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# A Comparative Analysis of Patient Visibility, Spatial Configuration and Nurse Walking Distance in Korean Intensive Care Units(ICUs)

- Focused on single corridor, Pod and Composite type units

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**Abstract**

**Purpose**: The purpose of this paper is to analyze a sample of single corridor, pod type and composite type of ICUs in terms of patient visibility, spatial configurations and nurse walking distance focused on Korean cases. **Methods**: The measures of static visibility were used to quantify the patient visibility (upper third part of the patient bed) from the nurse station. The measure of space programme and area distribution (patient zone percentage, staff zone percentage, circulation zone percentage, corridor length per bed, distance from nurse station (NS) to patient bed and departmental gross square meter (DGSM) per patient bed) were calculated by using AutoCAD and MS Excel programs. In the second step of analysis the values of space distribution were compared among the three type of ICUs as well as the nurse walking distance, DGSM per bed and gross factor. in the third step of analysis regression analysis was conducted for the possible correlation between visibility and space programme and area distribution factors as well as nurse walking distance factors. **Results:** (1) It was found that on average composite type unit offer highest value of patient visibility followed by pod type, while single corridor type unit offers the minimum value of patient visibility among the three plan typologies. (2) Average patient visibility and DGSM per bed shows a strong positive correlation ($r^2$=0.75) and p=0.026. (3) Average patient visibility and average distance from NS has a strong negative correlation ($r^2$=0.78), and P=0.02. (4) On average composite type unit offer the minimum walking distance from NS (7.22 meter) followed by pod type unit (8.35 meter) and single corridor (9.76 meter). (5) Maximum distance from NS was noted in single corridor (18.19 meter) followed by pod type unit (15.14 meter) and Composite type unit (11.1 meter). **Implications**: This study may contribute to the visibility analysis of existing and future ICU design in Korea to achieve maximum patient visibility and reduced nurse walking distance.

**Keywords** Intensive care unit, Critical care Unit, Patient Visibility, Visual surveillance, Nurse walking distance, ICU space programme and area distribution, ICU planning and design.

## 1. Introduction

### 1.1 Background and Purpose

Rashid M. presents an analysis of the physical design characteristics of a set of ICUs (Based on SCCM best-practice example), which indicates that, " the layout of an ICU is arguably the most important design feature affecting all aspects of intensive care services including patient privacy, comfort and safety, staff working condition, and family integration"[1]. On other hand, the Society of Critical Care Medicine design guidelines suggests direct visualization at all

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1) Rashid M. (2006) "A decade of adult intensive care unit design: A study of the physical design features of the best-practice examples." Critical Care Nursing Quarterly 29(4), P.282-311.

times with a preference for a line of sight between the patient and central nurse station.[2]. The study, titled "Relationship between ICU Design and Mortality", was the first to implicate patient visibility as a factor influencing patient mortality.[3]

In all ICU designs, nurses remain vigilant about their ability to see and access patients.

Therefore patient visibility and accessibility to patient bed may be termed as two major components of patient care in ICU.

### 1.2 Objectives of the Study

Objectives of this study is to understand the planning typological differences of ICU design in terms of staff efficiency, that is nurse walking distance and patient visibility from nurse station to patient bed, focused on single corridor, pod and composite type unit.

## 2. Literature Review

### 2.1 An overview of ICU:

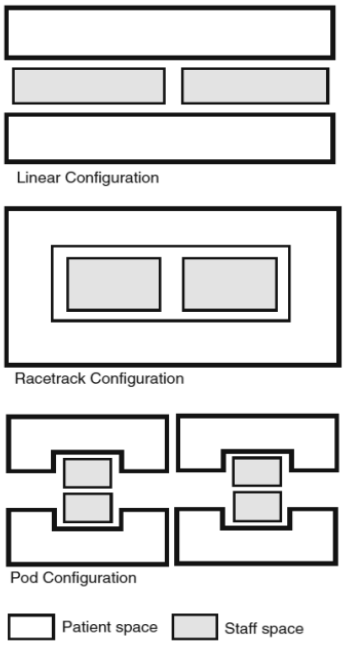
An intensive care unit (ICU), also known as an intensive therapy unit or intensive treatment unit (ITU) or critical care unit (CCU), is a special department of a hospital or health care facility that provides intensive treatment medicine.

Intensive care units cater to patients with severe and life-threatening illnesses and injuries, which require constant, close monitoring and support from specialist equipment and medications in order to ensure normal bodily functions. They are staffed by highly trained doctors and nurses who specialise in caring for critically ill patients. ICUs are also distinguished from normal hospital wards by a higher staff-to-patient ratio and access to advanced medical resources and equipment that is not routinely available elsewhere.[4]

**1) Plan Typologies of ICU:**

Although there is no specific plan typologies of ICU design, instead the general typolgies of hospital inpatient units are applied to the design of ICUs. Among the more commonly used planning typologies are Single corridor type, Double corridor type, racetrack type ,open-plan layout, radial layout or some combinations of the above.

