A Study on Establishing the Optimal Planning and Design Criteria for the Intensive Care Unit of Hospital in Taiwan

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Abstract

ICU space design is related to the quality of medical care and the integration of multidisciplinary profession. However, there are still no domestic planning and design guidelines in Taiwan currently. The Modified Delphi Method is a research methodology based on the expert's independent judgement, the structured information communication and the systematic judgement process. To promote the quality of decision-making, it is supplemented by scientific statistical methods. As the basis for the first round of the Delphi Questionnaire, this study has developed the first questionnaire based on literatures that proposes 31 important score items and 14 selective items for planning and design elements of ICU. Further we select 20 experts to participate in this Delphi research whom including hospital decision-makers, ICU attending physicians and their teams, and ICU ward nursing heads. Finally, the study statistics use the Quartile as a consensus function to analyze whether the expert opinions converges.

Including the 45 items, the analysis results show that the overall consent convergence rate of experts was 95.56% and 43 items reach agreement in three groups by the Kruskal-Wallis test. The more strict consensus standards are adopted among the 43 items for selection ICU design criteria, this study defined Q.D.$\leqq$0.60 is “high consensus”, Q1$\geqq$4, Q3=5 is “very important”, and P$\geqq$0.75 is “consensus standard” for select items. It summarizes the 25 key points of its optimal ICU design guidelines, and those according to strengthening infection control, improving care efficiency and appropriate environmental design.

Keywords: Hospital Architecture, ICU Planning and Design, Modified Delphi Method

Introduction

The definition and development of Critical Care Medicine is an important milestone in the modern medicine. It originated from Armenian War in 1850. The pioneer of modern nursing, Ms. Nightingale, believes that the injured soldier should be placed in a nearby nursing station for immediate and adequate care. In 1923, Dr. Walter Dandy set up a post-brain surgery care unit at John Hopkins Hospital in the United States, which was directly cared for by the neurosurgical team to form the prototype of a modern intensive care unit. In the 1950s, the University of Southern California officially defined the critical care. That is the care required active life monitoring and additional support for patients who were life-threatening due to illness or trauma. In order to perform life monitoring and support treatment immediately and effectively, the hospital building evolution is the establishment of a special site in the hospital, the so-called Intensive Care Unit (ICU). (G. Ristagno and M. H. Weil, 2009)

With the advancement of intensive medicine, the hospital's ICU is not only a site or a unit in the hospital, but also an advancement in medical specialties and an important issue for hospital operations. The success of ICU planning depends on the consistent design philosophy and clinical goals of the intensive care team and hospital decision makers. Neil A. Halpern (2014) argues that the ICU plan has four initial core principles: First, the ICU is a semi-autonomous small hospital. Second, its design is an complex and time-consuming process needed multidisciplinary integration. Third, the success of the design depends on the function Innovation, the space appropriation, the equipment management and cost constraints balance. Final, the safety of patients, medical staffs, families and the security of instruments and supplies must be considered into the design of the treatment environment.

This study intends to use the Modified Delphi Method to obtain the final professional consensus on this complex issue. It should reduce the repeated communication and the revision in the design process between the medical care team and the design planning team. In additional, the method assemble the literature also can explore the trends in ICU planning in the world. Through qualitative and quantity research, structured experts information circulation and systematic experts judgment process, this methodology expect to obtain the guidelines about the ICU design criteria in Taiwan. The research results can be used as an important reference and guideline in the concept and practice for Taiwan hospital ICU design.

2. Material

2.1 Modified Delphi Method

Delphi Method originated from Rand Corporation in 1948. It under the auspices of the US Air Force named "Project Delphi." For more than 60 years, it has evolved into a research method that draws on the advantages of both questionnaires and conference discussions. There are several main basic principles of the Delphi Law: (1) "anonymity group decision making": participants strictly abide by the principle of anonymity; (2) "control feedback principle": the questionnaire is repeated after each round of questionnaires is collected. The results of the survey must be returned to the panelists and as a revised reference for the next round. (3) "Expert Consensus": Experts can adhere to or modify their opinions according to the last feedback trends. The researchers use statistical methods to judge whether expert opinions converge and the project will proceed to be consistent until the research reach consensus.

