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ARCHITECTURAL SPATIAL ORGANIZATION OF PROVINCIAL GENERAL HOSPITALS WITH REGIONAL FUNCTIONS TO MEET DISASTER RESPONSE REQUIREMENTS

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INTRODUCTION

1. Rationale

Disasters (natural hazards, epidemics and mass-casualty incidents) have confronted and continue to confront hospitals with demand exceeding routine capacity, requiring a transition in operating state. Response capacity depends decisively on architectural spatial structure: layout organization, circulation, functional convertibility and the readiness of building services.

Vietnam is severely affected by natural hazards and epidemics. In 2024, the country recorded 1,340 natural-hazard events, causing 514 deaths and losses of VND 88,748 billion. Typhoon Yagi (September 2024) caused the largest flood in the Red River basin since 1971, while damaging healthcare infrastructure and sharply increasing treatment demand. The COVID-19 pandemic (2020–2022) revealed hospital space as a response bottleneck: receiving entrances were overloaded, corridors were occupied, and intensive-care expansion lacked supporting services.

Provincial general hospitals with regional functions (PGH-RFs) form the principal load-absorbing tier of the healthcare network, receiving referrals and treating severe cases locally. Decision 201/QD-TTg (2024) and Decision 1658/QD-BYT (2026) identify 17 hospitals across six socioeconomic regions as having regional functions, including regional disaster response. However, TCVN 4470:2012 has not established disaster response as a design objective, whereas international guidance such as the FGI Guidelines (USA), HBNs (UK) and Safe Hospitals (WHO/PAHO) introduced corresponding provisions many years earlier.

Existing PGH-RFs exhibit three structural limitations: rigid zoning without conversion mechanisms; building services designed for routine loads and difficult to expand rapidly; and densely occupied campuses lacking reserve space. The trend towards consolidated high-rise buildings creates additional constraints when vertical circulation is disrupted. A systematic study is therefore needed to develop theoretical foundations, a spatial organization model and architectural solutions for PGH-RFs to meet disaster response requirements.

2. Research aim and objectives

Research aim: to organize architectural space so that PGH-RFs operate efficiently under routine conditions while being able to change operating state promptly when disasters cause a sudden increase in healthcare demand. The three specific objectives are: (1) to propose an architectural spatial organization model for PGH-RFs based on space groups that meet disaster response requirements; (2) to establish a basic module M and a system of flexible mechanisms for converting architectural space between routine and disaster-response states; and (3) to propose architectural spatial organization solutions that translate the model into practice.

3. Research subject and scope

Research subject: architectural spatial organization in Vietnamese PGH-RFs to meet health-disaster response requirements. The survey focuses on 17 provincial general hospitals with regional functions under Ministry of Health Decision 1658/QD-BYT of 8 June 2026. These hospitals are assigned regional disaster-response responsibilities and represent diverse practical conditions (urban location, land availability, campus typology and regional natural-hazard characteristics) across all six socioeconomic regions.

The spatial scope includes spaces within buildings (layout, circulation and spatially associated building services) and outdoor spaces within hospital campuses (site planning, yards and outdoor infrastructure). The temporal scope follows the healthcare-facility network master plan for 2021–2030, with a vision to 2050, consistent with the PGH-RF upgrading roadmap and the reorganization of provincial administrative units.

4. Research methods

The dissertation combines six methods: document collection and synthesis (reviewing international literature on surge capacity, resilient health facilities and flexible design, and Vietnamese legislation, planning documents, regulations and design standards); field surveys at the 17 hospitals; analysis of practical responses to representative disasters in Vietnam and abroad; interdisciplinary integration (translating healthcare, building-engineering and human-behavior requirements during disasters into design directions); expert consultation (workshops and opinions from architecture, healthcare and management specialists); and modeling (developing three space groups, seven functional spaces, five spatial relationships, a module and six flexibility mechanisms, with validation through experimental design).

5. Research contents

The research comprises five cumulative strands. Strand 1 reviews theoretical and practical research in Vietnam and internationally to establish the research position and knowledge gaps. Strand 2 assesses architectural spatial organization in Vietnamese PGH-RFs across three campus types and draws lessons from actual response situations. Strand 3 develops the scientific foundations (theoretical, medical, practical and legal). Strand 4 develops a spatial organization model based on state-transition capacity (three space groups, seven functional spaces, five spatial relationships, module M and six flexibility mechanisms). Strand 5 proposes architectural solutions that give concrete form to the model and validates them through experimental design.

6. Scientific significance of the study

Scientific significance: the study creates a theoretical connection between two previously separate bodies of theory—emergency-response theory, which remains at healthcare-system level without architectural tools, and flexible-architecture theory, developed for routine operation without links to exogenous activation conditions—through an integrated framework applicable to hospital building layouts. It provides a model for classifying space by architectural characteristics rather than medical specialty, opening a new approach to hospital design that accounts for state-transition requirements.

Practical significance: the study provides solutions usable in design briefs, scheme appraisal and PGH-RF renovation and upgrading. Dual use and progressive activation enable hospitals to improve response capacity within phased investment, without waiting for a wholly new construction project. The findings may inform the development of hospital design standards and regulations in Vietnam.

7. Main research results

The dissertation produces three main groups of results. First, its scientific foundations comprise a theoretical framework of three foundational propositions for organizing PGH-RF space for multiple operating states; a synthesis of three overload situations (load-generating mechanisms, bottleneck sequences and distinctive spatial requirements); and five lessons with conditions for application. Second, the spatial organization model comprises a three-group space classification, seven response functions linked to routine spaces, a matrix of five relationships P1–P5, a modular grid M with three group-specific attribute sets, and a mapping of six flexibility mechanisms to the seven functional spaces. Third, the architectural solutions comprise conditions and site-planning solutions for three campus types; solutions for seven functional spaces, including response configurations and restoration methods; and a four-level progressive activation diagram establishing the order of spatial mobilization according to overload severity.

8. New contributions

First, the dissertation develops a theoretical framework integrating emergency-response theory with foundational architectural theory for PGH-RF spatial organization. It addresses a theoretical gap that existing research has not bridged: response theory has not reached the building-layout level, while flexible-architecture theory has not been linked to disaster-induced activation conditions.

Second, it proposes classifying hospital space by architectural characteristics (the specialization of building services and functional convertibility) rather than medical specialty, distinguishing it from all existing zoning systems. It also incorporates outdoor space into the model as a formal space group with a defined response role, rather than as ancillary floor area.

Third, it proposes architectural solutions based on dual use: each space serves a routine function, while its response function is a conversion layer activated when necessary and reversed afterwards. The approach shifts from passive reservation (constructing space to await use) towards integrated readiness in design, suited to the limited land and high routine operating loads of Vietnamese PGH-RFs.

9. Concepts and terminology used in the dissertation

PGH-RF: provincial general hospital with regional functions. Architectural spatial organization: the arrangement and interconnection of spaces, expressed through distribution, linkage and building services at three levels: the campus, functional block and room unit. Disaster response: the action phase when a disaster occurs or is imminent, within the cycle of prevention, preparedness, response and recovery. Surge capacity comprises staff, supplies, space and coordination; this dissertation focuses on the spatial dimension. A resilient health facility maintains essential services during and after an adverse event. Dual use: space serves routine activities, is prepared for conversion to a response function, and is restored afterwards.

10. Dissertation structure

In addition to the Introduction, Conclusions and Recommendations, the author's publications, References and Appendices, the main text comprises three chapters: Chapter I—Overview of architectural spatial organization in provincial general hospitals with regional functions to meet disaster response requirements; Chapter II—Scientific foundations for architectural spatial organization in PGH-RFs to meet disaster response requirements in Vietnam; and Chapter III—Architectural spatial organization solutions for Vietnamese PGH-RFs to meet disaster response requirements.

MAIN CONTENT

CHAPTER I. OVERVIEW OF ARCHITECTURAL SPATIAL ORGANIZATION IN PGH-RFs TO MEET DISASTER RESPONSE REQUIREMENTS

1.1. Disasters in Vietnam and their impacts on PGH-RF architectural space

1.1.1. Types of health disasters in Vietnam

Statistics from the Ministry of Health and relevant authorities identify three main groups. The first is mass health incidents (collective food poisoning and road accidents): in the first 11 months of 2024, 131 food-poisoning incidents affected 4,796 people and caused 21 deaths, including 29 large incidents involving at least 30 people, averaging approximately 140 people per incident; road accidents generate background pressure, averaging 17,000 accidents, 8,190 deaths and 15,096 injuries annually in 2018–2022. Speed is this group's dominant characteristic. The second is widespread infectious disease (SARS 2003, influenza A/H1N1 2009, measles 2014 and COVID-19 2020–2022), dominated by duration, with demand accumulating over weeks or months. The third is natural hazards and infrastructure disruptions (in 2024: 514 dead or missing, 2,207 injured and VND 88,748 billion in losses, 9.52 times the 2023 figure), dominated by the direction of impact: these events need not increase incoming patients, but can reduce operating capacity from within.

The three groups differ by impact origin and rate of development. Mass health incidents are sudden-onset exogenous disasters; epidemics are cumulative exogenous disasters; and natural hazards and infrastructure disruptions combine exogenous impacts with declining endogenous capacity. These differences in speed, duration and impact direction require spatial organization capable of changing state according to the situation.