Cadenhead, Charles. D. (2014). give the following three typologies of ICU design.[5]




**[Figure 1]** Plan Typologies of ICU[6]

**2) Patient Visibility in ICU Typologies:**

While stressing on nursing efficiency; Florence Nightingale, described the design element of visibility an essential component for the positioning a nursing station in the unit to ensure a view of the entire room both during daytime and at night.[7]

Although Compact circular plan type units are considered best in terms of patient visibility and nurse walking distance to the patient bed which was recognized by Yale evaluation as the most efficient plan. The major draw back of that unit is; the number and size of the patient rooms control the diameter of the circle, which often time give a central area out of proportion for nursing activity.[8]

In most best-practice ICUs, designers use multiple pods in an attempt to improve patient-staff visibility and to take services closer to patients.[9]

2) Society of Critical Care Medicine, 1995. Guidelines for intensive care unit design. Crit Care Med.23. Pp. 582–588.
3) Leaf, David E., et al. (2010). "Relationship between ICU design and mortality." CHEST Journal 137, no. 5: P.1022
4) "Intensive care unit" https://en.wikipedia.org/wiki/Intensive_care_unit, 2016.11.15.
5) Cadenhead, Charles. D. (2014). Architectural Design of Critical Care Units: A Comparison of Best Practice Units and Design. In Pediatric Critical Care Medicine (pp. 17-32). Springer London.
6) Cadenhead, Charles. D. op. cit. p. 20
7) Nightingale, Florence 1863. Notes on hospitals. Longman, Green, Longman, Roberts, and Green.
8) Kobus, Richard L.(2008). Building type basics for healthcare facilities. Vol. 13. John Wiley &Sons. p.140
9) Rashid M. (2006) "A decade of adult intensive care unit design: A study of the physical design features of the best-practice examples." Critical Care Nursing Quarterly 29(4), Pp.282-311.

The problems with pod designs compelled architect/designers to think beyond the current typologies for other options of ICU design.

**3) Nurse Walking Distance in ICU:**

Another factor which is related to better patient care is the distance traveled by nurses during patient care in ICU. Research indicates that nursing staff spend 28.9% of their time walking during their shifts.[10] Hendrich and colleagues (2008) found that nurses walked significant distances, on average 3.0 miles, during their shifts.[11] Bauer and Knoblich (1978) found that the average distance that nurses walk per shift is 3.89 miles in a general care unit and 5.13 miles in an ICU.[12] Evidence suggests that time saved from walking translates into more time spent on patient-care activities.

**4) Introduction of Korean ICU:**

According to Kwak, Sang-Hyun, et al.(2014), two university hospitals in Korea set up ICUs as postoperative respiratory care units in 1962.[13]

While Kim, Dong chan et al. (2015) claims that the first intensive care unit (ICU) in Korea was established in 1968 with six beds in a university hospital in Seoul.[14]

When the Korean Society of Critical Care Medicine (KSCCM) was organized in 1980, 18 university hospitals and nine general hospitals had ICUs.[15]

The number of ICUs has since expanded to 220 taking care of 3197 patients (data from a one-day survey in 2009).

In 2013, there were a total of 887 ICUs. The estimated 17 adult ICU beds per 100,000 population is comparable to that in other advanced countries.[16]

10) Burgio, Louis D., et al.(1990) "A descriptive analysis of nursing staff behaviors in a teaching nursing home: Differences among NAs, LPNs, and RNs." The Gerontologist 30.1 Pp: 107-112.

11) Hendrich, Ann, et al. (2008) "A 36-hospital time and motion study: how do medical-surgical nurses spend their time?." The Permanente Journal, 12(3), P. 30.

12) Bauer, H., and K. Knoblich. 1978. "[Recording of walking performance of nurses working in hospital departments]." Zeitschrift fur die gesamte Hygiene und ihre Grenzgebiete 24, no. 7 pp. 539-541.

13) Kwak, Sang-Hyun, et al.(2014) "Current status of intensive care units registered as critical care subspecialty training hospitals in Korea." Journal of Korean medical science 29.3 P.431

14) Kim, Dong chan et al. (2015) "The Past, The Present and the Future History of Critical Care in Korea and the Korean Society of Critical Care Medicine" ICU Volume 15 - Issue 2 – 2015, Country Focus Critical Care Medicine in Korea

15) Kwak, Sang-Hyun, et al. op. cit. p. 431.

