INTEGRATION OF CONSTRUCTION TECHNIQUES FOR SPECIAL ISOLATION WARDS OF HOSPITAL BUILDINGS

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ABSTRACT : The severe acute respiratory syndrome –SARS virus spreaded rapidly in Asia in 2003 caused a lethal and serious epidemic. Establishing special isolation wards of high-level epidemic prevention has becomes one of the most important tasks of epidemic prevention. Taking the biosafety level of US CDC biology laboratory as an example, the laboratory of the highest level, BL4 and that of the second high level, BL3 are only allowed to handle and research this kind of highly dangerous viruses safely, to ensure the safety of researchers and the surrounding environment.This research aims to study the functions and the design requirements of "special isolation wards", which is equivalent to the high-level biotechnology laboratory, and have an integrated discussion about the design and construction techniques of this kind of wards, expecting to provide a reference for constructing special isolation wards and maintaining operation safely in Taiwan.

Key words: Special Isolation Wards, Construction Techniques, Interface Integration,Biosafety Level 3

1. INTRODUCTION

1.1 Motivation

In the twenty-first century, human beings are encountering the threats of highly risky viral infection. To establish high-level special isolation wards hence has become one of important tasks in epidemic prevention. This type of wards is aimed to hospitalize patients who are infected with highly dangerous viruses. It should consider the prevention of cross-infection and the safety of medical personnel. Patients are quarantined within a designated area to arrest the spread of infectious viruses and protect the safety of the people. At the mean time, it provides a safe and comfortable environment to patients for medical treatment and care. This type of wards involve complicated ward design and construction interface, and the integration of core techniques thus becomes an important factor to construction quality and period of time.

1.2 Objectives

This research will analyze and discuss the following aspects based on experts' interview, literature review and case studies:

1. To discuss the functions and special requirements of "BL3(Biosafety Level 3) special isolation wards".

2. To set up the requirements and schema of construction, interior decoration, mechanical and electrical design, and medical facilities of this type of wards.

3. To clarify interfacial problems at each phase of this type of wards.

Therefore, this research would establish an integration mechanism of core techniques used in the establishment of "BL3 special isolation wards", providing a reference of clear operational procedures to construct this type of building.

1.3 Research Scope and Limits

BL3 special isolation wards in this research indicate "negative pressure" isolation wards. To set up an integration mechanism of core techniques, this research principally focuses on "new construction projects" of hospitals.

1.4 Methods and Procedures

After confirming research objectives and scope, literature review, experts' interview and case studies were carried out to find out the problems and important aspects about ward schematization and design to figure out the interfacial problems of each system which were subsequently analyzed to set up design and integration methods and tools to establish the hospital building , "BL3 special isolation wards". According to the aforementioned research methods, a flow chart depicting the research methods is shown in Figure1.

2. LITERATURE REVIEW, EXPERTS' INTERVIEW AND CASE STUDIES

The research reviewed literatures and analyzed the unique requirements and design essentials of high-level biology laboratory and special isolation wards; examined various completed or on-going construction cases; interviewed experts to clarify problems and analyze requirement essentials of each system; and finally based on collected information concluded the outline about the core techniques to establishing BL3 special isolation wards.

2.1 Literature Review

After analyzing and reviewing, sub-titles about the research are as follows:

1. BL3 Biology Laboratory.

2. Negative Pressure Special Isolation Wards.

3. Mechanical and Electrical Facilities and Equipments of Hospital and Laboratory.

4. System Interfacial Integration of Architecture, Interior Decoration, and Mechanical/Electrical and Medical Equipments.

2.2 Experts' Interview

This research collected knowledge and experience from

experts about the design and construction experiences of constructing special isolation wards , and concluded the main points and problems to be solved about establishing this type of newly built architecture. The research concluded the main points and problems to be solved about constructing this type of buildings. Finally it was expected to act as an important reference for the requirements to design special isolation wards and the integration of construction techniques in this research.Experts were interviewed with the following topics:

1. Functions and special requirements of BL3 biology laboratory and negative pressure special isolation wards.

2. Requirements and standards of related architectures, interior decoration, and mechanical and electrical design.

3. Requirements, varieties, and locations of related medical facilities.

4. Standard operational procedures for medical personnel, patients, articles and so on in the use of special isolation wards.

