Using Logic Model and Key Performance Indicators to Construct A Field Hospital for Coronavirus Pandemic Cases

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Abstract

Background. Field hospitals have been established as part of the COVID-19 pandemic response in a range of countries including the Kingdom of Saudi Arabia. Assess input, monitor activities and track output can be used to identify whether field hospitals are meeting their intended targets.

Method. Based on a case study approach, the reported results include field hospital construction project performance outcomes, a description of the design process and the development and application of key performance indicators to assess field hospital efficacy.

Result. Each of the logic model component (i.e. input, activities and output) has tailored indicators that address different aspects of field hospital; from the infrastructure work to the wider impacts on services.

Conclusion. The logic model components and related KPIs can be extremely important in terms of providing insights into how to achieve the field hospital's objectives.

Background

The severe acute respiratory syndrome coronavirus 2 global COVID-19 pandemic, has resulted in millions of infected patients and deaths worldwide (Radi et al. 2020). Around 80% of COVID-19 patients show no symptoms or only mild to moderate symptoms (Cascella et al. 2020, Lucchini et al. 2020, Velavan and Meyer 2020). No experts can predict the specific date when the COVID-19 crisis will end and the number of cases, critically ill patients and deaths have increased dramatically along with the growing demand for ward and intensive care unit (ICU) beds. More importantly, people with mild or no symptoms could unknowingly transmit the disease among their family members and the community. The spread of the virus could worsen the situation by increasing the demand for hospital-based medical care needed to provide therapeutic interventions and prevent the spread of the illness among family and community members (Lai et al. 2020, Yuan et al. 2020).

Many healthcare systems worldwide have thus experienced increased burdens due to the limited availability of hospital beds, and healthcare systems cannot manage the surge in the number of coronavirus patients (Yuan et al. 2020). These impacts on hospitals – whether immediate issues or long-term effects – can be expected in all types of disasters including pandemics, particularly when healthcare facilities lack plans to strengthen their surge capacity and staff resilience (Harley et al. 2010, Powers and Daily 2010). One of the available effective strategies for responding to pandemics is constructing temporary field hospitals to provide extra beds and other health care services, which may prevent healthcare systems from collapsing.

The concept and purpose of field hospital systems are complex, and their definition depends on the type of disaster. However, all field hospitals are constructed in specific geographical areas to manage high numbers of survivors of disasters caused by natural forces, wars and epidemics (Bar-Dayan et al. 2000, Zaboli et al. 2018). In the COVID-19 pandemic, temporary field hospitals have focused on admitting, isolating and managing patients with mild to moderate symptoms with positive COVID-19 tests or awaiting test outcomes.

The Chinese city of Wuhan in Hubei Province took the lead in establishing the first field hospitals to manage the surge in patient numbers (Yuan et al. 2020). The construction of temporary field hospitals is an extremely costly process, however, their success is undeniable, and this system has been adopted by many countries worldwide (Mateen et al. 2020). Tracking the key performance indicators (KPIs) of input, activities and output during field hospital establishment can help assess the success of each project in meeting its financial and other objectives. In addition, tracking KPIs could draw attention more quickly to areas that require modifications and rapid responses.

However, no practical example exists of using KPIs to evaluate the efficacy of field hospital construction projects. The present study thus sought to demonstrate the value of using KPIs and a logic model (i.e. input, activities and output) during the building of a field hospital to manage the coronavirus pandemic in Jeddah, Saudi Arabia. This goal was addressed by the following research questions:

RQ1: What are input, activity and output KPIs?

RQ2: How can the logic model approach be best applied to developing KPIs for field hospital construction?

RQ3: How can indicators be designed to reflect the level of work performance in field hospital projects?

RQ4: What information can the indicators draw on to assess field hospital construction accurately?

The following sections provide evidence of the importance of using sets of performance indicators and the selected logic model to identify field hospitals' principal elements and provide a solid foundation for developing appropriate KPIs.

Key Performance Indicators (kpis)

The primary reason for building the field hospital under study was to manage large numbers of infected patients with mild and moderate symptoms (Yuan et al. 2020). Although empirical data can be a potent tool in terms of increasing the efficacy of establishing and operating field hospitals, the need to respond quickly to unpredictable evolving issues during and after construction can take priority over performance evaluations (Savaya and Waysman 2005). In addition, because field hospitals are commonly built under pressure, a limited amount of time is available to collect information. Without a set of predefined performance indicators, administrators may have difficulty determining whether their field hospital was constructed as planned.