16) Lim, Chae-Man, et al.(2015) "Critical Care In Korea: Present and Future." Journal of Korean medical science 30, no.11 P. 1541.

**[Table 1]** Number (Percentage) of ICUs in Korea (2013)

| Classification of Healthcare Facility | No. of ICUs |
|---|---|
| Tertiary Hospital | 259 (29.2%) |
| General Hospital | 426 (48%) |
| Hospital | 162 (18.3%) |
| Long-Term Care Hospital | 12 (1.4%) |
| Clinic | 8 (0.9%) |
| Health Center & Country Hospitals | 2 (0.2%) |
| Korean Medicine Hospital | 4 (0.5%) |
| Korean Medicine Clinic | 4 (0.5%) |
| Armed Forces Hospital | 10 (1.1%) |
| Total | 887 (100%) |

Source: Medical Korea Statistics.[17]

## 3. Method:

### 3.1 Procedure of Analysis:

The analysis comprises of the following five steps as follows:

① Step-1 (Space Programming):

In the first step of the analysis the measure of space programme, which includes the departmental gross square meter (DGSM) per bed, gross factor and number of beds in the unit were calculated using Auto CAD and MS Excel.

② Step-2 (Area Distribution):

In the second step of analysis the factors of Area Distribution of ICU were calculated. each unit was broke down into the following three constituent areas that is, Patient zone percentage, staff zone percentage, and circulation zone percentage which were calculated using Auto CAD and MS Excel.

③ Step-3 (Nurse walking Distance):

In this step of analysis the distance from nurse station (NS) to patient bed was calculated for each and every bed of all the units using Auto CAD and MS Excel.

The minimum, maximum and average distance from NS as well as corridor length per patient of the unit were calculated as shown (Table 4).

17) "The Number of Delivery Rooms, Infant Units, Operating Rooms, Emergency Rooms, Intensive Care Units" http://www.medicalkorea.or.kr/content.do?method=getContent&gcd=G1001&cmscd=CM9015, Medical Korea Statistics, 2016.04.14

④ Step-4 (Patient visibility):

Patient visibility (upper third part of the bed) was calculated using Auto CAD and MS Excel.

⑤ Step-5 (Regression Analysis):

In the last step regression analysis was run to establish the correlation between patient visibility and area distribution, Space programme factors using IBM SPSS software.

### 3.2 Overview of the Cases:

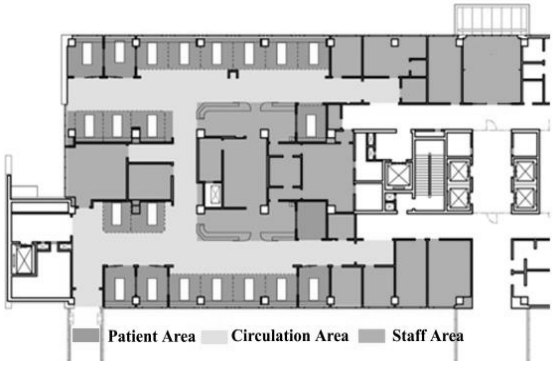
Six cases of ICUs having three different plan typologies were selected for the analysis from five Korean hospitals. In most of the cases, one sample was taken from each hospital with same layout.

#### 1) Single Corridor Type:

The beds in single corridor type are arranged on both side of a single corridor with nurse station on the either side of the corridor. In this category two cases were selected from two different hospitals as follows.

① Case-1: B.N.U. Hospital Double ICU:

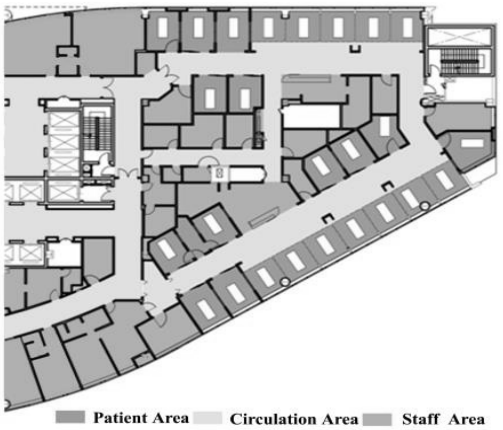
The planning typology of the B.N.U. Hospital is single corridor type. B.N.U. has a total of 770 inpatient beds. there are 43 ICU beds which are 5.5% of the total beds, of 12 beds in 1st ICU, 10 beds are in 2nd ICU. The first and second ICU is connected having combined central nursing space. The area per bed is 45.68m²/bed and the gross factor is 1.42.




