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Resilience Indicators for Barrier Free Planning and Design of Hospital Buildings in Multi-Disaster Scenario

Theme: Design for all as a key to disaster resilience of hospitals

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Abstract

Purpose: **The COVID-19 pandemic left the healthcare infrastructure upended given the patient surge. In India, hospital buildings were gravely impacted due to the compounding risks of the pandemic, floods and cyclones in 2021. This paper identifies the key resilience indicators featuring the barrier-free design and planning actions for the new construction of medium and large-scale hospital buildings with more than 100-bed capacity.**

Methods: **A modified Delphi technique is conducted in three rounds to identify the key indicators of resilience, wherein 57 indicators were identified in the first and second rounds of the survey. For the third round of the survey these indicators were grouped into three categories: a) master planning of hospitals campuses, b) Architectural design, c) building services and management. The corresponding indicators were ranked on a Likert scale of 1 to 9.**

Results: **The top 6 indicators are: 'barrier-free access to emergency services, 'linear configuration of buildings', 'location and modularity of building services', 'signages for internal circulation', 'circulation of high dependency patients, 'standardised structural grid for modularity of built-form.**

Conclusion: **Assessment of the top indicators highlight the importance of 'flexible and modular design' and 'barrier-free access' as key components of the resilient design of hospital buildings. These outcomes will help the construction professionals in making resilient hospital buildings to accommodate the patient surge.**

Key words: ***indicators, disaster resilience, barrier-free design, hospital planning, patient surge***

Introduction

Many climatic disasters through the decade and recently COVID 19 pandemic have posed grave challenges on healthcare infrastructure. Structural disruption, interrupting building services and discontinuity in medical supply chains are commonly observed during any calamity (Forbes, 2021). Inadequacy in healthcare services could directly lead to the uncontrolled spread of contagious diseases and other health risks (Govindan, K., et.al., 2020). Most recently, Gotri hospital, a Covid-19 facility in Vadodara, Gujarat collapsed due to strong winds generated out of cyclonic effects of Tauktae. After examination, it was found that the glass pane-façade was not designed to take the load of 60km/hr. Interior fitouts including the false ceiling and loose furniture fitting were also damaged. Given the inadequacy of the infrastructure, about 50 patients were shifted to other facilities. Despite, the early warning systems, 98 hospitals in Gujarat were

affected due to power outages and building service instability (IE,2021). The increment in the global frequency of hydrological disasters have resulted in severe loss and damages to healthcare facilities Over 168 hospitals in Kerala suffered loss and damages due to the 2018, floods. The cost of loss and damages was calculated up to a total of approximately Rs. 120 crores with the division being: hospital buildings (Rs 80 crore), medical equipment (Rs 10 crore), hospital furniture (Rs 10 crore), and medical supplies (Rs 20 crore) (Sphere India, 2018).

Thereafter many instances of disruption in healthcare infrastructure and services, the concept of resilient healthcare infrastructure gained its cognizance in 2020 through various policy and budgetary initiatives by the Government of India (GoI). In the Union Budget, 2020, GoI offered to increase public spending towards healthcare infrastructure from 1.6% to 2.5% of the GDP by 2025. This investment would reflect in reduction of out-of-pocket expenditure from 65% to 35%. Despite the policy interventions by the government, the need for assessing the hospital functionality was established with the COVID 19 outbreak along with the risks posed by natural disasters (Krishnan, S. and Patnaik, I., 2020). This paper intents to understand the nuances of 'resilience framework' in planning and design of hospital campuses with more than 100-bed capacity. As an outcome, a comprehensive literature review of various indicators of hospital resilience is presented. The corresponding indicators are then modified through three step delphi technique to systematically represent the opinion of the stakeholders.

Resilience of Hospital Buildings

Concept of resilience has been explored through various fields of ecology, environment, psychology, health, sociology and

engineering (Fleming, J. and Ledogar, R.J., 2008). The concept of resilience engineering focuses on unifying all the building's functions and its components (Holling, C. S., 1973). In the context of tertiary care hospital buildings, resilience is defined as *'the hospital's ability to resist, absorb, and respond to the shock of disasters while maintaining its critical health care functions, and then recover to its original state or adapt to a new one'* (Zhong, S. et.al.,2015). The components of resilience as derived through the definition are: a) resistance towards the extreme shocks, b) absorptive capacity of the system, c) response to aftermath of the disasters and d) adaptation of hospital functional capacity. These components of resilience have been looked from the perspective of management, with a focus on facility management and human resource management. Various hospital safety guidelines have revealed the structural and non-structural elements of the hospital buildings for risk mitigation. However, the role of design and planning of the hospital buildings in the resilience context have not been explored.