KPIs are defined as measurable values that determine whether a specific project is achieving its key objectives (Marr 2012). Indicators measuring a specific project's performance are of great importance to project managers. In the context of temporary hospitals, KPIs highlight different performance aspects of the project that are fundamental to providing insights into how to achieve field hospital goals by both controlling the epidemic and managing the surge in patients. According to Rozner (2013, p. 5), well-designed KPIs help field hospital decision makers as follows: “they can establish baseline information; set performance standards and targets to motivate continuous improvement; measure and report improvements over time; compare performance across geographic locations; benchmark performance against regional and international peers or norms; and allow stakeholders to independently judge health sector performance. KPIs can, therefore, help make project objectives explicit and enable managers to gather, process and report data to track the progress made towards achieving these objectives” (Ioan et al. 2012, p. 12).

KPIs need to be the product of logical and critical analyses and problem and solution arbitration. A practical tool that can help to conceptualise the production process in question is logic models (Rozner 2013).

Logic Model

Logic models are used to explain the links between problems and their solutions (Savaya and Waysman 2005, Zaboli et al. 2018). These models can support projects’ formation and define their success. Logic models help managers analyse problems, develop measures and articulate goals. These models can also be used to clarify project objectives and the steps necessary to achieve them. When a logic model is applied to a specific project, the model encompasses the following elements:

1. Input, which may include all resources that ensure the delivery of services
2. Activities, which can comprise actions that need to be undertaken to achieve the project’s objective(s)
3. Output, which may include the project’s results
4. Outcomes, which can involve the intended benefits for society at large

When project managers clearly describe the way that investments of time, effort and resources are expected to achieve the intended objectives, a strong basis is created for designing indicators that capture projects’ key components, which are vital to the assessment process. For example, in a field hospital construction project, a simple application of a logic model would be done as follows. If sufficient funding, planning and governmental support (i.e. input) are available to build and equip a field hospital to treat patients with COVID-19 (i.e. activities) and to operate at its maximum capacity (i.e. output), then the surge in patients will be accommodated (i.e. outcomes).

Outcome indicators are mainly used to assess the long-term benefits of operating field hospitals for the community. For instance, controlling the number of patients with COVID-19 reduces the number of critically ill patients and deaths and increases the community satisfaction with the hospital services. Because the present study focused on the field hospital construction rather than its subsequent operations, the outcome indicator was not considered.

The next step in the process is to identify the hospital components that are essential at each stage of the logic model. By developing indicators that track the different elements of the model, the hypothesised associations between input, activities and output can be tested to identify whether a significant relationship is present. Testing the connections between the project's main components at each stage of the logic model facilitates making adjustments to the project design as needed (Savaya and Waysman 2005). For example, if information is gathered on the activity of setting up the field hospital in existing infrastructure and on the outcomes delivered in project schedule reports, a relationship between the type of infrastructure and project completion time can be identified. Similarly, input indicators that assess the project schedule may reveal services limitations caused by infrastructure that act as barriers to additional adjustments to cope with increased capacity demands.

These insights can be used to improve the field hospital construction by increasing the infrastructure service capacity or adding external services to increase capacity upon demand. Thus, the assumption can be made that well-designed indicators enable the identification of emergent problems and adjustments to the project as needed (Savaya and Waysman 2005).

Methods

Field hospitals have played an important role in managing the surge in the number of patients with COVID-19. The present study integrated the aforementioned logic model (Savaya and Waysman 2005, Rozner 2013) with the experience reported in Wuhan, in China's Hubei Province (Yuan et al. 2020). A descriptive design was implemented to detail performance measures' development and application in order to track the key components of a field hospital construction project in Jeddah, Saudi Arabia, and to identify the challenges encountered during the building process. The findings of the current study provide an applied example of developing and embedding indicators to monitor and evaluate the efficacy of this construction project.

Data collection

The data obtained for the input, activity and output indicators were used to evaluate the process of constructing a field hospital to manage the surge in patients with COVID-19 in Jeddah, including gathering important information that can populate the relevant indicators. The data were collected in May 2020 by the primary author, who was also the project manager at the time of the study. The manager's responsibilities included managing, designing, engineering and supervising the Jeddah Field Hospital construction. The data collection covered all efforts made and tasks undertaken to complete the project successfully (i.e. finish the Jeddah Field Hospital). The project commenced on 4 May 2020, and it was completed on 6 June 2020 when the project objectives were achieved.

Setting

Jeddah is the second largest city in Saudi Arabia. According to the 2018 census, Jeddah has a population of about four million. According to the Ministry of Health (MOH) (2020), 'confirmed coronavirus cases were reported in 127 cities in Saudi Arabia, with more than 77% of the reported cases in Mecca, Riyadh, Jeddah, Medina and Dammam.' The main purpose of establishing the Jeddah Field Hospital was to care for patients with mild and moderate COVID-19 respiratory symptoms. By caring for those patients, the pressures that threatened the Jeddah health system could be controlled. The field hospital was established at an 8,000 square metre (m^2) site at Events Land in South Obhur, Jeddah. The hospital's maximum capacity is 800 patients and 3 critical cases.