**[Figure 2]** B.N.U. Hospital (1st& 2nd ICU- 2nd Floor)

② Case-2: New Y.S. Hospital MICU & SICU:

The planning typology of the New Y.S. Hospital is single corridor type. this Hospital has a total of 1,000 in patient beds. the number of ICU beds is 75, which are 7.5% of the total inpatient beds. ICU beds are direct-view type. There are 25 beds in MICU+SICU (2 units), The area per bed is 46.79㎡/bed and the gross factor is 1.43.



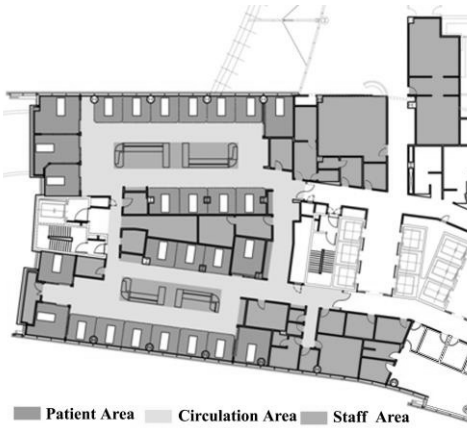

**[Figure 3]** New Y.S. Hospital (MICU+SICU-9th Floor)

#### 2) Composite Type:

In composite type design of ICUs the planning typology of two or more is combined to achieve a different type of unit design. the following two type of unit design uses the planning typologies of pod, and racetrack unit.

① Case-1: S.C. Hospital, MICU:

The planning typology of the S.C. Hospital is composite type. This Hospital has a total 700 beds. the number of ICU beds are 40, which are 5.7% of the total inpatient beds. There are 27 beds in MICU(2). The area per bed is 46.82㎡/bed and the gross factor is 1.51.

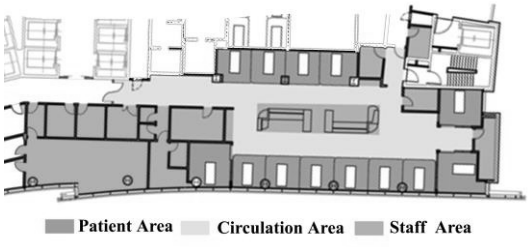



**[Figure 4]** S.C. Hospital (MICU-3rd Floor)

② Case-2: S.C. Hospital, SICU:

The planning typology of the S.C. Hospital is composite type. This Hospital has a total 700 beds. the number of ICU beds are 40, which are 5.7% of the total inpatient beds. There

are 13 beds in SICU. The area per bed is 51.55㎡/bed and the gross factor is 1.51.




**[Figure 5]** S.C. Hospital (SICU-3rd Floor)

**3) Pod Type:**

Pod are basically the units where patient beds are arranged around the nurse station for high visibility and ease of access to patient bed as shown in (Figure 1).

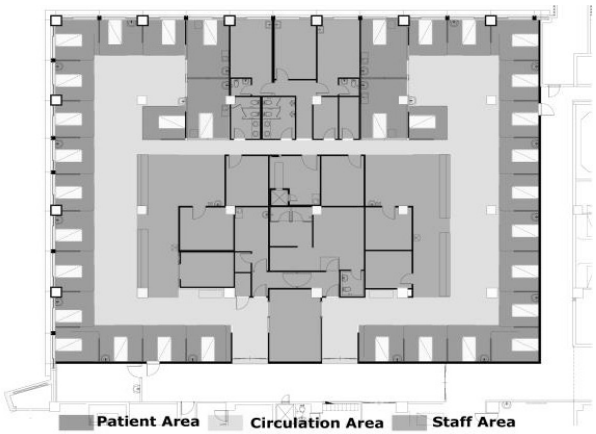
① Case-1: S.N.U.B Hospital, NICU and NSICU:

The planning typology of the S.N.U.B Hospital is pod type. This Hospital has a total of 390 beds. the number of ICU beds 29, which is 7.4% of the total inpatient beds. There are 15 beds in NICU and 15 in NSICU. The area per bed is 41.0㎡/bed and the gross factor is 1.48.

**[Figure 6]** S.N.U.B. Hospital (ICU-3rd Floor)

② Case-2: H.U.D.S.H. Hospital, MICU and SICU:

The planning typology of the H.U.D.S.H. Hospital is pod type. This Hospital has a total of 800 beds. the number of ICU beds 45, which is 5.6% of the total inpatient beds. There are 17 beds each in SICU and MICU. The area per bed is 44.3㎡/bed and the gross factor is 1.35.




