion of the Official Opening of the Ng Teng Fong Centre for Healthcare Innovation on 9 May 2019.

Horizontal Integration

Horizontal integration of care involves optimisation beyond the hospital shores, and leveraging on upstream and downstream resources to load balance the workload within the healthcare ecosystem.

There was a need to look into population health more, and right site care where possible. This relies on tapping more on primary care as well as step-down care partners as much as possible, instead of over-relying on tertiary care.

Also, because transfers between healthcare operators was critical to achieve this, there was a need to minimise any unnecessary wait for transfer due to lack of information.

To transform the mode of operations, the C3 team focused on:

a) **Shift in Mental Model** – There was a need to shift the mental model from inventory management to flow management. Real-time visibility of all key touch-points via automated reporting was critical to ensure alignment of stakeholders. In addition, seamless coordination was needed to avoid unnecessary delays due to manual coordination.

b) **Keeping Ahead** – To stay ahead of the game, predictive analytics was used to forecast workload, and allow pre-emptive load balancing. For example, the daily attendance at the Emergency Department (ED) could fluctuate from 350 to 500, depending on the day of the week, as well as seasonal factors. So, a C3 prediction model was developed, enabling the prediction of the ED attendance with up to an 83 percent accuracy.

c) **Leveraging on a Private-Public Partnership** – While C3 is a new concept in healthcare, TTSH and IHiS was able to leverage on ST Engineering's vast C3 experience applied in the defence industry for the development of the system.

d) **Technology Stack** – The C3 development had identified multiple scenarios, where additional capabilities would need to be progressively developed. As such, the system was set up with stackable individual technology modules, similar to putting together pieces of a jigsaw puzzle. Some pieces that were already in place include a bed allocation decision support system, as well as RFID tagging of patients.

e) **Providing Visibility via Sensors** – Instead of limiting the usage of IP cameras just for traditional security purposes, additional IP cameras were re-purposed and deployed to facilitate capacity management. For example, video analytics was implemented to monitor the number of people at the ED, and the number of patients waiting to register.

Game Plan

The C3 system aims to sense, think and respond to abnormal situations, optimising patient flow and care delivery.

This would require the system to deliver on 4 core capabilities:

- Monitor and sense the situation on the ground through the integration of multiple source systems
- Provide decision support by furnishing actionable insights and recommendations
- Optimise flow of patients with the use of prescriptive analytics
- Autonomy to self-learn and self-execute SOPs with the use of artificial intelligence

The C3 system would function as the “brain” of the hospital, where at least 80 percent of operational responses would be automated, leaving about 20 percent of more complex situations for staff to review and address with real-time decision support by the system.

To facilitate adoption, an agile methodology was adopted to provide opportunities for iterations.

Clinical and operational leads from key departments, as well as senior management were constantly engaged and given regular demonstrations of the C3 developments, before embarking on full scale implementation.

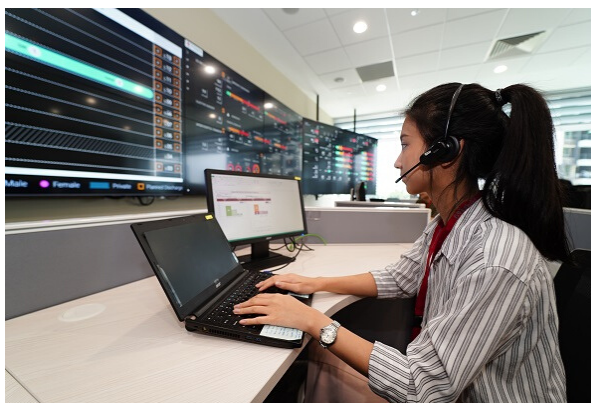
Lessons Learnt

Even though the C3 only went “live” in December 2019 for ED and inpatient management, preliminary measurements of improvement were promising. It was now possible to get a real time update of the following facilities:

- **Emergency Department:** Number of patients waiting to be registered, bed allocation, etc.
- **Bed Stock:** Number of beds available, broken down by type and location

- **Discharge Situation:** Provide visibility of bed availability of important downstream partners like nursing home and community hospitals

With these capabilities fully automated, the delay from manual relaying of information was minimised, and staff could shift their focus to more complex tasks.



Game Plan

New to stakeholders, it was initially challenging to demonstrate the benefits of the system.

“There needed to be an alignment of data interpretation. It was necessary to understand the workflow on the ground in order to understand the data that the system provides. In addition, as the concept was so new to many stakeholders, it was also important to adopt an agile implementation approach, and to always involve them and have regular read-backs, and learn how to fail fast and learn fast,” shared Mr Tan.