Physical design and infection control

Ensuring an appropriate field hospital design and infrastructure is a challenging task that requires much communication and collaboration between government agencies, stakeholders, the design team and experts in patient safety and infectious diseases (Schultz et al. 2012, Finestone et al. 2014, Al Thobaity et al. 2017). The physical design and infrastructure of the hospitals are important to ensure patient safety and infection control measures (Lateef 2009). Thus, the first step in planning a field hospital is to consider these two elements. A balance needs to be found between designing a hospital for COVID-19 patients and controlling the risk of patient injury and the disease spread among the healthcare team.

Before planning the facility, various meetings were held with stakeholders, government agencies and engineers, in which productive discussions about design and infrastructure took place. The structural design's initial visualisation was presented to ensure that the construction would meet the standards agreed upon and maintain appropriate coordination between the relevant parties prior to the building stage. The building is divided into five sections. Sections 1, 2 and 3 are for patients without risk factors, who require regular observation. Sections 4 and 5 are for patients with high risk factors, who require continuous observation. In addition to the patients' rooms, the design includes an admissions office, X-ray facility, laboratory, 3 ICUs, 3 storage areas, 7 emergency exit points and a pharmacy (see Fig. 1). The staff dining area is located in tents outside the building.

The facility was designed based on the requirements for infection control in terms of calculating the space between the beds of patients with respiratory disease (Stiller et al. 2016). According to Yu et al. (2007), a minimum of 1 m between beds is needed to reduce the risk of droplet infection. The area was divided into small spaces using aluminium partitions. Each space is 9 m^2 (see Fig. 2). The aluminium partitions were prefabricated and taken to the site for quick assembly. To maintain patient and staff safety, a wide corridor was built to facilitate the movement of patients and staff. The locations of fire extinguishers and emergency exit points were determined by experts.

Because the Jeddah Field Hospital would focus on admitting confirmed cases of COVID-19, patient-to-patient cross-infection was not a concern. However, medical personnel, particularly nurses, are at high risk of exposure, and they must use personal protective equipment (PPE). Although rooms with negative pressure are recommended for facilities caring for coronavirus patients (Alhazzani et al. 2020), the Jeddah Field Hospital plan did not include negative pressure rooms, so the entire area had to be considered contaminated.

The Centers for Disease Control and Prevention's (CDC) (2020) guidelines recommend the use of high-efficiency particulate absorption (HEPA) filters to control airborne infection. These filters were placed in each patient room in the Jeddah Field Hospital. Although HEPA filtration systems decrease the chance of airborne infection from 100–40%, they do not eliminate the need to use PPE. Unfortunately, PPE increases body temperature, and they can be tolerated for only a few hours (Lucchini et al. 2020). PPE also increases the clinical staff' workload and fatigue, so the Jeddah Field Hospital nurses need to rest in rotations of 3 hours to allow 6 nurses at a time to leave the 'contaminated area' for 1 hour and remove their PPE. The mandatory rest issue was managed by identifying one zone outside the contaminated area for putting on and taking off PPE.

Result

This section discusses the indicators used to assess the field hospital construction project undertaken to manage the surge in COVID-19 patients in Jeddah. The KPIs' components were identified using a logic model (see Fig. 3). The indicators' metrics were then developed as shown in Table 1. An example of indicator design is also provided, including important information sources used to populate the indicators.

Table 1
KPIs’ metrics

Logic model	**Indicator components**	**Metrics**
Input	Time and budget were critical factors in the field hospital construction, as 8 days with a budget of 0 Saudi riyals (SRs) were required to complete the task. Calculating time variance (TV) allowed the project manager to assess the project and related tasks’ progress. By closely monitoring the schedule, the manager could quickly attend to areas that required adjustments.	TV: Will the preparation of the field hospital infrastructure be completed on time?
Activities	Essential activity indicators included assigning adequate numbers of medical and non-medical personnel to the hospital, providing training, setting standardised **policies and procedures and ensuring adequate supplies and logistics management.**	1. Recruitment of potential medical and non-medical personnel: an adequate number of workers with the right qualifications and experience to operate the hospital 2. Preparation and training: a. Number of training sessions provided b. Number of staff receiving training c. Qualifications and experience of consultants providing training 3. Delivery of standard policies and procedures: **a set** of written **standardised guidelines** delivered in full and on time 4. **Supplies and logistics management**: number of operational contracts processed
Output	The number and quality of tasks completed and services provided to fulfil the field hospital potential were assessed. Output indicators were clearly connected to project activities.	Capacity utilisation rate (CUR): Is the field hospital fulfilling its potential in terms of the number of services that can be carried out with the resources provided?
Source: Authors		

Examples of Input, Activity and Output Indicators for Jeddah Field Hospital Project

Input Indicators

Assessing the availability of the resources required to construct the Jeddah Field Hospital was the obvious first step since the project could be negatively affected if these resources were unavailable. In this kind of project, a problem with resources is serious because the pressures that threaten to overwhelm the healthcare system can block the project managers' efforts to equip and prepare the hospital. Thus, designing the input indicators early in the process is important in order to monitor essential resources' availability and warn healthcare administrators if the resources are insufficient.