**[Figure 7]** H.U.D.S.H. Hospital (MICU & SICU-3rd Floor)

## 4. Analysis of the Cases:

### 4.1. Step-1 (Space Programming):

In the first step of the analysis the measure of space programme were calculated for each unit, which includes departmental gross square meter (DGSM) per bed, gross factor (GF) and number of beds in the unit were calculated using Auto CAD and MS Excel (Table 2).

The DGSM per bed of ICU was calculated as follows:

The DGSM per bed=

Gross Area of the ICU/ Number of ICU beds

For example the area per bed of case-1 is:

=1005m²/22

=45.68m²/bed.

**[Table 2]** Summary of Space Programme & Area Distribution

| Plan Type | Gross Factor | Area Per Bed | Patient Area(%) | Circulation Area (%) | Staff Area (%) |
|---|---|---|---|---|---|
| Single Corridor-1 | 1.42 | 45.6m²/ bed | 25.4 | 29.7 | 44.9 |
| Single Corridor-2 | 1.43 | 46.7m²/ bed | 29.8 | 29.9 | 40.3 |
| Pod Type-1 | 1.48 | 41.0m²/ bed | 32.8 | 31.3 | 35.9 |
| Pod Type-2 | 1.35 | 44.3m²/ bed | 29.1 | 33.2 | 37.6 |
| Composite Type-1 | 1.51 | 46.8m²/ bed | 27.4 | 33.9 | 38.6 |
| Composite Type-2 | 1.51 | 51.5m²/ bed | 29.9 | 33.8 | 36.3 |

### 4.2. Step-2 (Area Distribution):

In the second step of analysis the factors of Area Distribution of ICU were calculated. each unit was broke down into the following three constituent areas that is,

Patient zone percentage, staff zone percentage, and circulation zone percentage and which calculated using Auto CAD and MS Excel (Table 2).

### 4.3. Step-3 (Nurse walking Distance):

In this step of analysis the distance from nurse station (NS) to patient bed was calculated for each and every bed of all the units using Auto CAD and MS Excel.

The minimum, maximum and average distance from NS as well as corridor length per patient of the unit were calculated as shown (Table 3).

**[Table 3]** Summary of Nurse Walking Distance (Unit: Meter)

| Plan Type | Distance from Nurse Station | | | Average corridor length/patient |
|---|---|---|---|---|
| | Min. | Avg. | Max. | |
| Single Corridor-1 | 4.68 | 8.38 | 14.95 | 2.27 |
| Single Corridor-2 | 6.13 | 11.13 | 21.42 | 2.19 |
| Pod Type-1 | 3.85 | 8.20 | 14.45 | 3.20 |
| Pod Type-2 | 4.56 | 8.50 | 15.82 | 2.74 |
| Composite Type-1 | 4.63 | 7.42 | 11.61 | 1.90 |
| Composite Type-2 | 4.78 | 7.01 | 10.59 | 2.46 |

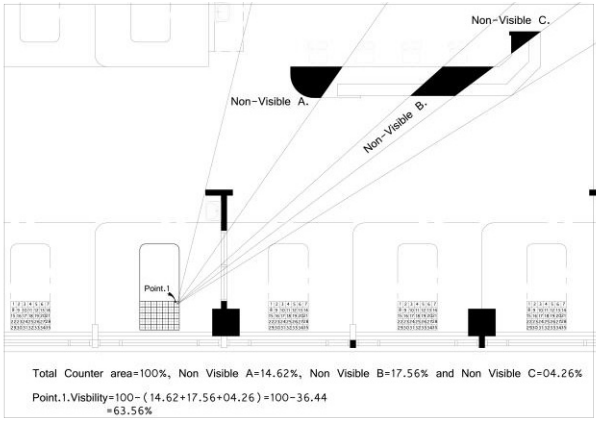
### 4.4. Step-4 (Patient visibility):

Patient Visibility was calculated for all the cases considering all the beds as well as Isolation rooms [Figure 9] to [Figure 14]. The calculation method of visibility devised by Ullah Ubaid. et. al. (2016) was used in this paper [Figure 8].[18]

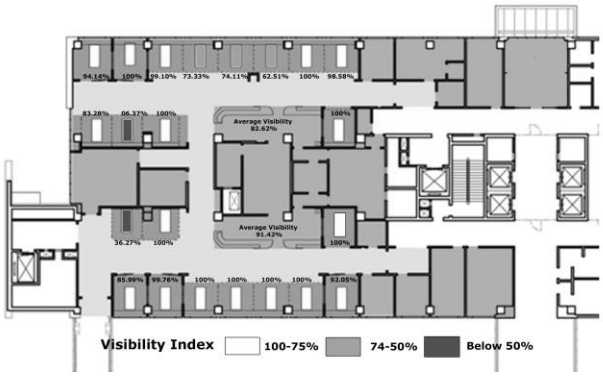
Their method of calculation is based on the criteria mentioned by Catrambone et al. (2009).[19]