5. Interfacial problems of each system and the important points of carrying out integration.

Since the design of isolation wards must be done in coordination with architecture, interior decoration, mechanical and electrical systems, and medical facilities, the interface is complicated and numerous so the integration of core techniques becomes an essential in order to increase the construction quality.

2.3 Collection and Analysis

According the analyses described previously, the research results were collected and concluded as follows:

The design requirements and standards of "BL3 biology laboratory", in accordance with the regulations of Center for Disease Control, the Department of Health, Executive Yuan, Taiwan R.O.C [1] are described under the following main titles :

1. Laboratory location.

2. Physical structural characteristics of partitions.

3. Air processing system.

4. Requirements for biological safety cabinets.

5. Laboratory's requirements for all HEPA filters.

6. Cleaning, sterilizing, and waste disposal systems.

7. Personal hygiene and safety facilities.

8. Laboratory facilities.

9. Emergency measures and laboratory monitoring regulations.

10. Performance validation and tests.

11. Laboratory testing items.

The above main items clearly state the important points while designing BL3 biology laboratory. The standards and main points of designing "BL3 special isolation wards" also base on that of BL3 biology laboratory including space planning, movement route planning, air conditioning and environment controlling systems, waste disposal and so on. The aforementioned is described in details as follows, according to the regulations of Center for Disease Control, the Department of Health, Executive Yuan, Taiwan R.O.C about "Standards of constructing special isolation wards" [2] [4]：

1. Standards of Isolation Facilities

(1) Independent building or isolated area.

(2) Each hospital bed should have an independent special negative-pressure control tent.

(3) Negative-pressure difference should reach 2.5mm H_2O and ventilation system should ventilate for 6~12 times per hour.

(4) Air conditioning system, independent installations, and exhaust pipes should be installed with HEPA filters , and should be maintained regularly. The exhaust outlets should be installed higher than the air recirculation zone of buildings.

(5) HEPA are defined as capable to filter out 99.97% particles, whose diameter is larger than 0.3μm long.

(6) Each ward should be equipped with a bath room for its own use. Pedal or automatic-sensor tap switch is used and the bath room has an independent discharging system. The produced waste water cannot be discharged until it is sterilized.

(7) A clearly designated waste room and related medical waste sterilizing equipments should be installed.

2. Safety Devices:

(1) High-temperature and high-pressure steaming autoclave.

(2) Fumigation implement.

(3) Biosafety level 3 cabinet.

(4) Storage, sterilizing and waste delivery devices.

(5) Emergency power supply system.

(6) UV light lamp.

3. Operational Requirements

(1) Each personnel should wear a completely aerated positive-pressure protection cloth (mask and gloves) or mask (with a breathing protection device) and an isolating cloth.

4. Waste Disposal

(1) Medical waste water must be sterilized chemically and disposed in accordance with regulations of water pollution prevention and other related regulations.

(2) Medical waste must be autoclaved and disposed in accordance with waste disposal and related regulations.

3. UNIQUE REQUIREMENTS OF BL3 SPECIAL ISOLATION WARDS

To set up the design outline of BL3 special isolation wards, apart from referring to the standards, framework and content of BL3 biology laboratory, due to the differences in application type, dealing objects, movement routs, room size and equipments, one should also adjust according to these differences. After integrating the analyses of literature review, experts' interview and case studies, a complete standard for the design of BL3 special isolation wards can be established.

While investigating the design requirements, in addition to study architectural hardware and facilities, medical personnel's operational regulations and standard operational procedures (S.O.P) must be incorporated to complete a scheme truly suitable to users. Thereby, this research successively studied the characteristics and requirements of BL3 special isolation wards, operational procedures of medical personnel working in the aforementioned wards, and the core techniques of BL3 special isolation wards, expecting to set up an appropriate technical integration of BL3 special isolation wards.

The so called integration of core techniques indicates the integration of each system required in the design stages,

standard operational procedures in the future use, and construction interfaces of architectural hardware in the construction stage, to avoid that the completed architecture does not meet the actual application. This includes clarification of interfacial problems, investigation on the methods of interface integration, and interface integration in the design and construction stages.