1.1.2. How representative disasters reveal spatial bottlenecks

In mass health incidents, the first point of failure is the receiving entrance: when arrivals over a few hours far exceed design throughput, entrance halls and adjoining corridors become waiting areas, with patients overflowing into emergency-department and adjacent inpatient corridors, obstructing emergency transport and undermining flow control. Food-poisoning patients require 6–24 hours of observation; inadequate short-stay observation space therefore causes corridor overflow. Road accidents spread bottlenecks into the surgery–intensive-care sequence when simultaneous surgical demand exceeds available operating rooms and teams.

During epidemics (the 2021 COVID-19 wave), three locations reveal the clearest problems: receiving entrances, where patients arrive simultaneously from multiple sources and infected and undetermined-status patients converge at one entrance without pre-reception buffers—the 2020 Da Nang outbreak, involving more than 41,000 people who had visited three hospitals, showed that entrance-control capacity determines the whole response chain; internal circulation, where many PGH-RFs already operate at 120–160% bed occupancy under routine conditions, making corridors the most common expansion space despite uncontrolled clean–contaminated flows and showing that adjacent enclosed spaces cannot convert; and peripheral expansion, where Ho Chi Minh City's plan for 60,000 beds, including 1,700 intensive-care beds, required dormitories, conference centers and sports halls without adequate piped oxygen or essential power, demonstrating that physical area does not create treatment capacity without services.

During natural hazards (Typhoon Yagi in September 2024, the strongest typhoon over land in 70 years), Quang Ninh General Hospital lost grid power for 12 hours; elevators stopped, and severely ill patients had to be carried between floors on stretchers via stairs. Some hospitals lost all backup power when generators in basements or ground floors flooded. Three structural weaknesses emerged: dependence on mechanized vertical circulation, insufficient sectionalization of services, and infrastructure locations that disregarded specific natural-hazard risks. The architectural requirement is sectional operational autonomy, maintaining essential functions in one part of a building when the rest is affected.

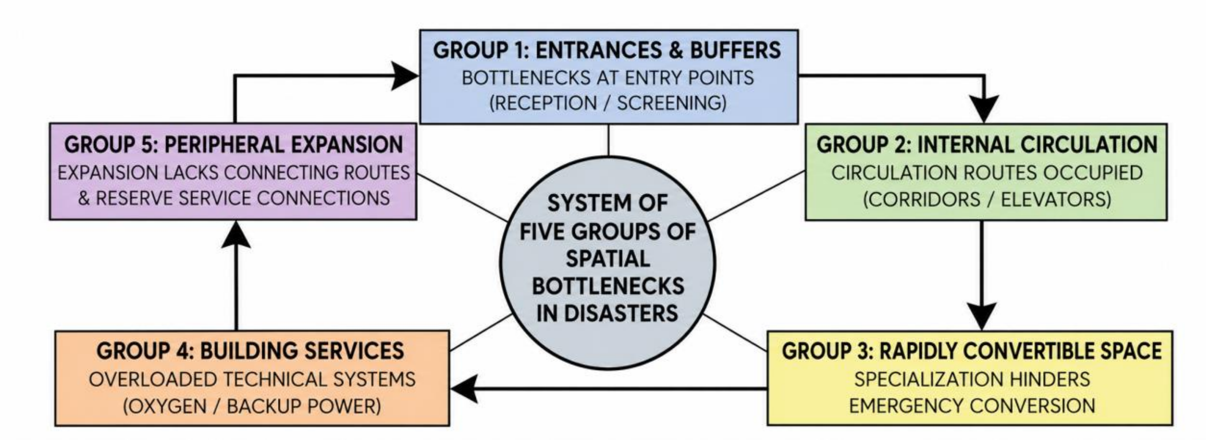

Figure 1.1: Cause-and-effect sequence of five groups of spatial bottlenecks

1.1.3. Synthesis

Comparison of the three event groups identifies five bottleneck groups: receiving entrances and screening buffers; internal circulation and flow separation; rapidly convertible space and reconfiguration; building services and reserve coverage; and peripheral expansion with ready service connections. The manuscript cross-checks these against a survey of 22 experts from six professional groups, whose mean ratings for the five groups range from 4.06 to 4.57 on a five-point scale (Appendices 5–6). Specialization improves routine efficiency but may restrict emergency conversion; the proposed model must resolve this tension.

1.2. Existing architectural spatial organization in Vietnamese PGH-RFs

1.2.1. Spatial structure under the current model

TCVN 4470:2012 organizes space through three principles: specialized departments (each with specific room, area and service requirements; greater specialization reduces functional interchangeability, while changes in care level immediately encounter fixed-service limits); distributing corridors (central corridors at least 2.4 m wide, or 3.0 m when incorporating waiting space, which become occupied under overload and spread congestion along the chain); and nursing units (care-level units with non-interchangeable technical requirements, without provision for alternative circulation or sectional interruption points). The standard is optimized for stable operation at normal loads and does not address surge capacity, phased functional conversion or independent sectional operation—a systemic gap at the standards level.

Three campus models have emerged in practice: dispersed campuses (multiple two- to five-storey blocks connected by corridors or bridges, common in 1990–2010, but with open spaces gradually filled by ancillary buildings and centralized services impeding independent block operation); consolidated high-rise campuses (the dominant trend since 2015, shortening interdepartmental distances but concentrating all flows into one structure under overload, congesting vertical-circulation nodes and creating high dependence on central services); and mixed campuses (high-rise blocks with low-rise satellites, the most common outcome of phased investment, creating the greatest flow-control difficulty and asymmetric service dependence). Their forms differ, but their operational limits under overload are similar.

The 17 PGH-RFs are distributed across six socioeconomic regions: Northern Midlands and Mountains (Phu Tho, Lao Cai No. 1 and Son La General Hospitals); Red River Delta (Viet Tiep Friendship, Thanh Nhan, Saint Paul, Bac Ninh No. 1 and Vietnam–Sweden Uong Bi General Hospitals); North Central region (Nghe An Friendship General Hospital); South Central Coast and Central Highlands (Da Nang, Khanh Hoa, Gia Lai Provincial Central and Central Highlands Regional General Hospitals); Southeast (Nhan Dan Gia Dinh Hospital and 115 Sai Gon General Hospital); and Mekong Delta (Kien Giang and Tien Giang General Hospitals). They represent diverse urban locations, land availability, campus types and regional natural-hazard characteristics, providing the survey basis for establishing model parameters.

Figure 1.2: Consolidated model – Lao Cai No. 1 General Hospital (Source: Lao Cai No. 1 General Hospital)

Figure 1.3: Mixed model – Bac Ninh No. 2 General Hospital (Source: Bac Ninh No. 2 General Hospital)

The crucial comparison concerns their similar operational limits under overload rather than their different forms: dispersed campuses lack control points and retain centralized services; consolidated campuses suffer vertical-circulation congestion and difficult sectionalization; mixed campuses additionally face complex flows and asymmetric technical dependence. Hospitals commonly lack phased development plans, protected reserve land and services designed for independent sectional operation. Consequently, their actual disaster-response capacities differ less than their external forms suggest.

Three mutually reinforcing land-use characteristics create limits that operational measures cannot readily offset: progressive densification, as accumulated infill gradually occupies internal open space; lack of protected reserve land, with allocated land maximally exploited within one or two investment cycles; and absence of transition buffers, as the public–treatment boundary consists only of a gate and one entrance hall, without depth to absorb several simultaneous incoming flows. Land, built form and infrastructure thus impose a capacity ceiling that operations alone struggle to overcome.

1.2.2. Assessment against disaster response requirements

The assessment framework identifies five spatial requirements when operations move from routine to overload: multilayer flow control; functional flexibility across care levels; expandable services with reserve capacity; buffer and peripheral expansion spaces; and independent sectional operation. Before examining limitations, existing achievements should be recognized: PGH-RFs partly maintain essential activities alongside response through sectional organization; possess high-technology clusters (emergency, operating rooms and intensive care) that can be strengthened progressively; and provide basic technical prioritization and infection control.

However, prolonged or excessive loads reveal three limitations in flexibility and conversion: rigid functional zoning imposed by specialization and technical boundaries; conversion to temporary intensive care blocked by minimum bedside services (stable-flow medical gases, continuous essential power and ventilation suited to dense equipment); and difficulty establishing pressure-controlled isolation rapidly. Four service and reserve limitations stand out: normal-load sizing without expandable reserve structures; oxygen bottlenecks with direct clinical consequences; essential power without scenario-based sectionalization; and ventilation that cannot readily change state by section. This explains why many COVID-19 responses increased area without proportionate treatment capacity.

Three successive limitations affect land and expansion: densely occupied campuses without prepared deployment space; peripheral expansion without minimum services or controlled access; and absent pre-deployment mechanisms (no priority-location inventory, principles protecting convertibility or reserve connection points). The gap between requirements and existing capacity concentrates in two decisive clusters: expanded intensive care and isolation linked to services; and convertible and expansion spaces linked to land and deployment readiness. Fundamentally, this gap results from design optimized for routine operation without integrating state transition as a basic design component.