Mr Bruce Liang, CIO, MOH and CEO, IHIS, added: “C3 is a greenfield project with no ready design references from the Healthcare sector. As such, it was relatively challenging to define the requirements, design the product and develop the computation model. To overcome these challenges, we adopted the agile development methodology which involved building the product iteratively and establishing a multi-disciplinary team which comprised clinicians, ops and tech professionals. We also leverage on industry partners who had experience in designing C3 systems in other industries.”



"Another challenge was the establishment of 'soft sensors' in traditional healthcare IT systems, to enable ops to monitor over 600 indicators across the hospital. Hospital IT products are not designed to communicate with a C3 system. As such, significant software engineering was involved in modifying several IT systems to feed to the C3 analytics model," said Mr Liang.

For ST Engineering, the initial challenges the team faced were related to the lack of healthcare operations knowledge and understanding of specific healthcare terminologies.

This was a steep learning curve for the team to overcome quickly in order to interpret and start building in the required business logic into the C3 system. The team, particularly the business analysts, worked closely with business users and the IHIS team, learning on the job to overcome these challenges.

Coupled with their experience in implementing the C3 system, the team was able to quickly translate the requirements into an operational C3 Smart Hospital System.

Looking Ahead

TTSH is on a continuous journey to enhance the C3 capabilities further. More sensors would also be installed on the ground and manual processes would be digitalised to provide more on the ground data back to the C3 system.

The hospital is also looking at implementing additional artificial intelligence (AI) technology, to allow the system to make 80 percent of operational responses autonomously, leaving 20 percent of the more complex situations to staff.

In addition to the ongoing vertical integration within TTSH, the next step would be to look at horizontal integration, and to make C3 a truly national system.

With its scalable structure, the system's capabilities would be extended upstream to link up with pre-hospital phase facilities, such as ambulances, and downstream to the community hospitals, enabling timely and seamless transitions between care facilities.

There are plans to subsequently extend the system to MOH and other hospitals, to help the public healthcare system to load balance and optimise patient care and national bed utilisation.

"To ensure that C3 system is extensible and scalable across all our public hospitals, C3 is hosted on Healthcare Cloud and designed to have a common infrastructure with modular features to enable speedier customization. When scaled at a national level, C3 will enable enhanced load balancing of our healthcare resources across the public hospitals to better serve our population, as well as allow for better coordination during a national crisis" said Mr Liang.

Box Story: Rapid Development for COVID-29

From the onset, seven different scenarios requiring the C3 system's response had been identified, ranging from peacetime matters, to crisis issues.

One of these scenarios was to prepare for a disease outbreak. When the COVID-19 crisis hit Singapore in February, the system's Disease Outbreak module was still being worked on. Both TTSH and IHIS accelerated the module's development, to quickly deploy relevant real-time monitors within a month.

With the ability to communicate and coordinate hospital-wide operations, based on timely data from across multiple systems and the frontline, it was possible to provide accurate ground sensing. C3 enabled real-time reporting of data, done via:

- Real-time Location Trackers (RTLS) and Radio Frequency Identification (RFID) to track the real-time movement of staff and patients.



- Pulling in key data and information from existing source systems, such as the inventory and turnaround time of laboratory and radiology test orders.
- Installation and linking up of CCTVs at key access points into the hospital to monitor and count the number of people coming in, to avoid chokepoints.

Through the real time visibility provided by C3, the hospital staff were able to identify and arrest escalating ground situations.

A good example would be in early February, when due to a change in case definition criteria, there was a surge in the number of cases at the screening centre of the National Centre for Infectious Diseases (NCID).

Attendance was three times higher compared to previous days, and this corresponded to a related rise for inpatient admissions into NCID.

Through the data pooled from CCTV footage and RTLS, the Operations Command Centre was alerted of the surge, before the ground team activated reinforcements.

Within 24 hours, because of the decision support provided by the C3 system, the team pre-emptively mobilised the manpower, equipment and other supporting resources to open five wards at NCID, and strengthened the support at the screening centre.

It has been a challenging time as the team worked tirelessly to refine the existing disease management flow and in developing various widgets to manage the current COVID-19 situation.

This was a great learning opportunity for the team behind C3, who were proud to be working on a project that would save lives and prepare Singapore for the future.

CENTRE FOR
HEALTHCARE
INNOVATION ®

© Centre for Healthcare Innovation
Permission required for reproduction.
Email: chi@ttsh.com.sg