Therefore, the research execution of the Delphi Method is different from the other general questionnaire survey methods. The main points are: (1) The object selected by Delphi Method is an expert, so it is a small sample survey. The background of the expert should be closely related to the professionalism, decision-making, forward-looking and predictive nature of the research topic. The number of experts is acceptable to 10 to 50 people (Jones and Twiss, 1978), but the experts who continue to participate need at least 10 people to reduce the error between members. (Reza and Vassilis, 1988) (2) The test procedure conducted by Delphi Method is repeated for several rounds with three rounds or more until the expert opinions converges. (3) To establish a "consensus function" for the expert opinions, it is necessary to set the standard. It mainly includes: the consistency test of the experts on individual items, the consistency of the experts on the overall questionnaire, and the consistency of the

different groups of experts on each question item.

The first round is an open questionnaire in the traditional Delphi method. This questionnaire is designed by the researcher who assembled the expert conclusions through their main axis of the research problem description. However, in this first stage, the open opinions summarized and edited were complicated and the questionnaire recovery rate was often lower and lower. Therefore, the Modified Delphi method develop to use the literature collection to replace the expert opinions description for the first stage questionnaire design. In the second round, the post-recycling opinion was analyzed. The contents were also released, added and deleted again to generate a third round of questionnaire. This is repeated until the expert opinion converges.

This study was carried out using the Modified Delphi method. After assembling the references and literature about the design elements for ICU, this study find that there are four key points for ICU design. These focus are "hospital decision-making perspectives" (including setting address, area size, construction cost, unit size and so on),"infection control views" (including how to reduce the hospital infection rate through space design, air pressure of the ward, HAVC system and so on), "clinical care perspective"(including the design of the nursing station, the planning of the service support area, the ward working line and so on) and"user perspective"(taking into account ergonomics, the needs of the staff considerations in the work area as well as the social support for patient's family).

The ICU planning can be roughly divided into two levels. The first level is the overall planning trend of the ward and the second level is the design principle of the ward space. The overall planning trend of the ward is mainly at the decision-making level, including ward attributes, ward size, regional configuration, infection control strategy, cost considerations and so on. The spatial design content includes ward design, support area design and family area design and so on. Incorporating foreign researches, winning design cases and their proposed conclusions, this study developed the main content of the first round questionnaire. Through the selection of experts, the research will proceed expert opinion surveys and statistical analysis of more than two rounds.

2.2 Experts selection for Modified Delphi Method

Valentin and Ferdinande (2011) believe that the participators for planning of ICU should include hospital managers and superintendents, intensive care unit director, attending physician and nursing chief, infection controller, architect and medical engineer. Some documents believe that the design of the ICU should involve family members. However, because the family members of the patients did not understand the professional medical care process, so it was excluded from this study for the experts group.

According to Valentin and Ferdinande's recommendations, this study selected 20 senior clinical directors to participate in this study who are from three hospital levels according with the evaluation system of Taiwan Health and Welfare Ministry. Among the 20 experts, there are 6 hospital decision-makers, 6 senior attending physicians, infection controllers, senior hospital construction engineering supervisors and 8 ICU nursing supervisors. See Table 1 for the experts details of their hospital level, position, clinical work experience, and ICU qualifications.

Table 1 the Experts List and their Qualifications

Category	Number	Current Position	Work experience	ICU experience
Hospital Decision Maker	A1	Medical Center Deputy Superintendent	＞30 years	10 years
	A2	Region Hospital Deputy Superintendent	＞30 years	25 years
	A3	Community Hospital Deputy Superintendent	＞30 years	(Orthopedist)
	A4	Region Hospital Teaching Superintendent	＞30 years	4 years
	A5	Medical Center Nursing Superintendent	＞30 years	16 years
	A6	Senior Hospital Design Planning Supervisor	＞30 years	(Architect)

Medical Staff and the Team in ICU	B1	Region Hospital ICU Doctor	＞20 years	15 years
	B2	Medical Center ICU Doctor	＞15 years	12 years
	B3	Community Hospital ICU Director (Doctor)	＞15 years	10 years
	B4	Medical Center ICU Doctor	＞15 years	12 years
	B5	Community Hospital Director (Doctor)	＞15 years	3 years
	B6	Community Hospital infection control staff	＞20 years	(Infection controller)
Nursing Head in ICU	C1	Medical Center Nursing Supervisor	＞20 years	20 years
	C2	Community Hospital ICU Nursing Head	＞20 years	15 years
	C3	Community Hospital ICU Nursing Head	＞20 years	7 years
	C4	Medical Center Surgical ICU Nursing Head	＞20 years	20 years
	C5	Medical Center Nurology ICU Nursing Head	＞20 years	22 years
	C6	Medical Center Medicine ICU Nursing Head	＞20 years	14 years
	C7	Medical Center Medicine ICU Nursing Head	＞20 years	19 years
	C8	Medical Center Medicine ICU Nursing Head	＞20 years	7 years

2.3 Statistical method for consensus function selection

In the Delphi research, there is still no clearly defined consistency standard about the “consensus function”. We can select mode, median or quartile as the consensus function depending on the needs and the purpose of individual research. (Anne et al, 1994) Therefore, in this study defines the consensus function for the "selective items" that are not sorted with more than 51% of experts agreement.(McKenng , 1994) Further, if more than 75% experts of the same opinion，this study is considered to reach a “consensus standard”.(Murry and Hommons,1993).