Hospital buildings represent one of the most complicated and critical emergency response resources (Shang, Q., et.al, 2020). A typical hospital facility depends on: a) access to hospitals, b) condition of the building services (mechanical, electrical and plumbing), and c) availability of healthcare workers (Fallah-Aliabadi, S., et.al., 2021). Malfunctioning of these elements will have a direct impact on the continuity of hospital functions and hence upended delivery of these services to the victims (Cristiano, S., et.al., 2021). Planning for unprecedented situations must estimate how patient surge can be capacitated within the hospital resources. These planning measures define the role for construction professionals, medical administration and disaster management administrators for manufacturing resilient hospital

buildings. In order to foster resilience in hospital facilities, identifying potential indicators for design and planning is prudent.

Methods

This paper has adopted Delphi method to identify potential indicators for ensuring resilience of hospital buildings (Freitas, Â.,et.al., 2018). The preliminary construct of these indicators is based on literature review of academic studies, standards, guidelines, norms and disaster assessment reports. These indicators are then modified through three stage Delphi method. This method allows the researchers to systematically weigh the opinion of the experts involved in planning, design and management of hospital buildings. The experts invited for this exercise were from the varied professions: medical officers, architects, planners, academicians, structural consultants and building service consultants. A total of 9 experts took part in the exercise after being versed with the aim and objectives of the survey. Transcript of records are processed by the author after the due written consent from the experts. In this paper, anonymity is maintained of the experts in accordance with the ethical approval by the institute. The methods for the identification of resilience indicators are explained in the following section.

Step-1

Table 1 indicates the preliminary construct of resilience attributes towards planning and design of hospital buildings with more than 100 bed capacity. These indicators are selected based on its frequency of occurrence in the corresponding literature.

Table 3 Preliminary construct of resilience indicators for hospital buildings

Code	Category	Preliminary Indicators	Source(s)
C1	Site assessment and planning	Accessibility to emergency and critical services	WHO, 2015; Jason Schroer., et. al., 2021
		Flexible grid planning for barrier free access	NDMA, 2016
		Site planning according to topographic profile	WHO, 2015
		Internal circulation and access ways	FEMA, 2008,2013,2020
		Adaptive planning of temporary camps to cater patient surge	PAHO, 2014; WHO,2015
C2	Architectural design	Elevated construction over stilts	FEMA, 2013
		Alternate entry and exits to critical services	FEMA2013; NDMA, 2016
		Installation of ramps for barrier free movement and access to medical spaces	WHO, 2015, 2019
		Flexibility for reorganizing space for expanding waiting areas	WHO, 2015; Anteby, R.,et.al., 2020
		Support infrastructure for healthcare workers and attendees to victims	WHO 2014, NDMA, 2016
		Signage for barrier free emergency movement and internal circulation	Shuayb, I., 2020
		Residential facility to accommodate additional hospital staff (on duty)	Toner, E.S., et.al.,2017
		Storage space and reserves of medical stockpiles and logistics	WHO 2015; Zhong, S., et.al., 2015
		Covered/Semi Covered spaces for refugee area setups	Krishnan,S.,et.al, 2020
C3	Building services and management	Modularity of HVAC systems for enhancing air exchanges	FEMA, 2013, 2020
		Uninterrupted supply of medical gas and electrical services in critical units	Cimellaro, G. P. 2021
		Decentralized (Independent) planning of	FEMA, 2020

Code	Category	Preliminary Indicators	Source(s)
		building services for the critical core	
		Location of medical services (Gas supply, lab equipment)	NDMA, 2016
		Planning for additional electrical load for expanded/special temporay facility	Krishnan,S.,et.al, 2020
		Robust Control, command and coordination systems for patient segregation and staff movement	Zhong, S., et.al., 2015; NDMA, 2016

The above set of indicators are also inclusive of 'evaluation framework' of hospitals including the hospital safety index, 2015. These indicators are divided into three categories as represented in table 1. These indicators are also in coherence with the components of resilience: resist, absorb, respond and adapt. Thus, unanimity of the resilience concept through design and planning of hospitals are maintained. For the purpose of evaluation of these potential indicators, the experts were invited through an online training program on 'Disaster Resilient Healthcare Infrastructure' jointly organized by the School of Planning and Architecture, Delhi and National Institute of Disaster Management, New Delhi in April 2021. The invited experts had more than 20 years of work experience in construction and management of large- scale hospital facilities. A content analysis of the transcript of records of the first round is represented in table 2.