1.3. International architectural spatial organization for hospital disaster response

Three representative models converge on a core principle. The American model uses the emergency department as the activation core, increasing capacity along a continuous sequence of convertible neutral spaces (the FGI Guidelines emphasize treatment expansion, alternative care facilities and modular structures). The European model (HBN 15-01, NHS, UK) emphasizes spatial sectionalization and containment, opening or closing areas without interrupting principal flows. The Asian model (Singapore's NCID) emphasizes negative-pressure isolation clusters with anterooms and interlocked doors, converting treatment areas according to activation times. Despite different emphases, all three favor hospitals whose spatial configurations can change to expand care and control risk, rather than simply adding area or beds.

Four design trends follow: dual operating modes become a fundamental requirement; convertible space becomes a recognized hospital component; sectionalization and flow separation become the dominant logic for infection risks; and isolation modules with anterooms become repeating organizational units. Five lessons and conditions for application in Vietnam are drawn: (1) critical-patient treatment chains must not depend entirely on mechanized vertical circulation (Japan's 2011 and 2016 earthquakes); (2) reception and triage buffers must be organized before disasters (SARS and COVID-19); (3) surge-response capacity derives from prepared service connections, not existing empty area (Huoshenshan, Nightingale and SURGE Hospitals); (4) regular, large structural spans (≥6 m) enable layout reconfiguration without structural intervention (Open Building and FGI); and (5) dual-use hospitals are more effective than dedicated reserve hospitals under resource constraints.

1.4. Related studies and the research position

International research has accumulated along five directions: surge capacity (Hick, Barbera and Kelen); resilient health facilities and recovery (WHO/PAHO's HSI); flexibility and functional adaptability (Habraken, universal patient rooms and Capolongo); prefabricated and modular hospitals (Huoshenshan and SURGE Hospitals); and guidelines and standards (FGI, HBN 15-01, HCAI California and SEIPS). Three systemic gaps remain. Theoretically, surge and resilience frameworks remain at healthcare-system level rather than building-layout level, while flexible design remains at room or unit level. Methodologically, tools linking disaster characteristics to spatial areas requiring activation are missing. In application, most studies address developed countries with abundant land, overlooking intermediate-tier hospitals in developing countries.

Domestic research remains limited. Ha Quang Hung's doctoral dissertation (2015) proposes a consolidated model for PGH-RFs, strong in routine operational efficiency but without clarifying state-transition mechanisms. Hoang Nghia Nam's doctoral dissertation (2014), approached through military healthcare organization, proposes temporary reception arrangements that are primarily reactive and have not been modeled as prepared configurations. Vietnamese hospital-architecture research focuses on optimizing routine operation, while disaster response is studied mainly through epidemiology and healthcare management rather than architectural spatial organization.

Accordingly, the dissertation builds on three bodies of knowledge (graduated surge-capacity frameworks, dynamic safety and resilience, and flexible layered-design principles) and pursues three contributions to address the gaps.

1.5. Research directions

The review establishes three hierarchically related research problems. Problem 1 is the lack of specialized theoretical foundations for PGH-RF spatial organization during disasters: surge-capacity and resilient-health-facility theories offer healthcare-system frameworks without architectural spatial-analysis tools; flexible-design theory addresses rooms or units; and the legal framework assigns responsibilities without corresponding design-standard requirements. Research question 1 asks: how can theoretical foundations be established for PGH-RF spatial organization capable of adaptation and conversion during disasters?

Problem 2 is the absence of a hospital-space classification model based on architectural characteristics and disaster response that identifies which spaces must remain stable, which can undergo controlled conversion, which emerge only upon activation, and the rules linking them. Research question 2 asks: how should PGH-RF space be classified architecturally to establish its organizational structure, linkage rules and conversion mechanisms? Problem 3 is the lack of specific architectural solutions to implement the model under Vietnamese PGH-RF conditions. Research question 3 asks:

how can architectural solutions give concrete form to the model while meeting disaster-response requirements and fitting Vietnamese realities? The problems form a hierarchy: theory provides the foundation; classification translates it into organizational structure; and solutions implement the model, directing the development of Chapters II and III.

CHAPTER II. SCIENTIFIC FOUNDATIONS FOR ARCHITECTURAL SPATIAL ORGANIZATION IN PGH-RFs TO MEET DISASTER RESPONSE REQUIREMENTS IN VIETNAM

2.1. Theoretical foundations

2.1.1. Theories of architectural spatial organization in PGH-RFs

Architectural spatial organization simultaneously establishes three relationships within a building's spatial system: distribution (where spaces are placed), linkage (how circulation, boundaries and access sequences connect them), and services (how technical systems serving each space are organized), considered at campus, functional-block and room-unit levels. The hospital's distinctive feature lies in services: a space is defined less by its shape than by the medical-gas provision, essential power, ventilation regime and cleanliness level ensured locally. This yields the chapter's foundational proposition: the specialization of building services is a criterion for classifying hospital space, alongside and independently of medical function.

Functional sequencing and zoning principles (the basis of TCVN 4470:2012) converge from three early-twentieth-century theoretical traditions, all assuming that space is optimized for routine use frequency; overload was never a design condition in classical theory. This body of theory leaves two foundations—the adjacency rules of the emergency–surgery–intensive-care chain and functional zoning for daily operation—and one requirement: an additional classification must consider how space responds to overload, complementing rather than excluding current zoning.

Typological evolution and indeterminate architecture (John Weeks's Northwick Park “hospital street” and the British Nucleus program) contribute two basic principles: separating fixed from changing components, with a stable circulation and services spine supporting variable elements; and standard units on a unified grid. However, these theories target long-term changes measured in years, not short-term emergency changes over hours or days followed by restoration. The two-grid problem—a functional grid derived from human and equipment dimensions and a structural grid of 6.0–7.8 m—establishes a premise: an appropriate organizational unit must meet the clinical functional-area threshold while matching the actual structural grid. PGH-RFs' regional functions also have three spatial implications: emergency, surgery and intensive care must exceed conventional proportions; multiple incoming flows require simultaneous access and processing; and campuses formed through successive investment phases must be treated as a structural characteristic.

2.1.2. Disaster-response theories

Surge capacity (Hick et al., 2009) has four dimensions—staff, supplies, space and infrastructure, and coordination—with space providing the foundation that determines the feasibility of the entire expansion process. Kelen and McCarthy (2006) add three operating thresholds (conventional, contingency and crisis), showing that capacity expands incrementally. Resilient-health-facility theory (WHO/PAHO's Safe Hospitals, with structural safety, operational continuity and response capacity as its three pillars) establishes mitigation by design as a central principle. Dynamic safety (Cimellaro, 2010) shifts assessment from "is the hospital damaged?" to "how long does the hospital take to restore treatment capacity?"

The three surge-capacity thresholds confirm that expansion is not an immediate all-or-nothing event, but a graduated process corresponding to situation severity. The dissertation adopts two foundational propositions—space and infrastructure constitute an independent dimension that can become a distinct bottleneck, and expansion is a graded process—to organize space across multiple activation levels. Dynamic safety also changes the design goal: a hospital should recover rapidly after impact, rather than be considered immune to impact. Mitigation by design requires resilience to be integrated from the initial design stage, rather than added after construction.

The Hospital Incident Command System (HICS) comprises incident command and four functional sections, together with an Emergency Operations Center (EOC) that must be separate from clinical treatment areas to preserve overall situational awareness and decision-making. Command therefore differs fundamentally from treatment and requires recognition as a distinct space type. Rapid triage (START, screening each patient in 30–60 seconds into four priority levels) and damage-control surgery (DCS, prioritizing vital-sign stabilization and increasing operating-room turnover while increasing pre- and postoperative intensive-care demand) both demonstrate that disaster clinical logic entails corresponding spatial logic. This underpins the functional-space model in the next chapter, based on protocols validated in emergency medicine.

2.1.3. Foundational architectural theories

The dissertation draws on five foundational architectural traditions: flexible design (Hertzberger's polyvalent space, usable in different ways without alteration; Leupen's frame and generic space, separating the fixed framework from neutral space); Open Building (Habraken's Support/Infill, developed into Kendall's base building/fit-out, allowing interior reconfiguration without structural intervention); Long Life–Loose Fit–Low Energy (Gordon, design with intentional spare capacity); evidence-based healthcare design (Ulrich and Hamilton, using research evidence in design decisions); and landscape as functional infrastructure (Bélanger's landscape as infraspace, supporting outdoor space as an activatable operational component). These theories share a missing link between flexibility and load thresholds, specific emergencies or phased activation times; the dissertation addresses this through dual use.

2.2. Medical foundations and spatial requirements for disaster response

Patient reception and treatment comprise six stages: reception and screening; priority triage; initial stabilization; emergency treatment or surgery; intensive care and observation; and referral or discharge. The key distinction from routine operation is that all six stages occur simultaneously rather than sequentially, generating parallel patient, staff and logistics flows within the same period. Time-based coordination cannot resolve these parallel flows, so physical spatial separation is required. This is the fundamental reason why certain response functions need dedicated spaces.

Three systemic spatial conflicts follow: service conflicts (high-pressure oxygen, uninterrupted essential power and pressure-controlled ventilation cannot be shared); circulation-control conflicts (clean–infected flows and patients, staff, supplies and waste cannot use the same route); and infection-control conflicts (anterooms and transition zones are mandatory). A function requires an independent space when it generates at least one conflict that cannot be resolved through shared space. This criterion determines the response-space list in Chapter III, rather than experience alone or conventional departmental divisions.