According to their method each bed was first divided into three parts, then the upper third part of the bed was divided into 35 tiles of 150 x 150 mm size. The center of each tile was connected to the nurse station without any obstruction. The visible area of each point was calculated and the average of all points was calculated for each bed, as shown in (Figure 8).[20]

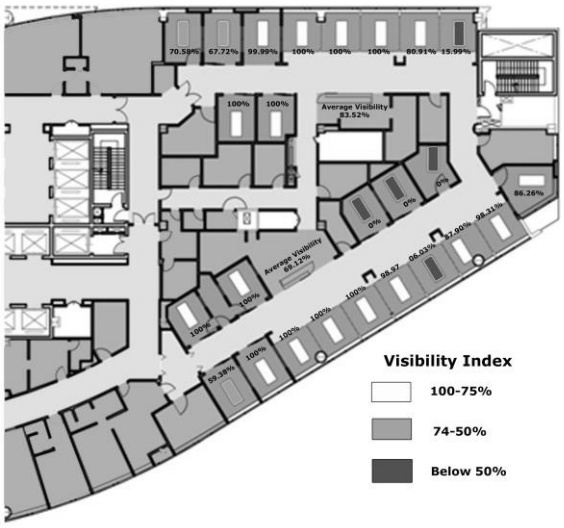
The overall visibility of each unit was then calculated taking average of the visibility of all the beds and isolation room in the unit (Table 4).




**[Figure 8]** Calculation method of patient visibility. Modified from Ullah Ubaid. et. al. (2016) with Permission.




**[Figure 9]** Visbility of B.N.U. Hospital (1st& 2nd ICU- 2nd Floor)

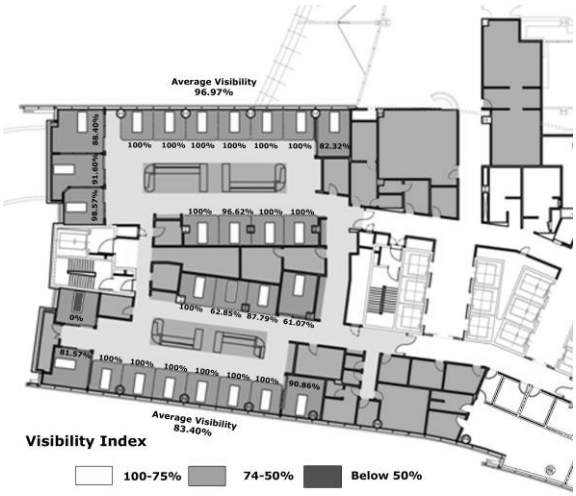



**[Figure 10]** Visibility of New Y.S. Hospital (MICU+SICU-9th Floor)

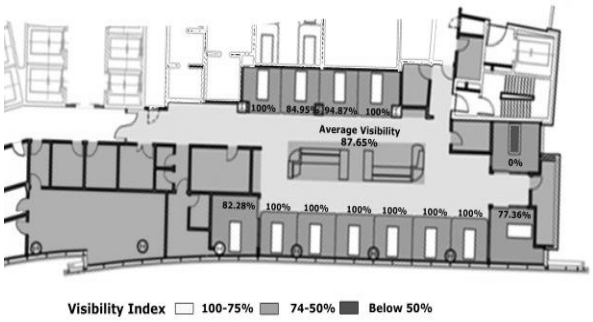
18) Ullah, Ubaid, et al.(2016) "A Study on the Development of Predictive Model for Patient Visibility in Korean Intensive Care Units (ICUs)." Journal of The Korea Institute of Healthcare Architecture 22. no.3 P. 32.

19) Catrambone, Cathy, et al.(2009) "The design of adult acute care units in US hospitals." Journal of Nursing Scholarship 41, no.1. P. 80.

20) Ullah, Ubaid, et al.(2016) op. cit. p. 32.