3.1 Characteristics and Requirements of BL3 Special Isolation Wards

BL3 special isolation wards are featured to quarantine patients in a designated space, to prevent the spread of infectious viruses and provide professional medical treatment. Hence, when a highly infectious patient is hospitalized, special isolation wards become a highly hazardous area. To prevent from the threat of infection outwards, the air conditioning pressure inside the wards must be negative. All personnel who enter the wards must be seriously monitored that monitoring systems are installed at the corridor outside the wards. The architecture should take into account the prevention of explosion and earthquake, and the exterior glass must be bullet-resisting glass. While carefully monitoring personnel entering the wards, any instruments and articles which they carry should be clearly and carefully recorded. A characteristic of negative-pressure isolation wards is that the atmospheric pressure inside the wards is constantly lower than that outside the wards, allowing the air outside flow into the wards through building's slight opening in a unidirectional way, due to the difference of air pressure. So the air inside the wards is isolated by the unidirectional way.

3.1.1 Design Requirements of Architecture and Interior Decoration of BL3 Special Isolation Wards

1. Space Planning

(1) Space division – quarantine area, non-quarantine area, buffer zone, and mechanical and electrical space etc.

(2) Confirmation of each movement direction (classification is dependent on different users such as medical personnel, patients, supplies, waste, maintenance workers, and so on).

2. Planning of facility systems and interior decoration

(1) Confirming the changes of pressure difference and air flowing direction in each room.

(2) Sockets, switches, and special lamps should possess airtight and flame-proof functions.

(3) Ceiling, wall and floor must be airtight and the materials should be resisting to washing, decontamination, and alkaline and acid.

(4) Door should be installed with inter-locking airtight devices, and the crack between a door and its frame should have release damper design to adjust air pressure.

(5) The ward should have air-locked double doors.

(6) Partitioning wall, exterior windows and interior glass windows must be airtight.

(7) Ante rooms such as changing clothes, Lysol shower , disinfecting , shoe storage, and protective clothes should be established and separated from each other with airtight doors.

(8) Autoclaving room is installed with double doors that an incomplete sterilization can cause the door unable to be opened.

(9) UV light sterilizing lamp, and medical implements are installed.

(10) Articles that cannot be sterilized in an autoclave can alternatively be sterilized in a soaking trough and fumigation pot.

(11) Hospital bed location and arrangement.

(12) The variety and location of medical equipments.

3.1.2 Design Requirements of Mechanical and Electrical System of BL3 Special Isolation Wards

While designing mechanical and electrical systems of BL3 special isolation wards, important points which should draw our attention are as follows:

1. Safety and hygiene (include outdoor surrounding environment of the wards and laboratories) must be in accordance with corresponding regulations about safety and hygiene.

2. Conditions of environmental controlling system: suitable temperature, humidity, air flow distribution, air pressure difference control, air flow speed, air quality, noise, vibration isolation, prevention of RFI(Radio Frequency Interference) / EMI(Electromagnetic Interference), and Electrostatic Discharge (ESD) etc.

3. Pipes and equipments of each system should be independent that cannot be shared with other wards.

4. Mechanical /Electrical equipments specifically for the wards are installed on upper floor of the wards. Except the essential perforation of conduits, the mechanical room must be completely isolated from the wards, and convenient for the maintenance workers to get in.

Since air conditioning system is an essential core technique, mechanical and electrical systems are divided to two sections for discussion : air conditioning systems and M / E systems:

1. Air Conditioning System

(1) The air conditioning system is only for the use in the wards that must not be recycled. The design to process waste air recirculation is incorporated.

(2) Negative pressure system.

(3) Air conditioning system of 100% completely outside air for ventilation.

(4) Inlet and outlet air must pass through HEPA filters (with efficiency to filter out 99.97% particles of 0.3μM diameter with end pressure loss 1" H_2O).

(5) Indoor pressure indicator should be installed at the entry of each room to ensure that the laboratory is maintained in a safe status.

(6) Air inlet and air outlet both have backup and emergency power supply. The branch pipes are installed with airtight closing valves for isolating sterilization.

(7) Exhaust air should be filtered through two layers of HEPA successively.

(8) HEPA filter box should be BAG-IN and BAG-OUT that the exhaust should go through the filter box and be sterilized by UV light.

(9) Location Planning of indoor air inlet and outlet.

(10) Planning of rooftop outdoor exhaust outlet.

(11) Planning of air flow circulation.

(12) Air outlet is located near to patients' head allowing contaminants can be drawn out easily.

(13) Pressure monitoring equipments are installed to ensure the maintenance of negative pressure.

(14) Exhaust design has heat-recovery devices to save energy.