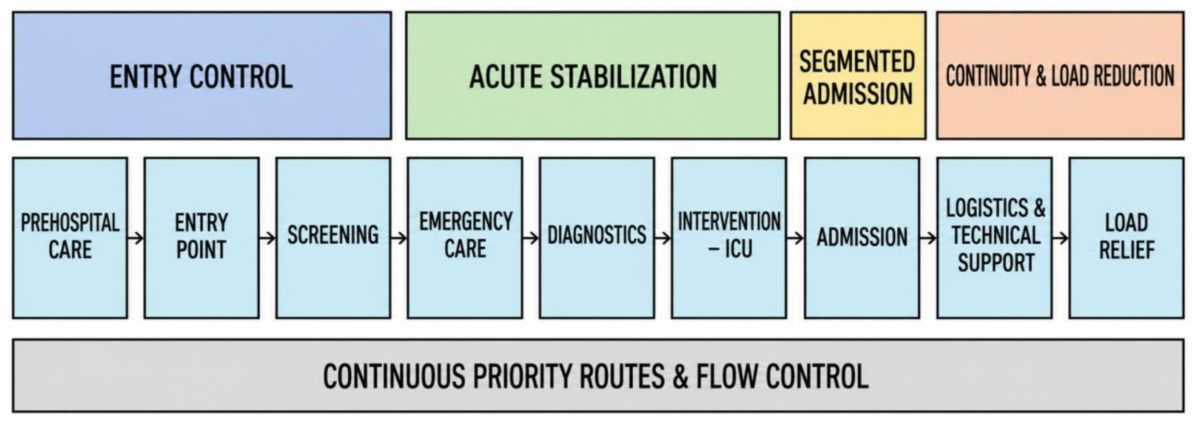

Figure 2.1: Patient reception and treatment during disasters and parallel operation

Three overload situations are analyzed using quantitative reference parameters. Mass health incidents: sudden increases over 1–6 hours; each triage station processes 60–120 patients/hour (100 patients/hour require 2–3 parallel stations, each approximately 9 m², with an access route at least 3.6 m wide); operating rooms at least 36 m²; and intensive-care bed positions at least 14 m². Widespread infectious disease: cumulative increases over weeks or months; single isolation rooms at least 11.2 m²; negative-pressure rooms with at least 12 air changes/hour and a −2.5 Pa pressure differential; anterooms at least 3 m²; and fully independent isolation ventilation. Natural hazards and infrastructure disruptions: backup power sustaining intensive care and operating rooms for at least 30 minutes during power-source transfer; generators at least 0.5 m above flood level; and services sectionalized by block or floor.

The three conflicts explain both the space inventory and why some functions require physical separation. During disasters, reception and treatment stages occur simultaneously, preventing a single space from serving different functions at different times as in routine operation. Rapid triage demonstrates that a fast clinical process requires several separate spatial zones operating simultaneously, rather than one receiving space. Damage-control surgery changes the surgical sequence from a single prolonged process into successive short steps, requiring tighter links between preoperative care, intervention and recovery. This directly supports the three-part emergency-surgery cluster in Chapter III.

Medical electrical, gas and ventilation systems follow the same three-tier hierarchy of clinical functions, with each function maintaining its tier across all three systems. Core services (medical-gas pipelines, independent ventilation and electrical sectionalization) are effectively permanent and cannot be added rapidly, so they must be integrated in design; furnishings, lightweight partitions and mobile equipment can instead be added over hours or days. In particular, geometric convergence shows that 36 m²—the operating-room threshold—encompasses all other thresholds: a 36 m² unit prepared with surgery-level services can accommodate any clinical function, or be subdivided into two intensive-care beds, three isolation rooms or three emergency-care positions. Although quantitative medical requirements differ by function, they converge on a common spatial unit rather than numerous disconnected room sizes.

2.3. Practical foundations for application in Vietnam

The 17 PGH-RFs span six regions and mostly occupy inner-city sites, imposing three dominant constraints: almost fully utilized land, with virtually no short- or medium-term campus expansion potential; very limited outdoor deployment land, varying greatly between hospitals; and development through successive investment phases, producing mixed campuses with intersections not designed as control nodes. Existing structural spans, commonly 6.0–7.8 m, determine spatial reconfiguration potential and provide one of the module's two origins, alongside minimum clinical functional area.

The prevalent 6.0–7.8 m spans reflect three decades of Vietnamese hospital design: 6.0 m spans are common before 2010, and 7.2 m and 7.8 m spans in newer buildings. Existing load-bearing structures cannot be changed, so spatial reorganization must work within the established column grid. A basic spatial unit therefore cannot have an externally imposed fixed dimension; it must adjust to the actual structural span. The surveyed span range and minimum clinical functional area jointly generate module M in Chapter III—one origin in structural logic and the other in clinical requirements.

Natural conditions across the six regions modify solution parameters: mountainous areas require autonomy when isolated; storm- and flood-prone areas require safe elevations for essential services and alternative access. High routine loads, phased investment and financial autonomy pressure hospitals to maximize space use, supporting dual use. Regarding technology (Section 2.3.5), mobile treatment equipment, oxygen systems and teleconsultation enable flexible deployment but depend on receiving infrastructure. Large-span structures, demountable partitions, service voids and prefabricated components provide conversion means. The gap to be addressed is integrating ready connections, sectionalization, reserve capacity and reconfigurable components into the design brief.

2.4. Legal foundations

The legal definition of disaster in the 2023 Law on Civil Defense includes "exceeding provincial authorities' response capacity," thereby defining both the concept and the threshold activating PGH-RFs' role. The 2023 Law on Medical Examination and Treatment (Chapter XI, Articles 115–118) and Decree 96/2023/ND-CP regulate resource mobilization and deployment, making response participation mandatory throughout the healthcare system. Since response is legally obligatory, the architectural spatial conditions for fulfilling that duty also become necessary requirements. The 2023 Law on Civil Defense and the 2025 Law on Disease Prevention (civil-defense Level 3 when epidemics exceed provincial response capacity) reaffirm the legal mechanism activating regional healthcare systems.

In network planning, Article 104 of the 2023 Law on Medical Examination and Treatment shifts from administrative-geographical referral tiers to three professional-capability levels (initial, basic and specialized), providing a legal basis for PGH-RFs. Decision 201/QD-TTg (2024) first formally establishes this concept; Decision 1658/QD-BYT (2026) identifies 17 hospitals and a three-tier disaster-response system: national response by leading central specialist hospitals, regional response by PGH-RFs, and provincial response by the remaining basic-level hospitals. Regional responsibilities have three spatial consequences: constraints on surge-capacity scale; a response-command space separate from clinical areas; and campus organization for multidirectional reception.

The current legal framework has four strengths: a clear disaster definition, mandatory response participation, specific PGH-RF response assignments, and recognition of the PGH-RF term in state planning documents. Yet a systemic gap remains: laws impose duties and plans assign tasks, but no document specifies the architectural spatial conditions for fulfilling them, while TCVN 4470:2012 does not establish disaster-response capacity as a design objective. This gap establishes both the study's urgency and its intended contribution: scientific foundations and architectural solutions bridging legal responsibilities and current design standards.

CHAPTER III. ARCHITECTURAL SPATIAL ORGANIZATION SOLUTIONS FOR VIETNAMESE PGH-RFs TO MEET DISASTER RESPONSE REQUIREMENTS

3.1. Viewpoints and principles for the proposed solutions

Four viewpoints are established: (1) organize space for routine and response operation, preparing conversion, expansion and reconfiguration within the architectural structure rather than constructing a separate reserve-building system; (2) treat response capacity as an architectural attribute, integrated through structural spans, clear heights, service-shaft locations, circulation and zoning relationships from the design stage; (3) classify space by convertibility, based on service specialization and functional convertibility; and (4) ensure feasibility under practical conditions and development trends, applying to both new construction and renovation, through phased investment within provincial hospitals' resources.

Five design principles follow: (1) stratify by spatial characteristics, identifying all spaces within three groups that complement medical zoning; (2) prepare services before conversion, anticipating essential power, medical gases, ventilation, information systems and reserve connections; (3) organize through adaptable modules; (4) control spatial relationships by priority and separation requirements, treating entrances, corridors, circulation nodes, buffers and transitions as control components; and (5) activate space progressively. Response capacity is organized as progressive activation across situation levels rather than a binary routine–emergency split, avoiding both delayed response and excessive investment. Section 3.1.3 links six components: three space groups, seven functional spaces, relationships P, module M, six flexibility mechanisms and four activation levels. Sections 3.2–3.3 establish the structure and conversion methods; Sections 3.4–3.5 translate them into solutions.

3.2. Architectural space classification and linkage rules in the disaster-response model

The dissertation proposes shifting the reference framework for hospital spatial organization from medical function to state-transition capacity. Unlike TCVN 4470:2012, which uses functional sequencing and departments to optimize routine operation, it assesses space through architectural characteristics, service preparedness and transition capacity. This classification does not replace medical zoning; it forms an additional architectural layer identifying each area's response role and potential. This is the dissertation's central proposition. The model comprises three nested components: three groups with different architectural characteristics, seven response functional spaces linked to routine spaces, and rules governing their relationships.