The goal of the input stage was to prepare for the Jeddah Field Hospital construction by ensuring that the design was appropriate and the infrastructure was in compliance with infection control and patient safety standards for facilities caring for COVID-19 patients with mild and moderate symptoms. In the selected logic model, the input indicator metric was total value (TV). The question addressed was as follows: Will the preparation for constructing the field hospital infrastructure be completed on time?

Calculating TV metric

Eight days and a budget of zero SRs were set as the parameters for completing all tasks related to the field hospital's design and infrastructure. The expectation was that, on day 4, 50% of the work on each task would be completed. On the schedule fourth day, the water closets (WCs), handwashing sinks, showers and power station were 15%, 20%, 10% and 0%, respectively, completed (see Table 2), which indicated that these tasks were off schedule. This delay was a serious problem that could have significantly held back the scheduled completion of the field hospital, and the problem required immediate attention.

Table 2
Design and infrastructure preparation (TV)

Service type	**Number**	**Task**	**Ratio**	**Actual cost**	**Completion %**	
					Day 4	**Day 8**
WCs	28	Increase number to 62	1 per 8 patients	Donated	15%	90%
Handwashing sinks		Install 20	1 per 25 patients	Donated	20%	100%
Showers		Install 18	1 per 27 patients	Donated	10%	100%
Sewer tank	1	Connect with drainage network	–	Drainage network company	50%	100%
Power generators	4	Add 1 more	–	Saudi Electrical Company	0%	0%
Aluminium partitions to divide space	–	–	500 spaces	Jeddah Chamber of Commerce	50%	100%
Telecommunication including Internet infrastructure	–	45	1 in every nursing stations and every department and administrators' office	Saudi *Telecommunication*	50%	100%
Staff eating areas	–	Build 3 tents	–	Donated	50%	100%
Staff exchange rooms	–	–	–	Jeddah Chamber of Commerce	50%	100%
Storage areas	–	3	–	Jeddah Chamber of Commerce	50%	100%
Budget				0 SRs		
Source: Authors						

The project manager sought to identify the problem and ways to get the schedule back on track. A careful investigation was undertaken, revealing issues with the plumbing infrastructure that required Jeddah's Department of Water and Wastewater's intervention. Communication was established with the relevant agencies, and the issues were resolved. Another assessment was conducted on day 6, which revealed that the work was progressing satisfactorily.

On day 8, the WCs, handwashing sinks, showers and power station were 90%, 100%, 100% and 0%, respectively, completed (see Table 2 above). Because of minor plumbing issues in the toilet installation, 90% of the WC work was finished, so this item did not need further intervention. The Saudi Electrical Company asked for two additional days to provide and install the power generator, but it was the backup system and thus the delay did not affect the project's scheduled completion date.

Activity indicators

The activity stage's goal was to equip the Jeddah Field Hospital with the resources and supplies required to treat COVID-19 patients with mild to moderate clinical presentation. The selected logic model included the following activity components:

- Recruitment of potential medical and non-medical personnel: number, qualifications and experience of the workforce needed to operate the hospital
- Preparation and training: number and topics of the training sessions planned for medical and non-medical personnel
- Delivery of standard policies and procedures: a set of written guidelines delivered in full and on time
- Supplies and logistics management :a number of contracts processed to operate the hospital

Recruitment of workforce: number and qualifications

An adequate, well-prepared workforce is unquestionably important to carrying out the hospital's activities (Azari et al. 2015). If the field hospital had not been equipped with enough qualified human resources, the plan could have failed. The project planners knew that the key factor in the hospital's success was its workforce (Azari et al. 2015).

The Director of Health Affairs and members of the Command and Control Centre in Jeddah Governorate has assigned the administration office the task of appointing the required workforce. The recruitment based on the volume and nature of the field hospital's services. The hospital was built to provide services to COVID-19 patients with mild to moderate symptoms able to manage their illness with minimum medical and nursing care. A specific number of competent personnel are required to ensure they can provide adequate medical care. The workforce indicators of staffing need (WISN) method (Shipp and World Health Organization 1998) was used to calculate the required number of staff members. This method determines the volume of work by multiplying the number of patients by the estimated time required to care for each patient. For example, the following ratios were determined: 1 nurse for 12 patients and 1 resident physician for 25 patients. These professionals would ensure the patients received timely care. The potential number of nurses, residents, specialists and internal consultants needed to operate the Jeddah Field Hospital was 84, 40, 20 and 10, respectively.