2. M / E Systems

Other than air conditioning systems, the M / E systems and medical equipments that this type of wards should be installed are listed below:

(1) Water supply system: general water supply, water supply systems for medical purposes and chemical solution preparation.

(2) Power supply system: general power supply, special power supply , emergency lighting and power supply, uninterruptiable power supply (UPS), and power supply for medical equipments.

(3) Fire protection system: fire-fighting systems, automatic fire extinguishing systems, fire alarm broadcasting equipments, and emergency broadcasting equipments.

(4) Low-voltage for communication system: security control system, intercom system, telephone piping system, communication cable system, central monitoring facilities, CCTV security monitoring facilities.

(5) Waste disposal system, waste water discharge system.

(6) Medical Facilities:

- Special gas facility systems: medical and experimental use of essential special gas, air, oxygen, nitrogen, vacuum, carbon dioxide and so on.
- Sterilizing system: lysol shower (chemical shower), fumigation devices.
- Facilities: Biosafety Cabinet, high-pressure autoclave, UV light sterilizing lamp, delivery cabinet.

Since this type of wards requires special mechanical and electrical systems, numerous pipes and frequent maintenance and repair, the space for pipes on top of wards require an independent floor that should be separated from wards. The space should be sufficient for maintenance and repair, and the perforation of pipes to the top floor structure of wards must be kept airtight and safe.

3.2 Standard Operational Procedures for Personnel and Articles in BL3 Special Isolation Wards

Standard operational procedures of BL3 negative -pressure isolation wards should be established according to medical personnel, carrying patients, medical waste disposal, supplies delivery, personnel of maintenance and repair and so on. According to the standard operational procedures (S.O.P), one can schematize the relationship between space and movement routes, and clarify conditions for each system and equipment to design wards that completely comply with requirements and criteria.

4. INTEGRATION OF CORE TECHNIQUES OF BL3 SPECIAL ISOLATION WARDS

The so called integration of core techniques is to integrate each system to construct architectural hardware at the stage of design, the standard operational procedures (S.O.P) in the future use, and the interfacial problems of each system of architectural hardware during the construction stage to avoid the completed architecture does not tally with the actual situation of use. Systems of architectural hardware include architecture and interior decoration system , mechanical / electrical systems, and medical facility systems. Architecture and interior decoration systems involve the structure of architecture, schematization of plan and movement routes, interior design and application of interior decoration materials. Mechanical and electrical systems include five major systems such as water supply and drainage, electricity, air conditioning, fire protection, and low-voltage for communication as for general architectures in addition to waste disposal systems. Medical equipment systems comprise medical gas (air, oxygen, nitrogen, and vacuum etc.) , sterilizing systems, biological safety cabinet, high-pressure autoclave, delivery cabinet, Lysol shower (chemical shower), and fumigation equipments etc. designed in coordination with BL3 special isolation wards. The integration of core techniques is illustrated in Figure 2.

As shown in Figure 2, core techniques are divided to two sections. One is architectural hardware, and the other is software that is standard operational procedures for personnel and articles. The integration of these two provides the reference to establish the requirements to designing special isolation wards. The core techniques are integrated as that intends to connect all problems occurred at each interface while designing and constructing hardware and software. That is to ensure the wards after construction is completed can be operated properly to meet the requirements, and obtain the highest benefits.

Interfacial integration [6] can be divided to design and construction two stages. The former stage can be further divided to design integration and SEM/CSD(Structural Electrical and Mechanical / Combined Service Drawing) integration, and the later is the integration of construction logical sequence. SEM/CSD integration is the first interfacial integration that mainly integrates architectural structures and the two-dimensional facilities and pipes of mechanical and electrical systems, and solves the three-dimensional conflicts and piping arrangement. The integration of construction stage is the second interfacial integration that is conducted based on the sequencing principles clarified by “Construction Stage Working Interfacial Chart” to obtain the sequencing of working items in each system , and avoid the confusion of predecessor and successor tasks.

5. CONCLUSION AND SUGGESTIONS

This research based on experts’ interview, literature review, and case studies clarified the functional requirements and designing main points of BL3 special isolation wards, and investigated the integration of each system. The research furthermore clarified the possibly upcoming interfacial problems about architectural design, interior decoration, mechanical and electricity systems, air conditioning, fire control and medical equipments during the stages of design and construction to solve complicated problems existed at each interface and avoid the problems, which are likely to influence the operational quality of special isolation wards. This type of wards was therefore secured to stably achieve the expected purposes, and provide an important reference for the design, construction, operation and efficient management of hospital special isolation wards.

