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Performance-based building design: Evaluation of the functional performance of the emergency department in Erbil city hospitals using patient feedback

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ABSTRACT

The emergency department (ED) is one of the most important departments in hospitals, which provides emergency care to patients who need rapid medical treatment. The configuration of the ED's interior spaces impacts their functioning and determines the hospital complex's performance. This study proposes a Performance-Based Building Design (PBBD) approach to ED layouts in Erbil city hospitals to determine which ED types achieve more functionality factors. The research objective is to inspect three different ED layout typologies and discusses the possibility of the spatial layout of each ED typology in creating a more functionally efficient ED. Eight ED were selected from eight hospitals in Erbil city. Quantitatively Post Occupancy Evaluation (POE) questionnaire form was distributed to patients to investigate their opinion on the availability of ED spatial layout variables. Statistical analysis is used for analyzing patient feedback and proving the research hypotheses. As a result, according to patient feedback, the ballroom layout typology was found to be the most beneficial since it has the most functional efficiency factors while popular and linear layout typology has the r. The research findings provide healthcare designers with a useful framework and resource for future designs, especially for treatment spaces within ED.

1. Introduction

The healthcare industry is one of the biggest and fastest-growing industries in the world which covers a wide range of architectural fields [13]. Hospital design should ensure that care delivery systems operate effectively and efficiently [20]. There are several strategies used in architecture to construct healthcare facilities. The most popular one is the practical design strategy approach and the most frequently applied practical approach is performance-based building design (PBBD) [4]. PBBD is a strategy that emphasizes what the building should contain rather than its design. It deals with how to design buildings while considering user needs and satisfaction. The basic concept of PBBD in the construction sector is performing building functionality [25]. According to [5], a building's functional performance explains and evaluates how successfully use-specific activities and processes can be conducted in the building. It focuses on the interaction between the building and its occupants [21]. The form of spatial configuration has an impact on how functionally efficient these places are [9]. Therefore, any modification to these systems results in a deficiency and a weakening in their functional effectiveness and level of performance [15].

The emergency department of the hospital is the first point of contact in the healthcare system. To provide the required services to patients, enhancing

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the performance of emergency departments in hospitals has been identified as a key objective of health policy-making [24]. The main goal of this thesis is to evaluate the impact of the spatial layout of ED in Erbil city hospitals on its functional performance efficiency in terms of its variables. It deals with the interior design layout of ED as a whole. Moreover, eight EDs with three different layouts (ballroom, podular, and linear (X, L, C, I, T, and H shapes)) representing Erbil city hospitals were selected as case studies and their functional performance is the main category that will be evaluated through its efficiency.

Post Occupancy Evaluation (POE) questionnaire form was used as a quantitative research method, which is distributed to the patients to evaluate the ED functional efficiency factors (wayfinding, accessibility, privacy, visibility, time spent-length of stay (LOS), and corridor circulation) and the spatial configuration of the selected layouts within the selected cases. The overall layouts were evaluated, through SPSS Program using the one-way analysis of variance (ANOVA). The key conclusion of this study is that according to patient feedback spatial configuration affects how effectively an ED functions. The overall layouts were evaluated, and the results showed that the layout plays a significant role in creating functionally efficient ED.

2. Research hypotheses

The layout of ED plays a critical role in its functionality and efficiency. Inadequate consideration of factors related to the design of these layouts in regards to their typologies may result in inefficiency in the process of recovery of patients at these hospitals. Theoretically, there might be a flaw in the systematic organization of this department, resulting in a weakness in the functionality of Erbil's current hospitals. The research hypothesizes that:

H1: The factors of functional performance are available in the EDs of Erbil hospitals to varying degrees due to their different spatial configurations.

H2: Considering the ED functionality, various ED layout typologies provide different outcomes.

3. Materials and methods

3.1. Study design

To investigate the role of spatial configuration on ED functionality, the Post-Occupancy Evaluation (POE) questionnaire, as a quantitative approach was adopted in this study. POE is a useful tool for evaluating building performance after they've been built and utilized for a while [8]. To address the complex connection between many elements of the built environment, photographs are utilized as the foundation for reflection during the interviews because many individuals lack the vocabulary to explain their spatial experiences. The diversity and flexibility of the approach made it appealing to a wide range of patients who were hospitalized in the emergency department allowing them to feel pleasant participating.