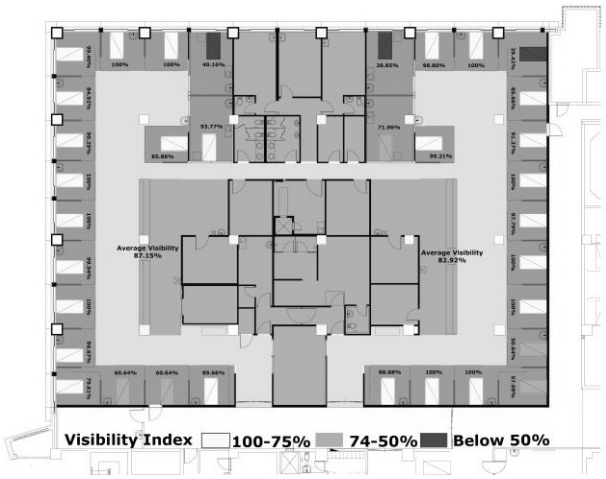



**[Figure 11]** Visibility of S.C. Hospital (MICU-3rd Floor)




**[Figure 12]** Visibility of S.C. Hospital (SICU-3rd Floor)


**[Figure 13]** Visibility of S.N.U.B. Hospital (ICU-3rd Floor)




**[Figure 14]** Visibility of H.U.D.S.H. Hospital (MICU & SICU-3rd Floor)

**[Table 4]** Average Patient Visibility & bed composition of the cases

| Plan Type | Case No. | Number of Beds | Number of Rooms (%) | Average Patient Visibility Percentage |
|---|---|---|---|---|
| Single Corridor | Case-1 | 15 | 7(31.81%) | 86.62% |
| | Case-2 | 12 | 13(52%) | 74.88% |
| Pod Type | Case-1 | 24 | 6(20.00%) | 91.99% |
| | Case-2 | 30 | 4(11.77%) | 85.03% |
| Composite Type | Case-1 | 19 | 8(29.62%) | 90.43% |
| | Case-2 | 10 | 3(23.07%) | 87.65% |

## 5. Synthesis:

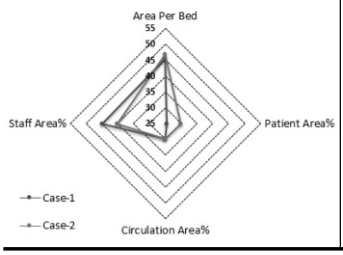
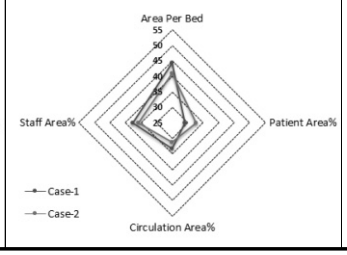
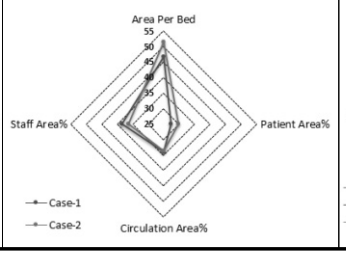
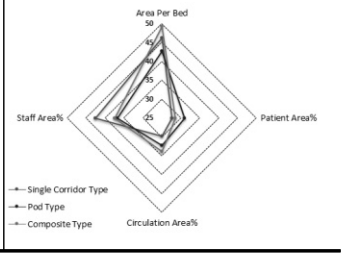
In the final step data from the above analysis was compared among typologies in terms of area distribution factors as well as space programming aspects. the factors of patient visibility and nurse walking distance were also compared among the three typologies as shown.

For the possible correlation among typologies regression analysis was used.

### 1) Comparison of Space Programme and Area Distribution among Typologies:

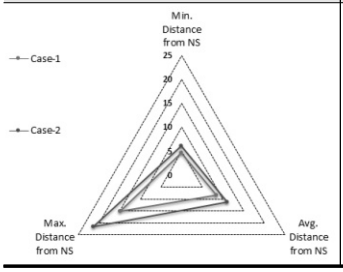
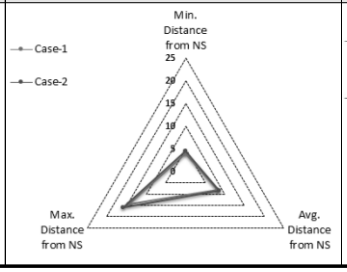
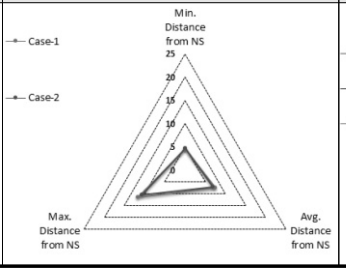
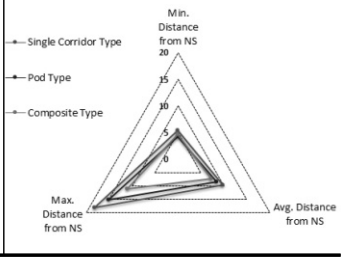
It was found that composite type unit has highest value of patient area per bed and percentage circulation area [Table 5]. It was also found that on average composite type unit offer highest value of patient visibility followed by pod type, while single corridor type unit offers the minimum value of patient visibility among the three typologies.