3.2.1. Three space groups and their architectural characteristics

The fixed specialized space group comprises areas with specialized services forming the treatment core that must be protected during response. Emergency surgery and expanded intensive care are its two representative spaces. The solution stabilizes the core, prepares adjoining space and services for additional load, and prioritizes horizontal ground-level access for critical-patient transport, limiting reliance on vertical circulation.

The neutral convertible space group comprises areas with neutral layouts and services that permit flexible conversion to emergency functions and subsequent restoration. It directly creates effective response capacity by relieving overload within the existing structure, implementing dual use. Minimum conditions include large structural spans, easily removable partitions, service connection points with substantial reserve capacity and sufficient clear height. Its four spaces are patient triage, expanded emergency care, infectious-disease isolation and the EOC. The field-deployment space group comprises areas without permanent treatment structures during routine operation; temporary response facilities appear according to the scenario, and the site is restored afterwards. Services arrive through prepared underground connections, supported by hardstanding, coordinated connection networks and convenient access.

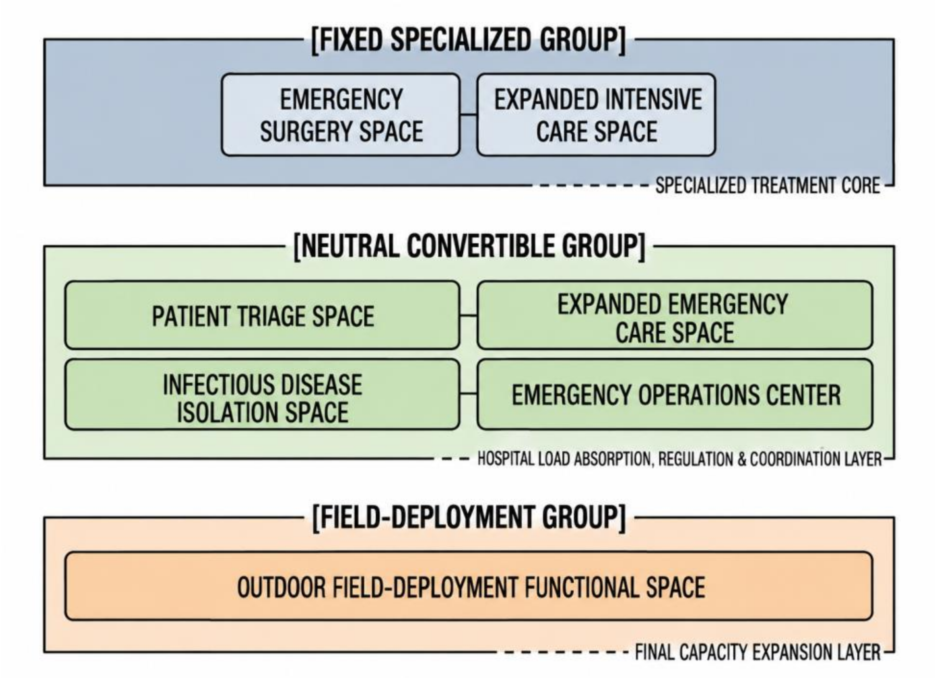

Figure 3.1: Mapping seven response functional spaces to three space groups

3.2.2. Seven disaster-response functional spaces

Based on the three space groups and three conflicts, seven functional spaces are established: emergency surgery and expanded intensive care (fixed specialized group); patient triage, expanded emergency care, infectious-disease isolation and the EOC (neutral convertible group); and outdoor field deployment (field-deployment group). Under dual use, these do not exist as detached new construction; they are linked to one or more convertible routine spaces: emergency surgery to routine surgical clusters; expanded intensive care to the original ICU plus technically equipped inpatient strips or intermediate care; triage to entrance halls, covered approaches and waiting areas; expanded emergency care to observation, day-treatment or adjoining inpatient strips;

isolation to sectionalizable inpatient clusters; command to meeting or briefing rooms with independent entrances; and field deployment to parking, hardstanding and reserve land with direct vehicle access. Other support functions (emergency testing, supplies storage, family waiting and logistics) do not generate sufficient conflict to require independent spaces; the seven therefore constitute a necessary and sufficient system.

3.2.3. Spatial relationships

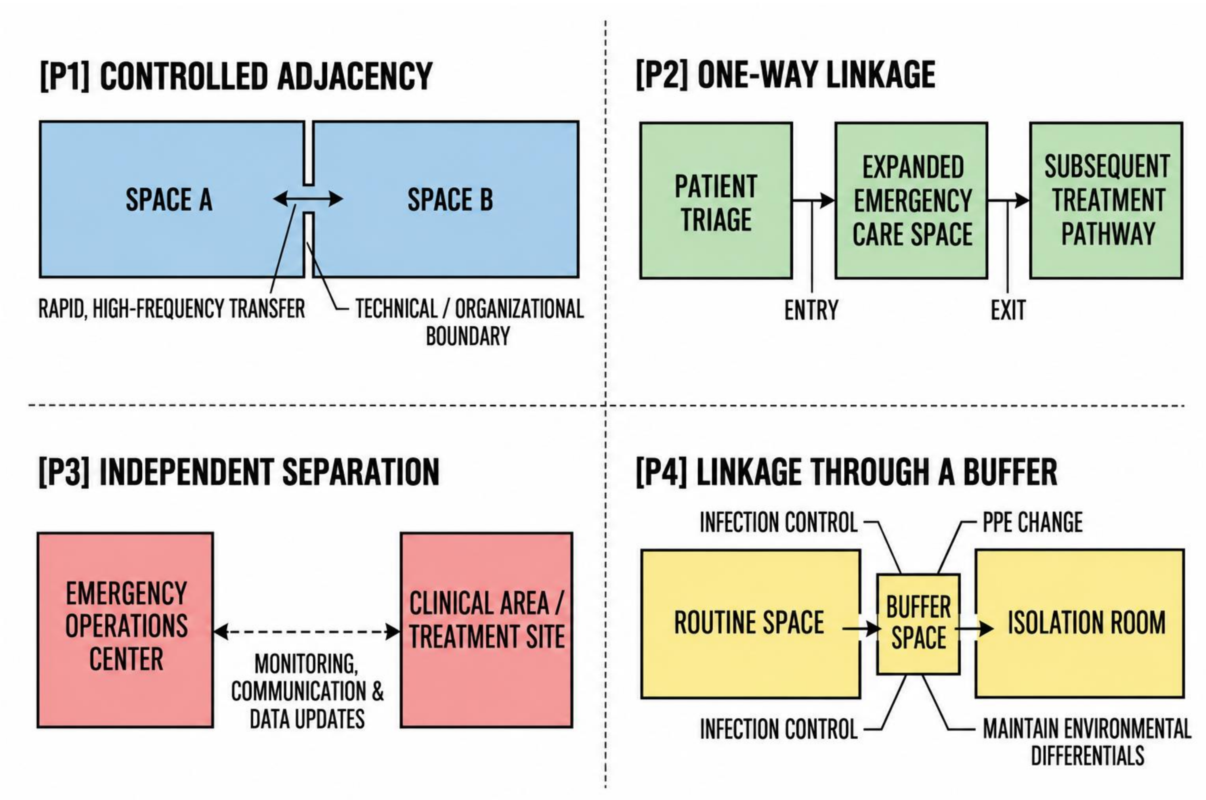

Figure 3.2: Spatial relationships P1–P4 in the response model

The seven spaces form an ordered network derived from the three conflicts. Five relationships are identified: controlled adjacency (P1) for pairs needing rapid access while retaining technical boundaries (expanded emergency care–emergency surgery and surgery–expanded intensive care); one-way linkage (P2) where unidirectional flows prevent congestion (triage–expanded emergency care and outdoor deployment–main building); independent separation (P3) where direct connection risks system failure (the EOC must remain separate from clinical areas while maintaining strong information links); linkage through a buffer (P4) where infection conflicts require a transition layer (infectious-disease isolation); and priority hierarchy (P5), a conflict-resolution principle ranking P3 and P4 above P1 and P2 when all placement requirements cannot be met simultaneously. These relationships identify routine spaces that can and cannot be mobilized for conversion.

3.3. Basic module and flexible conversion mechanisms

3.3.1. Module M and the spatial organization grid

Module M is the minimum functional spatial unit shared by the three groups, defined by three conditions: area no smaller than 36 m², following the study's selected functional threshold; square or nearly square shape; and sides compatible with the structural grid, with module boundaries on column axes. M adjusts to each building: 7.2 × 7.2 m gives approximately 51.8 m²; 7.8 × 7.8 m gives approximately 60.8 m²; and 6

× 6 m, or 36 m², is the lower-bound case. Module selection relates to accommodating temporary deployment units and organizing the outdoor grid. These values underpin the model's organization and must be checked against each function's specific design requirements.