Regarding the workforce, the hospital’s staff include 135 nurses, 40 residents, 20 specialists and 10 internal consultants. In addition, the personnel comprises 8 laboratory technicians, 18 X-ray technicians, 4 dieticians, 20 infection control experts, 8 safety officers, 6 quality and patient safety practitioners, 4 information technology (IT) technicians, 4 statisticians, 8 paramedics, 2 chest physiotherapists, 40 pharmacists and 4 psychotherapists. The support staff also includes 6 administrative workers, 10 food servers, 6 clinical engineering and maintenance staff and 92 environment cleaners and supply chain workers (see Table 3).

Table 3
Workforce calculation per 12 hours

Specialty	Ratio per shift
Internal consultant	1:100
ICU consultant	1:3
ICU specialist	1:3
Internal specialist	1:50
Resident	1:25
Nurse	1:12 for mild cases
Nurse	1: 6 for moderate cases
ICU nurse	1:1
Medication preparation nurse	1:25
Nursing supervisor	1:50
Nursing director	1:500
Laboratory specialist	1 haematology machine: 1
Laboratory technician	1 haematology machine: 1
Laboratory specialist	1 biochemistry machine: 1
Laboratory technician	1 biochemistry machine: 1
Laboratory specialist	1 coagulation machine :1
Laboratory specialist	1 arterial-blood gas machine :1
Laboratory supervisor	1
X-ray consultant	1:250
X-ray technician	1 portable X-ray machine: 2
Infection control expert	1:50
Statistician	1:250
Paramedic	1 ambulance:2
Psychotherapist	1:250
Respiratory therapist	1:3 ICU patients
Dietician	1:250

Source: Authors

Specialty	Ratio per shift
Food server	1:100
Pharmacist	1:50
Pharmacy technician	1:50
Public health expert	1:100
Clinical engineering and maintenance	3
Medical supply chain worker	4
Admission office worker	2
Medical coordinator	2
Employee affairs staff	4
Safety officer	8
Quality and patient safety practitioner	6
IT technician	4
Environmental cleaning and waste management staff	92
Source: Authors	

Preparation of medical personnel: training sessions

During the COVID-19 pandemic, hospital and clinical staff have had to go beyond their daily routine duties. Some staff members have been required to carry out unfamiliar tasks in stressful situations (Yuan et al. 2020). These demands mandate that all hospital medical staff undergo ongoing training so that they are prepared to contribute effectively to meeting the hospital's demands while dealing with the coronavirus pandemic.

Similarly, medical personnel assigned to work in the Jeddah Field Hospital were required to have been trained to manage COVID-19 patients and adhere to infection control precautions. However, not all medical staff in this hospital had previously managed COVID-19 patients or worked with infectious diseases. Thus, an education plan was needed to train and prepare these staff members to work in the field hospital to ensure they were ready to perform the planned tasks. Three metrics were identified and calculated as follows:

- Number, qualifications and experience of consultants providing training
- Number of training sessions provided
- Number of staff members receiving training

Fourteen infection control nurses with a master's and/or doctorate and 2 consultants and 2 IT technicians were drawn from the main MOH hospitals to provide the training programmes. The plan covered three main preparation areas: infection control, clinical care of coronavirus patients and electronic medical records (EMRs). The content of training programmes for infection control and clinical management of coronavirus patients were carefully selected using updated CDC (2020) guidelines. Content on 9 topics, including the learning materials, were prepared by infectious disease experts to be given online to more than 200 medical personnel. The main topics included, among others, infection prevention and control guidelines, PPE use, hand hygiene, alternate care sites, individuals at higher risk for severe illness, clinical care guidance and therapeutic options.

The medical personnel also participated in live demonstrations of how to use EMRs while carrying out planned care routines. This training included an introduction to the electronic information system and ways to use EMRs to present patient data to the medical team, order medication from the pharmacy or check lab results. Non-medical personnel also received training in hand hygiene, including washing hands with soap; appropriate methods for using alcohol rubs; the use of standard facemasks; and social distancing.

Procedures and policies standardization

The medical workforce was drawn from various hospitals and backgrounds. To maintain a smooth workflow and all medical care and interventions' consistent quality, specific standards, procedures and policies were written for the field hospital. The standardised policies and procedures ensure that all medical staff will comply with the same standards of care and work in unified teams. The policies and procedures guidelines cover a wide range of areas, such as patient admission and discharge, consultation and referral, infection prevention and control measures implementation, PPE use, preparation for all emergencies, medical waste management procedures and supply chains.

The Jeddah Field Hospital admits only COVID-19 patients with a mild to moderate clinical presentation. Thus, the services are divided into three levels of care: 1) regular care for patients with no or low risk factors, 2) high-level care for patients with high risk factors requiring close observation and 3) critical care for patients developing respiratory distress symptoms. Anxiety and depression are expected among patients with COVID-19 so mental health care is provided by a psychotherapist. A consultation and referral system is in place for those patients who become critically ill or require mental health support.