This research completed the mechanism to integrating core techniques and functional requirements for establishing

"BL3 special isolation wards". The "software" (user's functional requirements and operational procedures) and "constructing hardware" (the techniques of each design and construction system) were compared interactively to set up the framework of technique integration to clarify and integrate each interfacial problem and appropriate technical regulations of BL3 special isolation wards.

Suggestions for future researches:

Due to the limit of research scope, to extend the effectiveness and reproduction of this research scope, there are three suggestions for future researches:

1. Post-Occupation Evaluation of BL3 laboratory that is currently operated.

2. Validation and Qualification plan of BL3 special isolation wards.

3. Investigation on the document management of pratical validation .

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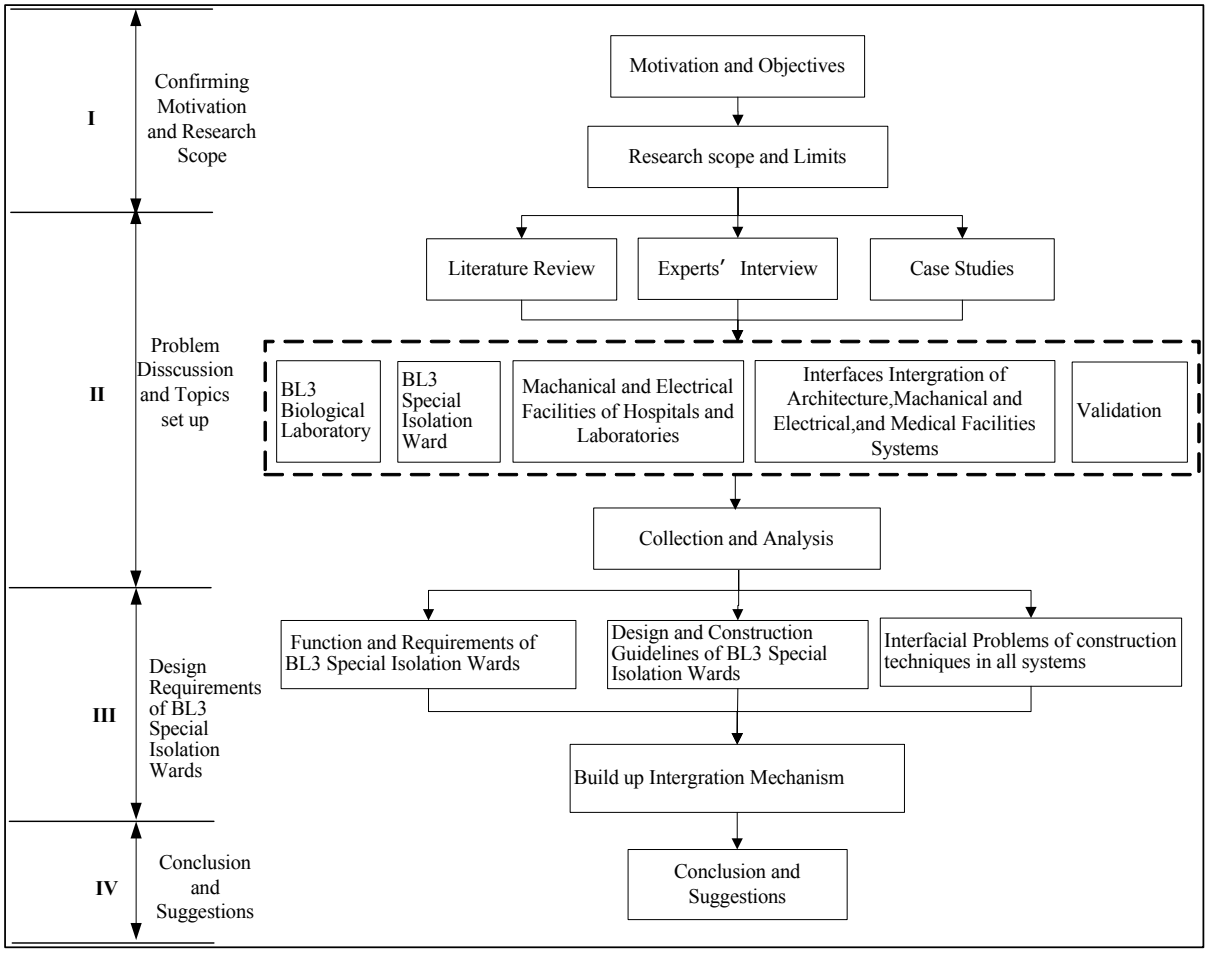