According to the content analysis, maximum importance was given to 'Barrier free access to emergency services and modularity of structural grid of hospital buildings' and 'Direct correlation of adaptation planning with the extended bed capacity to accommodate the surge'. The respective concerns are identified after calculating the frequency of occurrence of the key

words/terms from the content analysis of the transcript of records from the first round of Delphi method.

Table 4 Content analysis of round 1 of Delphi Method

	Frequency of occurrence			
Concerns/Challenges	Code	Overall	Medical	Non-Medical
Site review according to ecology, environment, climate, geology and topography	C1	1%	0%	2%
Site assessment according to urban demographics to calculate the patient surge	C1	5%	5%	5%
Implementation of Building Code/Safety guidelines	C2	6%	2%	8%
Data assessment of disaster victims and loss of healthcare provisions is not accounted	C3	8%	10%	6%
Cost effectiveness of decentralization of building services	C3	10%	15%	8%
Plug and play of essential building and medical services for functioning of critical facilities in case of damage to hospital buildings	C1	10%	13%	7%
Over/Underutilization of hospital resources in case of patient surge	C3	3%	5%	2%
Lack of Healthcare Workers due to unavailability of personal and financial incentives	C1	13%	15%	12%
Direct correlation of adaptation planning with the extended bed capacity to accommodate the surge	C2	13%	20%	9%
Barrier Free access to emergency services and modularity of structural grid of hospital buildings	C1	14%	12%	16%
Site monitoring for building services in case of providing extended facilities	C2	8%	4%	11%
Flooding due to improper drainages at site level and due lack of maintenance of building services	C2	10%	0%	16%

1 Step-II and III

An online survey was designed to estimate the importance level of each indicator. This importance level was measured on a 9-point Likert scale.

1	2	3	4	5	6	7	8	9
Least Important				Moderately Important				Most Important

The construct of resilience indicators was revised according to the outcome of the first round of Delphi survey. After tabulating the descriptive statistics from the second round of the survey, third round of survey is modified. After formulating the final set of resilience indicators for the third-round, final ranking is done by the same set of experts.

Indicators of resilience

Master Planning of Hospital Campuses

In India, IS 12433-2 (2001) is a code of practice for basic planning requirements of 100 bed hospitals, prescribed by the Bureau of Indian Standards (BIS), GoI. The functional requirement of hospitals for site development is derived from IS 12377.1988. Several standards, norms and guidelines have been provided by national and international organization for the purpose of design, planning and development. Based on these standards and identified academic literature, broad domains for site assessment are: site selection, site review and assessment, urban controls and concept planning. The indicators identified for these domains are derived as per frequency of their occurrence of the key terms in the identified literature. Table 1 presents comprehensive list of derived indicators for the respective

domains. These indicators collectively correspond to the master planning of hospital campuses in view of fostering resilience.

Table 5 Resilience indicators for Master Planning of Hospital Campuses

Domain	Code	Indicator	Rank
Site selection	**S1**	**Access to site**	**1**
	S2	**Location of Hospitals Site as per geological conditions**	**9**
	S3	**Urban demographic profile**	**5**
	S4	**Hazard and vulnerability profile**	**11**
	S5	**User identification and typology**	**13**
	S6	**Segregation of spaces as per type of medical services**	**15**
Site review and Assessment	**S7**	**Superimposition of micro-zonation maps**	**4**
	S8	**Review of micro and macro climatic conditions**	**14**
	S9	**Review of site ecosystem and local environment**	**18**
	S10	**Soil Assessment**	**12**
	S11	**Topographic assessment**	**16**
Urban controls	**S12**	**Compliance to government regulations**	**19**
	S13	**Formulation and compliance to bye-laws**	**17**
	S14	**Guidelines for buildable areas**	**20**
	S15	**Vertical and horizontal segregation of departments**	**6**
Concept planning	**S16**	**Accessibility to emergency services**	**3**
	S17	**Efficient planning of ambulatory services**	**21**
	S18	**Parking and quick access to emergency areas**	**10**
	S19	**Building typology and configuration**	**2**
	S20	**Planning in view of topographic profile**	**22**
	S21	**Planning of site services**	**8**
	S22	**Spatial allocation for refugees/victims/patient surge**	**7**
	S23	**Temporary built expansion for adaptation of medical services**	**23**

Architectural Design

Resilient design studies have been explored from the perspective of structural integrity and resistance to external shocks. Considering hospital resilience as system's functional capacity to withstand external pressures of disasters, a coherence between built form, structure and medical functions are set. In this section, potential indicators covering the architectural aspects have been

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identified. These indicators are categorized into 3 domains of architectural design: a) spatial planning and allocation of departments, b) built form and structure and c) Movement and circulation, as represented in table 4.