Supply chain and logistics management

Patient care activities are important in field hospital work, but these hospital operations involve other activities. Supply chain and logistical support directly affect the quality of patient care and outcomes (Levine and Shetty 2012). For instance, delays in drug and medical supplies because of the pandemic has directly affected patient care. Significant logistical resources are required to provide services, such as medical supplies and equipment (e.g. portable X-ray machines), adequate PPE, transfer and referral, medical and non-medical waste management, environmental cleaning and food supplies for patients and staff.

All care is reported using EMRs. This initiative was undertaken by the E-health Agency at the MOH. Patients' electronic records include vital signs and medications, laboratory results and radiology treatments, which helps the staff continuously monitor patients (Atreja et al. 2008). EMRs can support clinical decision making through alerts about critical clinical data, thus helping clinicians to identify patients who require high-level or intensive care. In addition, EMRs can provide pharmacists with the data required to control the release of drug supplies and need to refill prescriptions (Levy et al. 2010). Almost 95% of the EMR system was installed in the Jeddah Field Hospital.

Four operational management contracts were processed for the Jeddah Field Hospital: 1) food supplies management, 2) medical waste management, 3) medical gas and 4) environmental cleaning. All four contracts were fully processed with Jeddah's Directorate of Health Affairs and the MOH support.

Output indicators

In the output stage, the goal was to ensure that the Jeddah Field Hospital was ready to operate at its maximum capacity. Output indicators include the number and quality of tasks completed and services provided to meet the field hospital's full potential. Output indicators are clearly connected to project activities. Using the selected logic model, the output metric was capacity utilization rate (CUR). The question answered was as follows: Is the field hospital meeting its potential in terms of the number of services that can be carried out with the resources provided?

Calculating CUR

The current output produced with the installed infrastructure, utilities, equipment, supplies, services and workforce serves a 500-bed capacity (see Fig. 4). The output produced by the installed equipment allows the admission of a maximum of about 800 patients. Thus, the CUR is 62% (i.e. 500/800 × 100), so around 40% of the hospital's capacity could still be utilised.

Discussion

Due to decision makers' follow-up and continuous support, the construction and preparation of the Jeddah Field Hospital was finished on time. The Jeddah Field Hospital includes 62 WCs, 20 handwashing sinks and 18 showers, all of which were installed. The building is divided into 500 patient rooms, each of which is 9 m^2. The facility also has 3 storage areas, 1 admissions office and 16 nursing stations that include 16 medication refrigerators, 21 cabinets, 31 computers and 31 printers. In addition, the staff have 20 changing rooms inside the hospital and eating areas in 3 tents outside the building. Each room is equipped with adequate equipment (e.g. a bed, intravenous stand, infusion pump, HEPA filter, sharps container, hazardous waste container and oxygen cylinder [size M250]). The hospital also has suitable medical equipment including, among others, 17 defibrillators with 12 electrocardiogram (ECG) leads, 45 Dinamap monitors to measure vital signs, 45 pulse oximeters, 45 electronic thermometers, 4 ECG machines, 45 glucometers, 21 fluid warmers and 21 blood warmers. Other essential equipment comprises

4 portable mechanical ventilators, 10 portable cardiac monitors, 15 syringe pumps, 30 portable suction machines, 21 nebuliser machines and 17 crash carts with accessories.

The KPIs to assess the efficacy of a field hospital construction project in Jeddah, Saudi Arabia was used. The following paragraphs provide the conclusions after discussing the key indicators that were the most extensively used to evaluate this project. In the current study, input indicators were used to measure the resources that were essential to establishing and operationalising this field hospital, which included cost, infrastructure and design. The input also comprised indicators of the target population's characteristics, such as the number of patients eligible for admission and the field hospital services. To set up a field hospital such as the facility under study, project managers and health planners need to check the available infrastructure and develop an appropriate design that allows for renovations (Yuan et al. 2020). These aspects are important input components that help ensure that the field hospital functions well (Yuan et al. 2020). Determining how well the infrastructure elements and design are functioning and how effectively the construction funds are being spent requires well-defined indicators. In the Jeddah Field Hospital case study, time and cost were used to judge the hospital site's preparation. The selection of these two indicators facilitated capturing all relevant aspects of the project's conditions (Council 1998).

Activity indicators were used to assess the degree to which the field hospital was delivered as planned. These indicators allowed the project manager to identify any obstacles to implementation. In the Jeddah Field Hospital, the assessment of design activity indicators included three essential components: who conducted the activity, what they did and where they were working (Savaya and Waysman 2005). For instance, regarding the infection control training sessions in a programme to prepare the field hospital staff, important aspects were whether the educators delivered the content, what the training sessions included and whether the sessions were provided to all staff before they began working in the field hospital. All these details helped the field hospital administrators identify which indicators could contribute to the project's success.