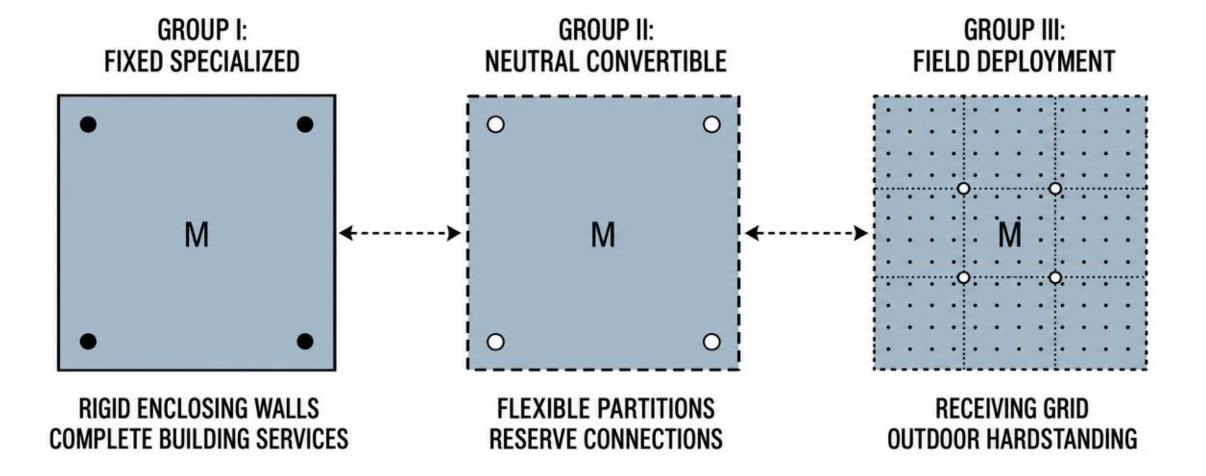

Figure 3.3: Module M in the three space groups

The seven functional spaces are expressed as n×M, where the number of M cells varies with hospital size and response level, while architectural attributes vary by group: rigid enclosing walls and complete services in the fixed specialized group; flexible partitions and reserve connections in the neutral convertible group; and a receiving-grid cell on hardstanding in the field-deployment group. A continuous indoor–outdoor M grid connects permanent treatment space and temporary deployment within one unified system. Service-connection locations, outdoor grids, clear heights and partition adaptability must therefore be established during initial design.

3.3.2. Six flexibility mechanisms based on routine space

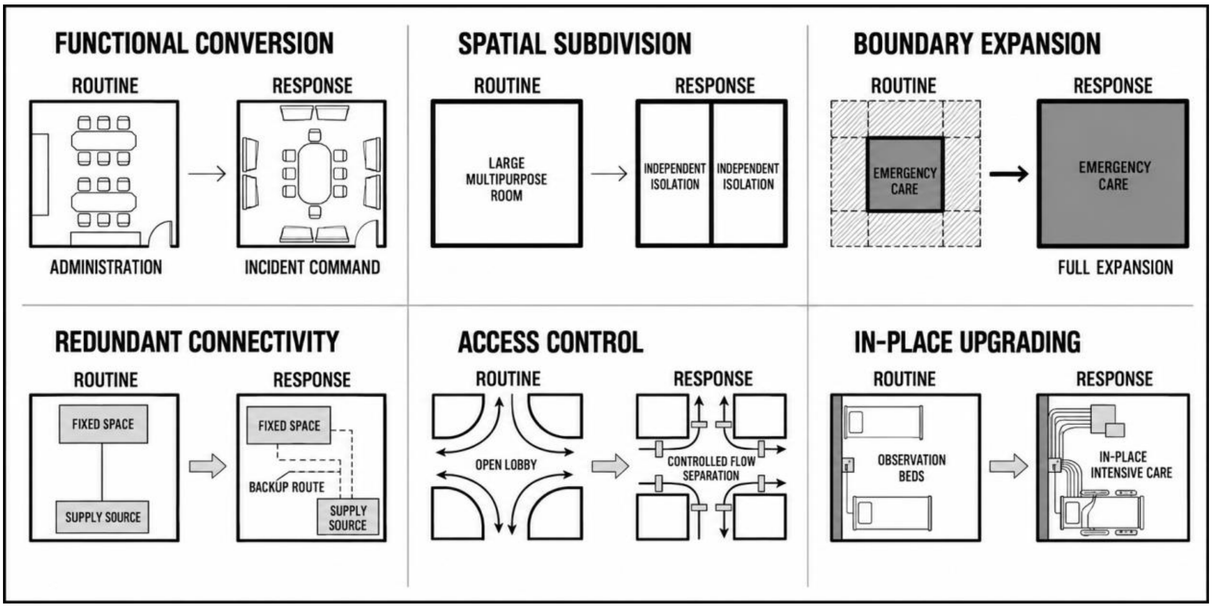

Figure 3.4: Six flexibility mechanisms based on routine space

Six flexibility mechanisms transform an M cell from routine use into a response configuration through three kinds of action. Changing use within a cell: functional conversion retains boundaries while changing furnishings and activating connections, suited to the EOC; in-place upgrading provides higher-level care at the same location through prepared services, suited to expanded intensive care. Changing boundaries between cells: spatial subdivision separates a large cluster into smaller independent cell groups or opens connections, suited to isolation; access control changes a receiving-point M boundary from open to controlled, suited to triage. Changing cell numbers and connections: boundary expansion adds adjacent or outdoor M cells, suited to expanded emergency care; redundant connectivity ensures that each important M cell retains backup electricity, medical gases, water and transport access, suited to the fixed specialized group.

Where several mechanisms operate simultaneously, the dominant one determines the architectural prerequisite: without its design-stage preparation, the space cannot perform its response function even if other mechanisms work. M and the six mechanisms are two sides of the same organizational system: M defines the constituent unit, and the mechanisms define permitted transformations. Response-space convertibility thus derives directly from the modular grid rather than from an additional set of solutions outside the system.

3.4. Architectural spatial organization solutions at campus scale

Four fundamental conditions enable the three-group model in site planning: critical-patient transport must prioritize a horizontal sequence from triage through expanded emergency care to emergency surgery and intensive care, without elevator dependence; field deployment must directly adjoin the site perimeter and have independent vehicle access; the EOC must have a separate entrance outside clinical flows; and the M grid must continue from indoors to outdoors.

For dispersed and mixed campuses—the most favorable because some buildings have direct ground access and outdoor land is available—the dissertation establishes a four-component framework: an emergency-treatment core directly accessible from ground level (surgery–ICU clusters with short, continuous transport routes independent of elevators); intermediate conversion resources ranked by priority (primary resources near the access spine and treatment core, supported by administrative blocks and meeting rooms for command); an outer layer prepared for phased field deployment (load-bearing surfaces, underground service connections on the M grid and independent vehicle access); and inter-block routes integrated into the response infrastructure (stretcher-width routes without level changes or steps, usable during power failure with manual-opening backup).

For dispersed and mixed types, the task is to redefine the response roles of existing campus components rather than add an entirely new structure. Intermediate conversion resources are divided into two levels rather than treated as a homogeneous reserve. Primary resources are both close to the main access spine and directly connected to the emergency-treatment core: outpatient blocks near the entrance, inpatient strips adjoining surgery–ICU clusters, and covered waiting at the first receiving layer. Supporting resources include administrative blocks, meeting rooms and independently accessed spaces suitable for command. The outer layer—yards, parking and landscape buffers—is designed initially as phased deployment space: first for preliminary triage or buffered waiting, then for field treatment when indoor absorption capacity is exceeded.

For consolidated high-rise campuses, where response chains must cross inherent vertical distances, four solutions correspond to four intervention levels: a dedicated receiving floor (a fully convertible ground floor with a dedicated transport ramp replacing elevators, wide enough for stretchers and usable during power failure); an elevated deployment surface level with the treatment core (ambulance-ramp access and complete service connections for elevated reception, triage and deployment); the roof of a low-rise ancillary block as an intermediate deployment surface (reducing vertical distance, provided adequate load capacity is designed from the outset); and an independent emergency nucleus outside the main building (a new structurally separate low-rise block containing the entire fixed specialized group with independent services and power, suitable for completed high-rise hospitals).

The solutions are consolidated into two layers of core architectural conditions for assessment and appraisal. Structural conditions, assessed as present or absent, comprise direct ground access to the critical-treatment core (DK1); separated flows and independent entrances for field deployment (DK6) and command (DK3, DK7); a continuous indoor–outdoor M grid; and sectional interruption points on corridors. Measurable technical conditions comprise structural span ≥6 m, i.e. ≥1M (KT1); transport-route width ≥2.4 m (KT2); clear height ≥3.3 m (KT3); rapid bedside connections with at least one oxygen outlet and four essential-power sockets (KT4); anterooms ≥3 m² each (KT5); and at least 4M of adjacent convertible Group 2 space (144 m² at the lower-bound module) (KT6). These conditions are unobtrusive in daily operation and often overlooked, yet cannot be retrofitted or added after building completion.

3.5. Spatial solutions for three groups and seven functional spaces

Each functional space is considered in routine and activated states, identifying the flexibility mechanisms, applicable module M and governing relationship P. For the fixed specialized group, solutions retain the space's inherent structure while establishing surrounding conditions that protect capacity under overload: sizing for activated extreme scenarios; positioning according to mandatory access directions; convertible adjoining strips allowing the core to absorb area without lowering treatment standards; and internal dual-use buffers. Both spaces share three constraints: synchronized reference grids (cluster size in multiples of M and boundaries with Group 2 aligned to M); direct ground access; and central oxygen and essential-power capacity sized for extreme scenarios as the simultaneous load of the core and all reserve areas.