In the “importance score items” that are sorted, this study uses Quartile to eliminate the influence of extreme values as the consensus function. This study analysis the first quartile (First Quartile; Q1 indicates) and the third quartile (Third Quartile; Q3 indicates) for each item. If Q1≧3, Q3=4, it is defined that this item is “important”. If Q1≧4, Q3=5, it means “this item is very important” in this study.(Huang Youjie, Luo Shaolin, 2001)

Further, this study uses quartile deviation(Quartile Deviation; Q.D. indicates) as the basis for verification on the overall experts opinion. The calculation formula of Q.D. is one-half the difference between the Q1 and Q3. The smaller the Q.D. value, the smaller the difference in each one and the higher degree of consensus in Delphi research. This study use Likert Scale and analysis the quartile for the consensus function value. If Q.D.≦0.6, it means that the expert opinion reaches “high consensus”; While 0.6<Q.D.≦1.0 means “moderate consensus”; Q.D.>1.0 means “not reached consensus”. (Yang Yizhen, 1999) Because the Delphi research conducted many times, experts with shallower opinions would change their opinions. It will get the median finally which is close to the "true value" of the overall opinion (Li Guozhong, 1999)

Finally, this study will end the survey just when more than 80% of the questionnaire items reach QD≦0.6 as the overall consistency and opinion convergence (Mead, 1992) In addition, in order to understand the similarities and differences between the three groups of experts opinion about ICU design planning, this study also carried out the K-W test (Kruskal-Wallis test) for the consistence test for "hospital decision-making executives", "ICU attending physicians and their teams" and "ICU ward nurse supervisors".

Results

3.1 Questionnaire recovery results

The first round of the questionnaire was completed from March 20 to April 30, 2017. Twenty questionnaires were all collected, but two were partially missing. As a analysis result of the overall 43 items, 4 "selective items" and 6 "importance score items" did not converge; the overall consistency ratio was 79.07% (<80%). It didn't reach the convergence. Therefore, the study feedback the results to the 20 experts by illustrating the P value and Q.D. value in the first round questionnaire items as the second round reference, and the second round of questionnaires was issued on May 10, 2017.

The second round questionnaire also summarize the open opinions of the first round into the second round questionnaire content. Two items are added: "There is a hospice care zone in the vicinity of the ICU" and "There is a CT room in the ICU for avoiding frequent movements just as those multiple trauma patients." After theses increase, the total number of items in the second questionnaire reaches 45.

The second round of the questionnaire was completed from May 10 to June 30, 2017. Eighteen questionnaires were recovered and the recovery rate was 90%. As a result of the overall analysis, only 2 of the 45 items have not reached convergence. These 2 items are "the best area of each bed"($P < 0.5$) and "setting the shower room for man and women separately " (QD=1). The overall opinions convergence ratio is 95.56% which meets Mead's definition of consistency verification standard for more than 80% of the items. The survey is ended and the statistical analysis results of the overall "selective items" are shown in Table 2 an "importance score items" are shown in Table 3.

3.2 Statistical Analysis Results

In the "Selective Item", 13 of the 14 items have reached consensus that these opinions are considered to be a consensus as discussed by McKenng (1994). Further, there are 11 items that more than 75% experts express the same opinion reveal the opinions convergence in the view of Murry and Hommons (1993). See the Table 2 for details. The p values of these 11 items of ICU planning consistency opinions are indicated in bold in the Table.