Output indicators refer to the activities' direct products. The latter were measured based on the volume of work being completed (Savaya and Waysman 2005). In the Jeddah Field Hospital project, the output components used to assess workforce recruitment included, among others, the number of medical personal (e.g. nurses, physicians and technicians), of training sessions and of learning materials. When these indicators were combined with activity indicators, they described the relationship between the project's budget and product. Thus, the output indicators provided measures of efficiency and economy. Tracking output indicators regularly contributed to assessing the project's progress and detecting delays.

Lessons to be learned

A field hospital construction project is a complex initiative. Various important lessons can be learned from the project under study. First, although many field hospitals have been built worldwide to manage the surge in the number of COVID-19 patients, the problems associated with logistics support, particularly supply chains, are a serious issue that need to be managed. Supply chain managers are responsible for equipping field hospitals with the required medical supplies, which include, among other items, medication, equipment, PPE and beds, as well as non-medical services such as food services and waste management. Any delay in these items and services' availability or delivery could potentially reduce the field hospital efficiency (Jawab et al. 2018).

Second, timely and appropriate data resources can influence planning and construction decisions. The provision of timely information facilitates, monitoring the progress of field hospital construction and the budget cycle in the finalisation stage. Collecting data on input and activity indicators beginning with day one of the project is important, because the greatest challenges can arise during the initial phases.

Finally, the community and stakeholders' support is vital to field hospital projects. Donations of time, effort, labour, money and supplies were essential to reducing the time and cost of constructing the Jeddah Field Hospital. Many of the utilities and infrastructure services were donated (see acknowledgement).

Conclusion

In May 2020, a field hospital was constructed and inaugurated in Jeddah, Saudi Arabia. KPIs were used to assess the efficacy of the project as the hospital was built. These indicators were found to be extremely important in terms of providing insights into how to achieve the field hospital's objectives. In addition, the selected logic model was found to be a useful approach to the development of KPIs for field hospital construction projects during a pandemic.

Affairs, Jeddah Governorate, Ministry of Health. Donors - Jeddah Chamber of Commerce, AL Murjan Group Company and Abdul Latif Jameel Outdoor Advertising Company Ltd. Drainage Network Company, Saudi Electrical Company, Jeddah Municipality.

Abbreviations

ICU: Intensive care unit

KPIs : Key performance indicators

MOH: Minestry of health

PPE: Personal protective equipment .

HEPA: High-efficiency particulate absorption

TV: Total value

CDC: Centers for Disease Control and Prevention

WCs: Water cycling

WISN: Workforce indicators of staffing need

EMRs: Electronic medical records

CUR: Capacity utilization rate

ECG: Electrocardiogram

Declaration

Ethics approval and consent to participate.

Ethical approval was granted from Jeddah institute review board, Jeddah Directorate of Health Affairs (H-02-J-002), to use the project data in this study. Consent is not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article

Competing interests

Authors have no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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Authors contribution

Alshehri, provided the data; Al Moteri, Plummer Virginia, Endacott, Ruth and Al Thobaity, wrote the manuscript. All authors have read, reviewed and approved the manuscript.