Table 6 Resilience Indicators for hospital architecture

Domain	Code	Indicator	Rank
Spatial planning and allocation of departments	**D1**	**Modularity of structural grid for inter-departmental connections**	**7**
	D2	**Spatial arrangement of building clusters to accommodate surge in case of disaster**	**15**
	D3	**Accessibility of Helicopters/choppers**	**17**
	D4	**Planning of Support Infrastructure for attendants**	**8**
Built-form and Structure	**D5**	**Interior finishes of walls, floors, doors and windows**	**12**
	D6	**Typology and Configuration of building form**	**9**
	D7	**Elevated Plinth/ Stilt/Raised Construction**	**6**
	D9	**Alternate Entry and Exit at grade/Upper Levels**	**13**
	D10	**Planning flexibility (temporary facilities Flexibility of reorganizing Space in case of surge of patients)**	**3**
	D11	**Covered/Semi Covered spaces for Temporary set ups**	**14**
	D12	**Installation of ramps for circulation of victims**	
	D13	**Choice of material for ceiling and flooring of the hospitals to mitigate fire risk**	**11**
	D14	**Flexibility of Interior fit-outs**	**4**
Movement and Circulation	**D15**	**Horizontal and vertical movement of high dependency patients units (HDU/ICU/CCU)**	**10**
	D16	**Connectivity to hospital infra for managing such capacities**	**14**

Domain	Code	Indicator	Rank
	D17	Protocol for signages and layout diagrams for HDU patient and staff movement in case of surge	5
	D18	Easy access and wayfinding to the utility core (staircases, ramps, lifts, toilets)	15
	D19	Barrier free access to emergency and critical services	2
	D20	Universal access to medical first aid	1

Building Services and Management

Hospital system functioning is highly dependent on uninterrupted functioning of mechanical, engineering and plumbing (MEP) services. Given the multiple inter-dependencies of these services this section identifies a set of indicators that are categorized into two major domains: a) design of building services and its operations and b) management and maintenance, as presented in table 5.

Table 7 Resilience indicators for design of building services and management

Domain	Code	Indicator	Rank
Design and Operations	B1	Type of HVAC service to the critical units, wards, OPD and IPD (Centralized/decentralized)	6
	B2	Location of source supply of Medical Services (medical Gas supply, lab equipment) to critical units on stilt floor to avoid flooding	2
	B3	Modularity of HVAC system for varied air exchanges in the isolation facilities	5
	B4	Provision of uninterrupted supply of	1

		electrical services for critical areas	
	B5	**Fresh water supply in case of flooding**	**9**
	B6	**Installation of HEPA and UV filters for better indoor air quality**	**8**
	B7	**Flexible design of services for future expansion in case of surge**	**6**
Management and Maintenance	**B8**	**Maintenance of oxygen levels in critical units**	**4**
	B9	**Water proofing of basements and avoiding drainage failure including pipe bursts**	**10**
	B10	**Seismic support to the services cables for electrical supply**	**13**
	B11	**Services design and maintenance minimizing patient self-harm opportunities**	**3**
	B12	**Grading of power supply as per clinical risk grade**	**7**
	B13	**Appropriation of pressure differentials of HVAC systems**	**14**
	B14	**Terminal equipment location**	**11**

Conclusion

This paper presents a comprehensive set of resilience indicators for planning, design and management of hospitals to combat the aftermath of disasters. These indicators are directly correlated to the components of resilience and can be used for the purpose of evaluation of hospital functions. The ranking of these indicators gives perceptive importance of these indicators for the management to take priority actions. The results of this paper highlight the importance of 'site accessibility' and 'access to emergency areas' for the purpose of adaptation planning of hospital buildings. Considering the architectural and building services attributes of design, highest importance is given to 'locational and modular planning of building services',

'configuration and typology of the built spaces' and 'barrier free access to the emergency areas'. Various codes of practices mandate the construction professionals to adhere to these indicators, however, these are often not given priority in planning and construction practices. A comprehensive list of planning and design considerations and emphasis given to the key indicators, thereby helps the professionals to incorporate resilient design practices for both retrofitting and new construction of hospital campuses.

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