According to Q.D.$\leqq$0.6 as the expert opinion reached "high consensus" and while Q1$\geqq$4, and Q3=5, it indicates the item meets the definition of "very important", the results of the second round found that 30 of the 31 importance scoring items have reached "high consensus", and 18 of them were met with the definition of "very important". Further chose the average score (μ value)> 4.5 as the "most important consensus", there are five planning content shown respectively: (1) each bed of the life support system should have a warning system linked to the nursing station (μ = 4.9444), (2) the most important factor of the ICU layout is considered the patient care field of vision linked with medical staff care movement line (μ = 4.8889), (3) ICU should design a multi-function room for staff conference, visit discussion, teaching activities and so on. (μ = 4.6667 (4) The Infection Control Hazard Assessment (ICRA) is an important consideration for the ICU's construction or renovation (μ=4.61). (5) The wash sink should be located at the entrance of the ward, or at the end of the bed. (μ=4.5556). The μ value and Q.D. values of these items are indicated in bold in the Table 3.

Table 2 Statistical Results of 14 "Selective Items" in the two rounds of Delphi Research

	ICU design factors-- "Selective Items" in the Delphi questionnaire	1st Round P(Proportion)	2nd Round P(Proportion)
	Part 1--Overall planning trend		
1	You will suggest that construct an ICU is better than renovation.	0.8947	**1.0000**
2	You will suggest that the 'single specialty' ICU is better than 'general' ICU for the quality of medical care.	0.8947	**0.9444**

3	The optimum scale for an unit is 10-19 beds.	0.7368	**1.0000**
4	The ratio of negative pressure bed in an unit is at least 1:10.	**0.3684***	0.7222
5	The optimum layout for an unit is “racetrack”, better than “parallel corridor open”,“cruciform” and ‘radial’.	0.5263	**0.9444**
	Part 2--Space design principle		
【A 】Ward Design			
1	Double compartment for each bed (no door) is the best for the ward.	**0.5***	0.5556
2	For a separate compartment of each bed, the optimal design for the care station should be a "4 bed module".	0.55	**0.7778**
3	The optimum size of each bed is : 9-10㎡, or11~15㎡, or16-20㎡, or 21-25㎡, or over 25㎡ ?	**0.5＜***	**0.5＜***
4	Patient life support systems and medical instrument systems use the cantilevered medical columns preferably instead of power column on the headwall.	0.85	**0.8824**
【B 】Support Service Area Design			
1	The design of the nursing station should be a decentralized style for the higher proximity and efficiency of the nursing care.	0.95	**1.0000**
2	The design of the support service area required by the care team should be the Central Care Station arrange in pair the Observatory	**0.5＜***	**0.8333**
3	The support service space should be dispersed in other appropriate spaces in the ward, taking into account the efficiency of use.	0.65	**0.9444**
【C 】Family Area Design			
1	The family waiting area is recommended to be located outside the ICU (considering family members will interrupt treatment, initiate infection, bring noise, etc.)	0.95	**1.0000**
2	It is not suitable for family areas in the ward to set companion beds, clothing cabinets, tables and chairs, etc.	0.80	**0.8824**

***sign indicates**: the ratio value P is less than 0.51, and the expert opinion does not converge. McKenng (1994)

Table 3 Statistical Results of 31 "Importance Score Items" in the two rounds of Delphi Research

ICU design factors-- "Importance Score Items" in the Delphi questionnaire		1st Round		2nd Round	
		μ	Q.D	μ	Q.D
	Part 1--Overall planning trend				
1	Infection Control Hazard Assessment is important for new ICU construction.	4.95	0	**4.61**	0
2	Cost consideration is important for ICU construction or renovation.	3.70	0.5	3.778	0
3	Patient distribution and disease pattern is important for an ICU whether	4.15	0.125	3.944	0