Emergency-surgery space derives from a routine surgical cluster designated as the priority core, organized in three adjoining components—preoperative care, operating room and recovery—with a minimum of 3M ≈108 m² and at least two clusters for parallel operation. The core remains fixed while both ends expand through openable boundaries with Group 2 under damage-control-surgery principles. Beyond the threshold, additional capacity transfers to a field-surgery unit through connections at the building envelope. Expanded intensive care comprises the original ICU and upgraded Group 2 space of at least 4M (144 m² at the lower-bound module), operating across three care tiers: original ICU, expanded ICU from prepared inpatient space with bedside trunking, and intermediate care. Its reversibility is the model's clearest, because the same partition boundary and trunking serve activation and restoration.

Emergency surgery participates in four-level progressive activation. Initially, interventions are organizational: prioritizing operating schedules and shortening preoperative procedures. At higher levels, boundaries at both ends of the sequence open, extending preoperative and recovery areas into expansion strips and increasing waiting-stretcher and recovery-bed positions without changing operating-room numbers. At the highest level, added capacity transfers to field surgery through envelope connections, sharing instrument and intensive-care routes with the fixed cluster. Afterwards, priority operation ends, expansion boundaries close to restore Group 2 uses, and field connections return to standby; no structural change is required. Immediate restoration follows directly from keeping the core fixed: all changes occur at its boundary, leaving its specialized interior intact.

Unlike Group 1, designed once for a stable operating configuration, the neutral convertible group requires one design for two uses: routine and activated. Expanded emergency care combines the existing department with adjacent resources in priority order: emergency observation, day treatment, nearby inpatient strips, then specialist outpatient areas that can temporarily suspend service. Four selection criteria apply: the same level, few public-flow crossings, bedside trunking meeting KT4 and demountable boundaries. Each expansion module of at least 1M is a complete conversion unit, mobilized progressively. When activated, expanded emergency care combines the original core, adjacent reinforcement strip and route to outdoor deployment, forming a controlled junction of three flows, with direct P2 links to triage and the shortest P1 links to surgery and intensive care.

Infectious-disease isolation derives from a sectionalizable inpatient cluster with a separate entrance, sufficient buffer area for anterooms and independent service branches. Four conversion conditions apply: sectionalization by control points, anterooms ≥3 m² each, one-way entry, and ventilation separation or adjustment at local branch level. The activated configuration has three layers—clean zone, anteroom and isolation room—with a dedicated anteroom for each patient unit and doors between layers that do not open simultaneously. It requires separate P4 access, a location downwind of prevailing winds and a minimum cluster of 4M. Triage and the EOC need little physical architectural intervention: triage uses covered receiving spaces directly accessible from ambulances, creates one-way START flows (P2) and offers the highest reversibility; command converts an independently accessed meeting room with reliable telecommunications into three HICS zones, with backup power independent of clinical supply and P3 separation from clinical flows.

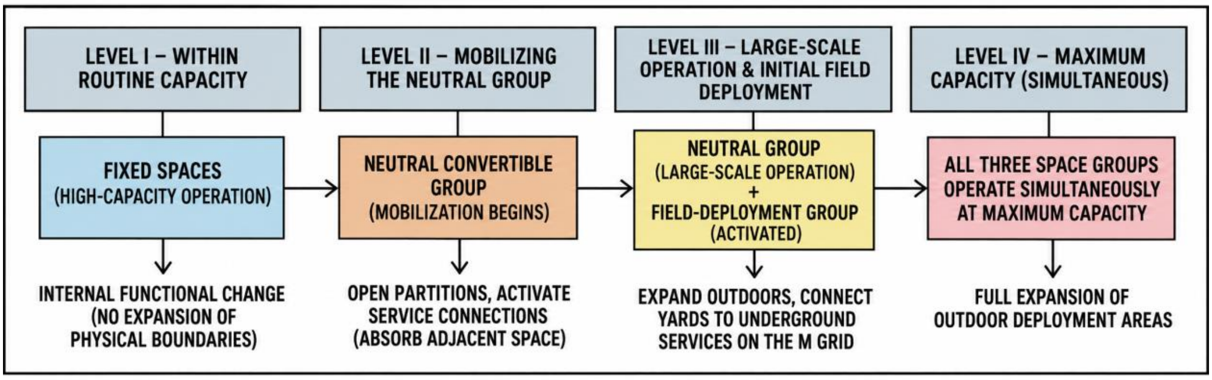

Figure 3.5: Progressive activation across four situation levels

The field-deployment group focuses on receiving surfaces, connection grids and access, with two zones for two scenarios: rapid deployment beside expanded emergency care for mass trauma (at least 4M), and larger peripheral deployment downwind for epidemics (at least 8M). Five architectural conditions apply: load-bearing surfaces;

electricity, water, oxygen and drainage connections on the M grid; independent vehicle access; an unobstructed layout; and ground levels above the design flood. The last reflects Vietnam's conditions, where storms and floods both trigger response and disable outdoor areas. All seven spaces share one characteristic: response capacity depends on architectural conditions integrated during design, rather than additions after completion.

Four-level progressive activation is a scale of spatial mobilization according to overload, not a disaster classification. Level I, within routine capacity: spaces change internal functions without expansion or boundary changes. Level II, mobilizing neutral convertible spaces: dedicated triage is established, while expanded emergency care absorbs adjacent area by opening partitions and activating connections. Level III, high-scale convertible operation and initial field deployment: the hospital expands outdoors, yards connect to underground M-grid services, and isolation clusters activate if required. Level IV, all three groups operating simultaneously at maximum capacity: outdoor deployment expands fully and the EOC coordinates the hospital as a node in an inter-hospital response network. Each transition both opens response space and releases its underlying area from routine use.

3.6. Experimental design

The experimental case is the Internal Medicine Building in the project to construct that building and renovate Saint Paul General Hospital (12 Chu Van An, Ba Dinh, Hanoi): four above-ground floors, one basement and 129 internal-medicine beds, inserted between two existing buildings on a dense inner-city campus, with an irregular 6.4–7.5 m column grid. It was selected because a complete design dossier is available for this Grade I frontline inner-city Hanoi hospital; it represents common and particularly difficult infill and renovation conditions, directly testing the mixed-campus framework; it has ground-floor emergency and intensive care with horizontal ground access; and its irregular grid rigorously tests module M's self-adjustment.

Indoor structural bays provide approximately 46–48 m², exceeding 36 m², nearly square and aligned with column axes; outdoors, the service grid is 6 × 6 m. These dimensions demonstrate M's adjustment to building conditions. Response functions are linked to routine spaces and a preparedness layer of removable partitions, ready connections, anterooms, control points and underground connections. Triage, emergency and intensive care are organized at level ±0.00; existing surgery connects through a second-floor bridge. Fourth-floor isolation flows are separated through P4; outdoor deployment must preserve campus vehicle routes and access requirements.

The four-level activation simulation establishes transition and restoration sequences. Level I immediately strengthens reception in the entrance hall. Level II, within two hours, establishes triage in the hall and forecourt and opens finance-area partitions for expanded emergency care (an additional 5M, approximately 20 stretcher positions). Level III, within 12 hours, converts the hall into command, activates a 30-bed isolation unit, opens rapid outdoor deployment and upgrades intensive-care beds. Level IV, within 72 hours, expands into the garden, coordinates blocks through the bridge and shifts the basement to disaster logistics. Afterwards, boundaries close on the M grid and the building is restored without structural intervention. Three central propositions are illustrated: the state-transition framework works in renovation and infill; M adjusts to irregular column grids and continues outdoors; and dense inner-city land constraints can be addressed through existing architectural resources—the ground-accessible first-floor core, basement depth and links with existing buildings.