**[Table 5]** Comparison of Area Distribution and Gross Factors among three Plan Typologies

| Single Corridor Type Unit | Pod Type Unit | Composite Type Unit | Comparison of Mean |
|---|---|---|---|
|  |  |  |  |



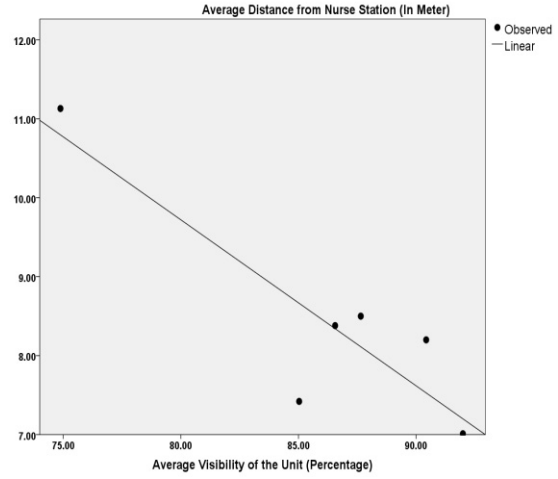
**[Table 6]** Comparison of Nurse Walking Distance among three Plan Typologies

| Single Corridor Type Unit | Pod Type Unit | Composite Type Unit | Comparison of Mean |
|---|---|---|---|
|  |  |  |  |



**2) Correlation between Average Patient Visibility and Average Distance from NS to Patient Bed:**

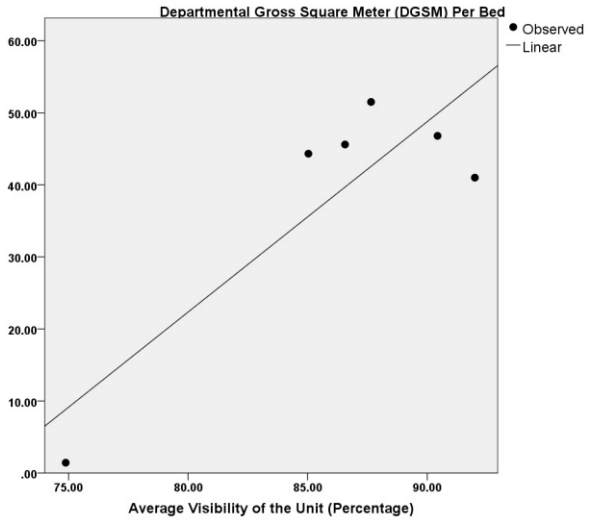
It was found that average patient visibility has a strong negative correlation with average distance from NS to patient bed in the unit ($r^2$=0.78), and P=0.02. (Figure 15). This implies that ICUs with compact configuration, small corridor size or sub nurse stations may produce enhanced patient visibility and vice versa.




**[Figure 15]** Correlation between Average Patient Visibility and Average Distance from NS to Patient Bed

**3) Correlation between Average Patient Visibility and Departmental Gross Square Meter (DGSM) Per Bed:**

A strong positive correlation ($r^2$=0.75) and p=0.026, was found between average patient visibility and departmental gross square meter per bed (Figure 16).




**[Figure 16]** Correlation between Average Patient Visibility and Departmental Gross Square Meter (DGSM) Per Bed

This implies that the above equation is not by chance, as this relation is also visible in the departmental gross square meter per bed. while an increased DGSM per bed means that increased nursing area which along with reduced walking distance enhances patient visibility in the unit.

## 6. Conclusion:

The results of this study can be concluded as:

(1) It was found that on average composite type unit offer highest value of patient visibility followed by pod type, while single corridor type unit offers the minimum value of patient visibility among the three typologies.

(2) Average patient visibility and DGSM per bed shows a strong positive correlation ($r^2$=0.75) and p=0.026.

(3) Average patient visibility and average distance from NS shows a strong negative correlation ($r^2$=0.78), and P=0.02.

(4) On average composite type unit offer the minimum walking distance from NS (7.22 meter) followed by pod type unit (8.35 meter) and single corridor (9.76 meter).

(5) Maximum distance from NS was noted in single corridor (18.19 meter) followed by pod type unit (15.14 meter) and Composite type unit (11.1 meter).

The results shows that patient visibility is affected by space programme and specifically by area distribution and nurse walking distance in Korean ICUs.

The findings of this study, although of a limited number of cases, demonstrated that apart from traditional typologies; composite type design may prove itself superior in terms of patient visibility and nurse walking distance. although the area per bed is also the highest as compared to the other two type unit in this study. other factors of patient care and staff ease in composite type unit need further studies to be established as a good design option when compared with a large sample of plan typologies.

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