	construction or renovation.				
4	ICU with a single specialty attribute is safer for ICU patient care.	4.10	0.5	4.444	0.5
5	ICU with a single specialty attribute is more efficient for management	4.10	0.5	4.389	0.5
6	Patient care vision and medical staff working line are the important considerations for the overall ICU layout.	4.85	0	**4.889**	0
	Part 2--Space design principle				
【A 】Ward Design					
1	The bedside of the bed should be at least 60 cm away from the wall.	4.10	0.5	4.167	0.5
2	The end of the bed should be at least 150 cm away from the wall, 150 cm on the rotating side and 120 cm on the non-rotating side.	4.40	0.5	4.389	0.5
3	The cantilevered medical power columns is more proximity and efficiency than the power column on the headwall.	3.95	0	4.278	0.5
4	Cantilever medical column has architectural considerations.	4.30	0.5	4.333	0.5
5	Each bed area should have a toilet to handle the patient's blood and fluids.	3.70	0.5	3.167	0.5
6	Washing sink should be located at the entrance or at the end of the bed.	4.60	0.5	**4.556**	0.5
7	Each bed should have an ringing bell (calling bell).	4.60	0.5	4.333	0.5
8	Life support alarm system of each bed should be linked with station.	4.90	0	**4.944**	0
9	Each unit ICU ward should have natural lighting and out-of-window views.	4.35	0.5	4.333	0.5
10	There is a hospice care zone in the vicinity of the ICU.			3.889	0.375
11	There is a CT room in the ICU for avoiding frequent movements just as those multiple trauma patients.			3.611	0.5
【B 】Support Service Area Design					
1	The nursing station should have a broadcasting system.	3.95	0.625*	3.611	0.5
2	Have a superintendent office.	4.15	0.625*	4.167	0.5
3	Setting the shower room for man and women separately	4.05	0.625*	4.000	0
4	Large instrument placement area should be set.	4.50	0.5	4.333	0.5
5	A multi-function room should be setted for staff conference, visit discussion, teaching activities and so on.	4.55	0.5	**4.667**	0.5
6	There should be a lounge room for dining or rest.	4.50	0.5	4.278	0.5
【C 】Family Area Design					
1	The number of waiting chairs and beds should be at least 1.5:1 .	3.95	**0.75***	3.765	0.5
2	The design of this area should take into account the privacy.	4.37	0.5	4.000	**1.0***
3	This area has a toilet or there is a neighboring toilet available.	4.37	0.5	4.235	0.5
4	This area has a lounge room.	4.00	**0.75***	3.941	0
5	This area has a sleep room.	3.53	0.5	3.375	0.5
6	This area has a medical counseling room.	4.37	**0.75***	4.412	0.5
7	This area has a dietician room.	3.16	0.5	3.000	0.25
8	This area has a laundry room.	3.26	0.5	2.563	0.5

***sign indicates**: the ratio value Q.D. >0.6 indicates the expert opinion does not converge.

The value show as the bold indicates the most five important opinions in this survey.

This study further analyze whether significant differences in the planning and design opinions between the three groups of experts by the Kruskal-Wallis test. As a result, it find that there were significant differences among the three groups only "men and women changing rooms and showers" ($p=0.049$) and "with staff restrooms" ($p=0.033$). The remaining 43 opinions were all consistent. The verification results of K-W are shown in Table 4. Finally, because the experts agree proportion is too low (first round, $P=0.2$) about the family area is set up in the ward, this study delete the 4 important score items in the second round. The contents are: provided with the accompanying beds, TVs, clothing cabinets, tables and chairs, and even computer networks in ICU wards.

Table 4 K-W test results of the opinions consistency of the three groups of experts

ICU design factors-- "Importance Score Items" in the Delphi questionnaire	χ^2	df	p-value
setting the shower room for man and women separately	6.040	2	0.049＜0.05
This area has a lounge room for the staffs.	6.818	2	0.033＜0.05

4. Conclusion

This study has completed literature collection, questionnaire editing, expert selection, repeated testing and statistical verification analysis. It is expected to propose the recommendations and guidelines for the planning and design of ICU in Taiwan's hospitals. For the selection of planning and design criteria, the more strict consensus standards are adopted among the 43 items that have obtained expert consensus in the research results. One condition to meet the definition of “high consensus” is QD≦0.60. (Yang Yizhen, 1999) Another one to meet "very important" definition is Q1≧4, Q3=5. (Huang Youjie, Luo Shaolin 2001) The strict consensus standard about the select items agreement ratio is P≧0.75. (Murry and Hommons,1995) Summing up the statistical results, this study categorizes all items into three spindles and 25 guidelines. The three spindles are "Enhanced Infection Control", "Enhanced Care Efficiency" and "Appropriate Environmental Design" .According to these three views, the detail guideline content are summarized in Table 5 "Taiwan Intensive Care Unit Planning and Design Guidelines".

In addition to the results of the research on Taiwan's local experts, this study also found that there are two very different design ideas between Taiwan and foreign design trends,. The two important differences are: single ward design and family area design. In this study, the experts considering the limited ICU area in Taiwan, most of them choose a semi-open type of bilateral compartments for each bed. (P value is 55.56%) On the literature and the winning cases, the design trend in the world is a closed single-person wards conducted with a full perspective glass ward door. The main consideration is reducing nosocomial infections. (Teltsch et al, 2011) (Levin et al, 2011) However, studies have also suggested that single-person wards do not help with super-bacteria (MRSA) control, and even due to the person's increased hand washing, not the design of a single-person room. (Cepeda et al, 2005). Despite this, the American Institute of Architects still lists the ICU single ward as a design guide. The French government also requires that all new ICUs in the hospital in the next 20 years must be single-person wards.