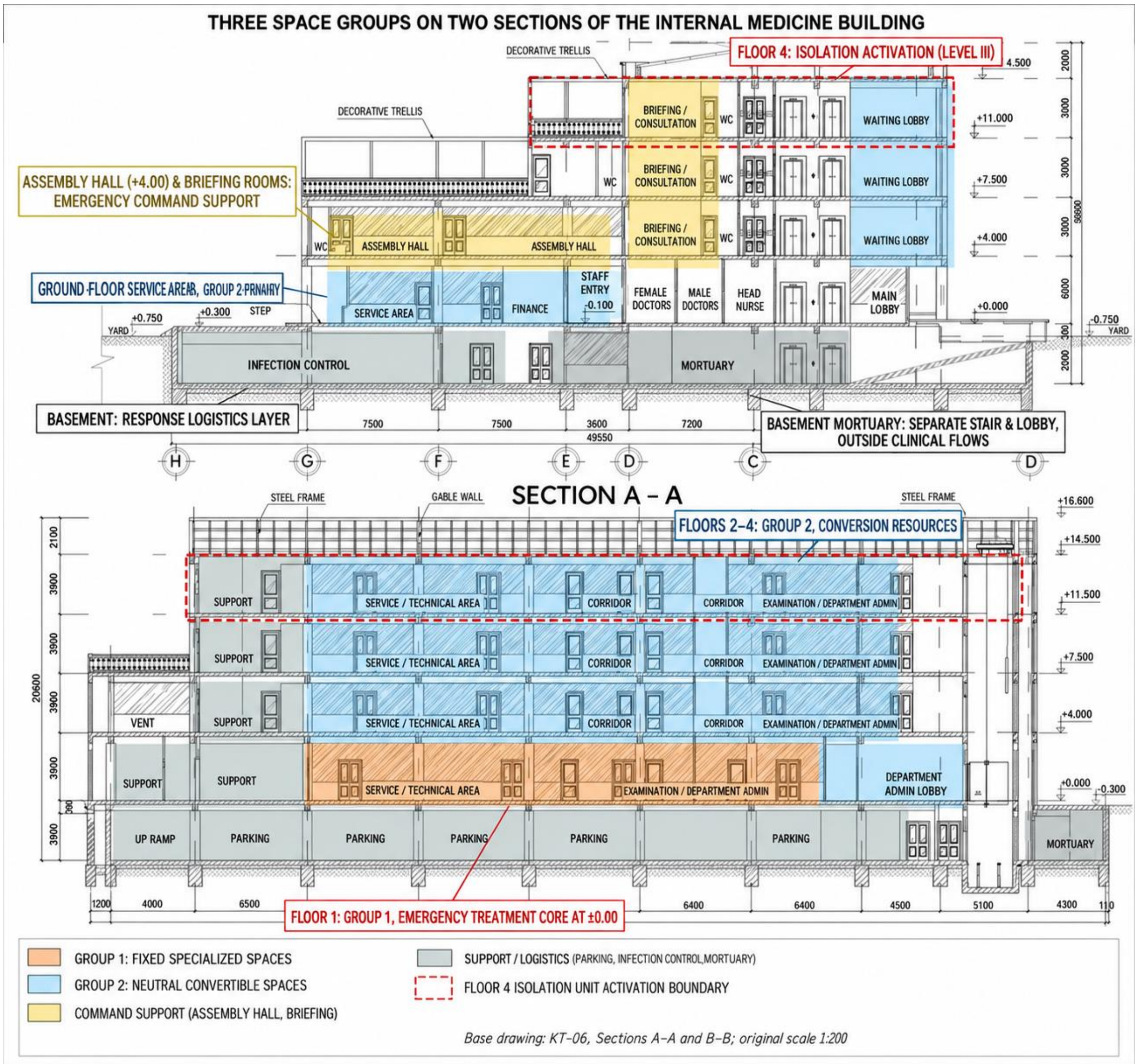

Figure 3.6: Three space groups on two sections of the Internal Medicine Building

Dissertation Table 3.12 summarizes estimated modular capacity: from a baseline of 36 fixed emergency beds, approximately 20 indoor stretcher positions are added at Level II and 12–16 outdoor tent beds at Level III; approximately 30 isolation beds with anterooms are provided; command occupies a 312 m² hall; and field-deployment space is at least 14M, approximately 500 m². The scheme uses the ground-floor core, basement logistics and inter-block routes without increasing floor area in the conversion solution. These are design results and spatial-capacity estimates, not measurements from actual operation or exercises.

3.7. Discussion

Classifying space by convertibility differs from existing frameworks—WHO 2015 assesses overall safety, FEMA 577 classifies damage and TCVN 4470:2012 zones by specialty—by treating space as a reallocatable resource, enabling questions about the number of convertible units, preparedness and activation times. Reverse checking demonstrates two-way completeness: each Chapter I bottleneck is addressed by at least one solution component, and every model component can be traced to a practical problem. The dissertation also acknowledges operational-management critiques (HICS and EOC): spatial organization and command capacity are enabling conditions for one another, not substitutes; spatial organization is a prerequisite that must be resolved first so operational capacity can function.

Module M's three simultaneous conditions—area ≥36 m², square shape and sides matching the structural grid—resolve a common hospital-design conflict: standards specify individual room areas without relating them to structural spans, forcing architects to solve each room separately. M aligns functional and structural grids from the outset while adjusting to each building. The six mechanisms differ from international flexible-design frameworks by defining goal-directed transformations from routine space to response configurations, rather than classifying general flexibility attributes. Five relationships P1–P5, especially P5 as a conflict-resolution rule, establish that system safety takes priority when routine operational convenience conflicts with response safety.

Research limitations: the theoretical framework addresses PGH-RFs with at least 500 beds. The three selected disaster situations—mass casualties, epidemics and infrastructure disruption—cover most practice but exclude chemical and radiological disasters requiring specialized decontamination. In renovated hospitals with irregular grids and fully utilized land, the model shifts from a design tool to a diagnostic tool identifying missing architectural conditions. The dissertation distinguishes transferable principles—space classification, spatial relationships and progressive activation—from context-dependent parameters, including structural-span ranges, regional disaster intensity and thresholds in current standards, which require adjustment elsewhere.

Regarding operational and investment feasibility (Section 3.7.4), the dissertation distinguishes preparedness costs integrated into routine works from costs of providing infrastructure after an event. Receiving surfaces, connections and independent access must be identified in phased investment plans. The model defines spatial conditions; mobilization also depends on command, delegated authority, training and reallocation of routine activities. Four activation levels connect architectural configurations with operating decisions. Future research should broaden surveys, test multiple hospitals, integrate BIM, simulation and exercises, and assess economic efficiency and inter-hospital coordination.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The dissertation develops an architectural spatial organization framework for provincial general hospitals with regional functions to meet disaster response requirements under Vietnamese conditions. All three research objectives are addressed, yielding three main groups of results.

First, corresponding to Objective 1, it establishes viewpoints and spatial organization principles underpinning hospital design for two operating states. It proposes classification by two core criteria—service specialization and functional convertibility—forming three space groups, seven response functional spaces and five relationships P1–P5. Response space is thereby identified as an internal hospital organizational system rather than a disconnected addition, shifting from buildings designed for ordinary activities to buildings capable of adapting under overload.

Second, corresponding to Objective 2, it establishes basic module M as a unified organizational unit for all three groups, from indoor space to outdoor yards, and proposes six flexibility mechanisms for converting routine space into response configurations and restoring it afterwards. This connects the established principles with their concrete implementation in architectural design.

Third, corresponding to Objective 3, it proposes site-planning solutions for Vietnam's three common types—dispersed, mixed and consolidated high-rise—develops detailed solutions for three groups and seven response functions, and establishes progressive activation across four situation levels. The solutions translate disaster-response requirements into controllable design decisions on location, linkage, conversion and expansion, connecting static design with dynamic operation.

Classification by convertibility complements medical functional zoning, identifying each space's response role and capacity. Outdoor spaces are integrated with defined tasks and service conditions. Experimental results illustrate applicability; capacity gains and activation times require further validation through simulation, exercises and actual operation.

Together, these results form a continuous logical sequence from viewpoints and principles to spatial classification, the basic module and flexibility mechanisms, then to organizational solutions and activation. The dissertation both develops hospital-design theory for disasters and narrows the gap between broadly directional international principles and the specific spatial requirements of Vietnamese PGH-RFs.

RECOMMENDATIONS

First, in design, disaster-response requirements should enter PGH-RF design briefs from project preparation. Basic-design documentation should treat identification of grid M, provision of connections for neutral convertible spaces and receiving surfaces for field deployment as mandatory components, rather than later additions.

Second, the next revision of TCVN 4470:2012 should add six areas: (1) disaster response as a mandatory design objective for hospitals with regional functions; (2) classification by service specialization and functional convertibility; (3) sectional interruption points on corridors and alternative vertical circulation; (4) expandable reserve services, including essential-power sectionalization, reserve medical-gas connections and independently operated ventilation sections; (5) formal recognition of reserve land and outdoor field-deployment space; and (6) a technical appendix specifying minimum service thresholds for each clinical response function.

Third, in sectoral management, the Ministry of Health and Ministry of Construction should jointly develop a tool for assessing spatial readiness in existing hospitals to prioritize renovation and phased investment. Assessment should connect architectural conditions with staffing, equipment, management arrangements and essential-service continuity.

Fourth, in education, healthcare-building design courses should include space capable of state transition, emphasizing scenario analysis, spatial-resource identification, linkage organization and assessment of new construction and renovation schemes. Fifth, future research should extend surveys and experiments to hospitals of different sizes, campus types and structural conditions; combine BIM, simulation and exercises to assess mobilization capacity, conversion times and effects on routine operation; and examine economic efficiency, inter-hospital coordination and situations requiring specialized response spaces.

Implementation requires coordination of architectural solutions, activation procedures, resource organization and investment planning. For existing hospitals, the model also identifies missing conditions and renovation priorities; for new construction, conversion conditions should be integrated from the design-brief stage.

AUTHOR'S SCIENTIFIC PUBLICATIONS RELATED TO THE DISSERTATION

1. Vuong Ngoc Hai (2025), *Economic efficiency of reserve-space organization in provincial hospitals: Cost–benefit analysis and return on investment*, Economy and Forecast Review, eISSN 2734-9365, published 23 June 2025.
2. Vuong Ngoc Hai (2025), *Effects of disaster-context factors on spatial organization in provincial general hospitals in Vietnam, Journal of Science, Architecture & Construction, ISSN 1859-350X, No. 62, October 2025, pp. 10–12, 26.*
3. Vuong Ngoc Hai (2025), *Integrating disaster-response capabilities into refuge spaces in high-rise provincial general hospitals in Vietnam: an architectural approach*, Journal of Science, Architecture & Construction (English Version), ISSN 1859-350X, No. 63, December 2025, pp. 9–13, 18.
4. Vuong Ngoc Hai (2026), *Relationships between disasters, medical emergencies and reserve-space organization in provincial general hospitals, Vietnam Journal of Construction – Ministry of Construction, ISSN 2734-9888, February 2026, pp. 186–189.*