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Figures

Figure 1

Schematic diagram of Jeddah field hospital’s layout Source: Authors

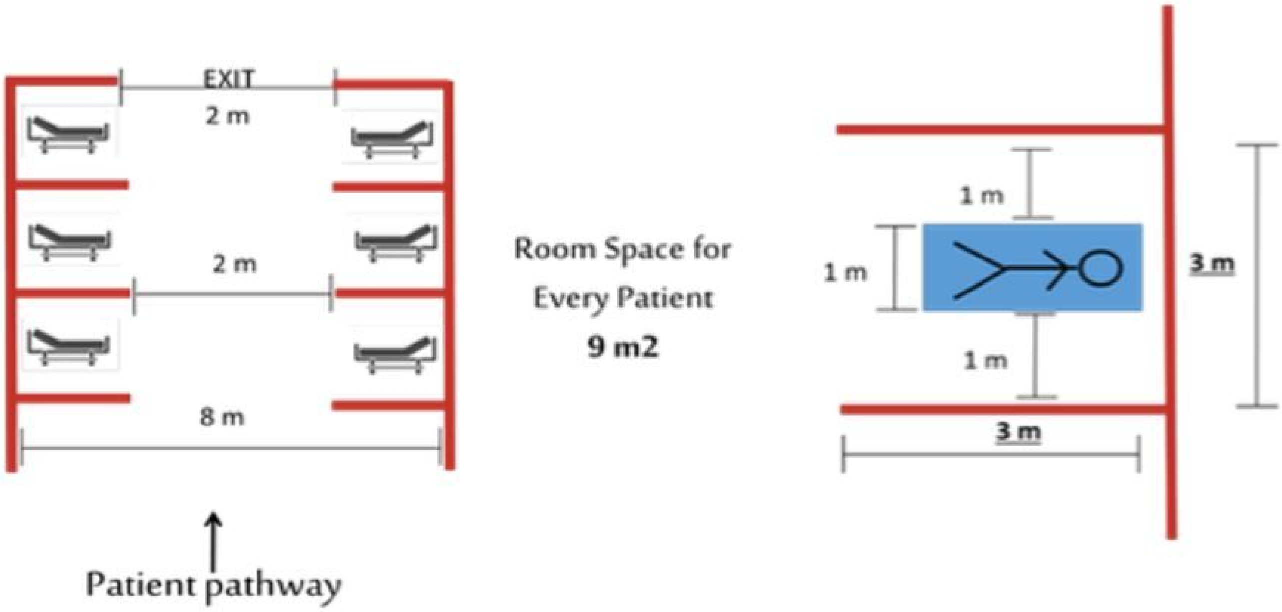

Figure 2

Patient room layout Source: Authors

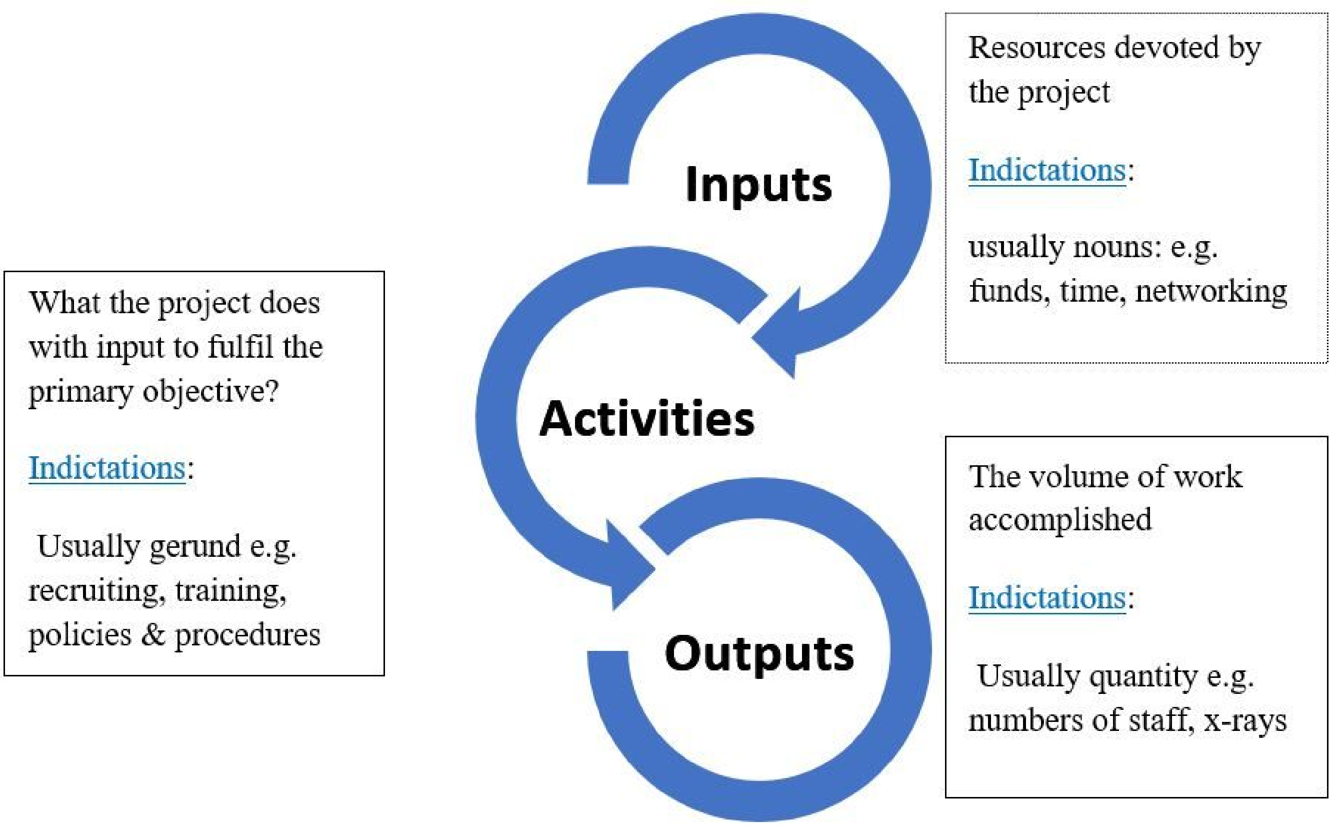

Figure 3

Identification of KPIs' components using the logic model Source: Adapted from the Kellogg model of input to impact, Nixon 2012

Figure 4

Equipping the Jeddah Field Hospital Source: Authors