Secondly, the experts of this study don’t agree the family stay in ICU ward based on the infection considerations.(The P value of the disapprover is 88.24%) However, the “Hospice Palliative Medical Guidelines” proposed by SCCM and ACCC in the United States and the “Environmental Design” of the family area planned by Mahbub Rashid (2010) support the treatment that are considered to be family decision-making. Therefore, in the best ICU design case selected by AIA in the United States from 1993 to 2012, the proportion of family members in the ward has increased from 12.33% in the previous decade to 70 in the next decade.

Table 5 Taiwan Intensive Care Unit Planning and Design Guidelines

strengthening infection control	Choosing a new address for new construction will be better than renovated
	Sensory hazard assessment is important for new or renovated
	Each sink should be located at the entrance of the ward or at the end of the bed
Improving care efficiency	**The integral design:** single specialist property ward planning to improve safety, quality and efficiency patient care vision, medical staff care line, the optimal size of a unit: 10-19 beds, the optimal configuration of the ward is "racetrack"
	The ward design： the bedside of the bed should be at least 60 cm away from the wall ,the bed end should be at least 150 cm away from the wall, 150 cm on the

	rotating side of both sides, and 120 cm on the non-rotating side. the cantilever medical column has higher accessibility and elasticity than the bedside embedded medical gas cabinet. The columns should have architectural considerations. Each bed should have a ringing bell (calling bell), The living system should have an alarm warning link to the nursing station. Each bed is a separate compartment and the observation station is optimally designed as a "4-bed module". Nursing station should be decentralized design.
	The support service area design： Support service area should be the central nursing station plus observation station, the space should be dispersed to improve care efficiency
appropriate environmental design	**The integral design:** Each unit should have natural lighting and window view
	The ward design： an office for leader, an area for instrument and a multi-purpose room for education training and conference, and a lounge room for dining and rest.
	The support service area design： The family waiting area is outside of ICU, including a toilet and a disease interpretation room.

Supplementary Note 1: The ward of the "racetrack configuration" is mainly centered on the nursing station and the observation station surround the nursing station just as figure 1.

Supplementary Note 2: "4-bed module" refers to the design of the "4 beds, observation stations for 2 nursing staff" based on the care of the manpower just as Figure 2.

Figure 1 The racetrack configuration of the ICU layout by James WP and Tatton Brown W.

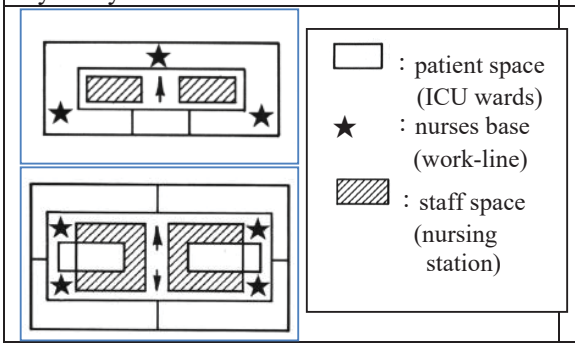
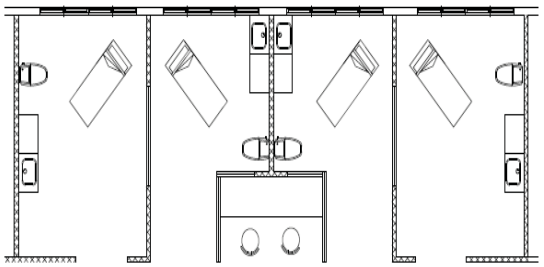


Figure 2 Optimal design module for the nursing staff observation station



This study has the following contributions to the empirical research of hospital ICU design planning: First, for the design of ICU provides an expert structural communication results and the comparison of domestic and international design opinions and trends. In this Delphi decision-making model, research analysis hope to reduce the futile discussion and revision design of the team. Second, this study compared with foreign design trends and viewpoints provides an important reference for the design ideas and a feedback for the experts. Third, the study concludes with recommendations for design planning guidelines. This result is a very specific improvement for setting standards in Taiwan. Finally, the research will investigate the current situation of more than 7,000 ICU beds in Taiwan to compare the similarities and differences with the design criteria proposed in this study in the future. In the future, we can conduct further evidence-based research for these specific design criteria, and proceed the excellent design case competition to advance the level of ICU design.

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