Figure 1. Research procedures

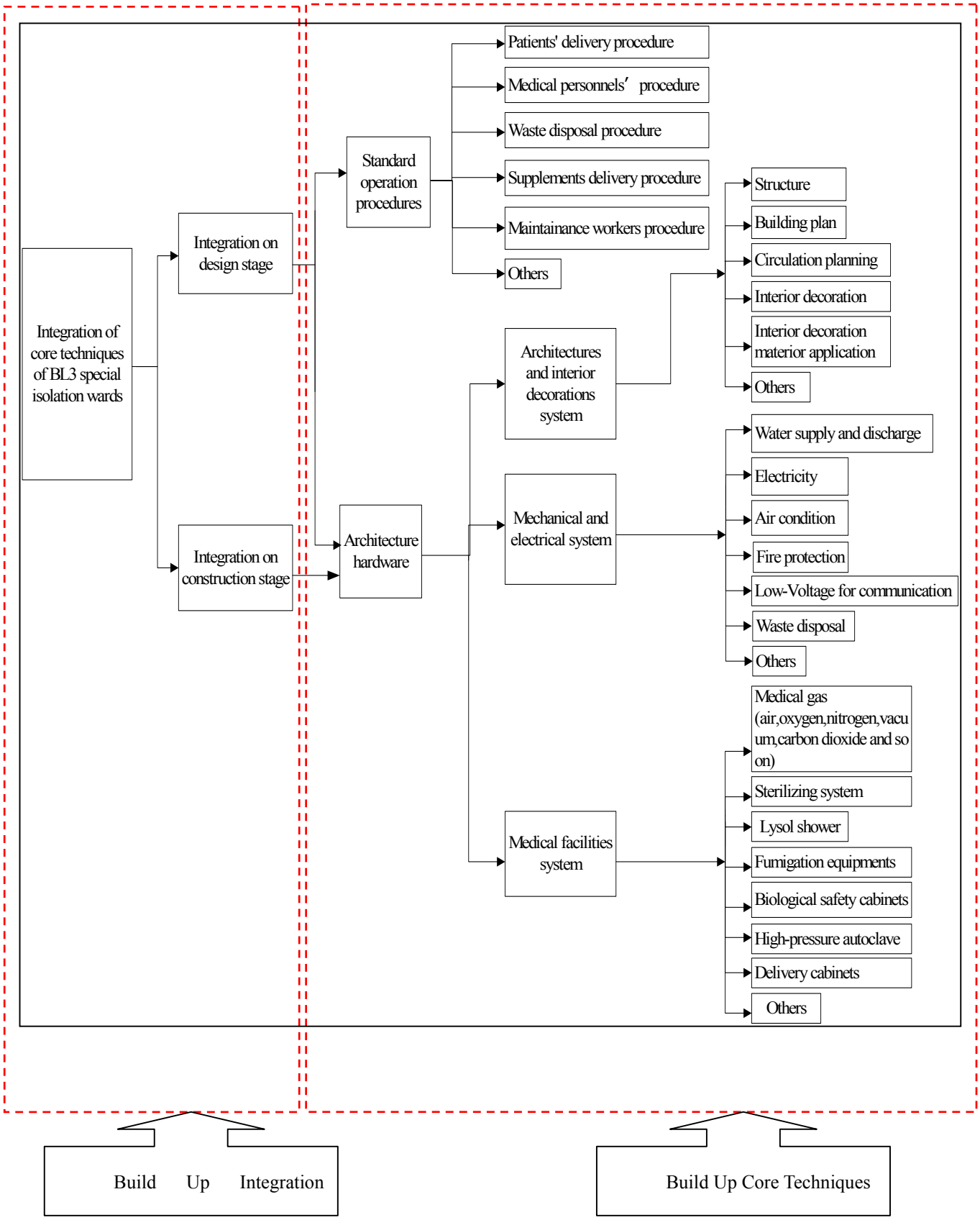

Figure 2. Framework of core techniques integration