3.2. Data collection

Before the interviews, the researcher walked through the department and photographed patient rooms, nurse stations, and the most common corridors (e.g., from the ambulance station to the emergency department or from the waiting room to triage to the patient room). To capture the role of spatial configuration in ED patients' experiences as adequately as possible, data were collected at the department itself. ED layout typology variables such as evaluations of privacy, accessibility, corridor circulation, visibility, time spent – length of stay (LOS), and wayfinding were the main aspects of the questionnaire design used in this study. The questionnaire had a total of 26 questions for patients, the responses were rated on a 5-point Likert scale, with 1 indicating very dissatisfied and 5 as very satisfied. The patient or their companion's questionnaire was created while the patient was awaiting discharge or admission to the hospital, to ensure that, the survey results accurately represented the ED's overall performance. These individuals were chosen at random for their desire and ability to answer. A questionnaire form was in English language but the researcher explained the questions to them in Kurdish, which is the patient's mother language so that they can understand and respond more easily.

3.3. Data analysis procedure

This study used IBM SPSS (Statistical Package for the Social Sciences) software version 25 to evaluate the collected surveys from patients in each case study, and the mean of each variable reflects the analysis of respondent answers to the questionnaire. The mean and standard deviation are employed in this form of analysis to determine the levels of satisfaction for each statement questioned within the selected factors. This program includes a variety of tests. The one-way analysis of variance (ANOVA) was used to evaluate the responses.

4. Variables of emergency department layout design

The spatial configuration of the ED impacts its functionality and the way the department treats its patients [26]. Through ED spatial configuration, many variables affect its functionality and are associated with the design of the ED layout. Based on previous related studies, this study highlighted some of the basic factors associated with the design of the ED layout, each of which can be used to assess diverse typologies. This disparity may result in varying amounts of functionality between patients in the ED. The most important of these factors and variables used in the study are listed below:

4.1. Privacy

Privacy is the way healthcare architects assist in legally keeping patient information and examinations from becoming viewed by anybody other than his care physician. Privacy influences patient treatment, patient well-being, and of course operation. The patient room must be designed to be calm and quiet, due partly to the separation of the nurse's station with glass walls and the use of a mobile nurse call system. By upgrading private rooms with enough space for patients, visitors, and staff and putting the patient's satisfaction in the institution first, the hospital can better serve its patient's costs [22].

4.2. Corridor circulation

Corridors in healthcare facilities should be designed to enable convenient access to all services in the unit, and provide easy patient, employee, and equipment flow with little oncoming traffic. It is critical to monitor and secure the surroundings and unauthorized personnel should not be allowed inside the department [14]. According to [11], the ideal circulation ratio for the ED is 40%. Corridors provide patients, relatives, and staff access to all sections of the emergency department, as well as service areas, stores, and equipment that is routinely or quickly needed. Corridors must be wide

enough to accommodate bariatric patient trolleys and related equipment, as well as allow for pedestrian circulation in both directions [7].

4.3. Visibility

Another important aspect of the ED's quality of care is visibility. It makes ED easier to keep patients' medical rooms and their health. The staff becomes more aware of patient situations as a result of increased visibility. Furthermore, visibility influences the quality of clinical cooperation by facilitating routine face-to-face interaction. A layout that obstructs view creates the potential for physical security problems. Removing visual barriers to provide strong visual access to the patient rooms was one of the most often noted reasons in responses. Also, teamwork and efficiency are improved by removing barriers surrounding nursing stations and increasing visibility [17].

4.4. Accessibility

The emergency department should be located on the ground floor and apart from other entries to the health care institution, there must be two entrances, one for patients who are arriving by walk and one for an ambulance entry patient. To enable the entry of ambulances and other vehicles delivering patients, entrances must be conveniently accessible from public roadways. the patient entry and transport arrival space should be sheltered, and well-marked in certain circumstances for easy accessibility, and a separate, controlled ambulance entry is required; it must be located close to reception/triage to allow for better observation of those entering the department. In all parts of the department, patients should have easy access and spaces for wheelchairs and stretchers to circulate [14].

4.5. Time spent/Length of stay (LOS)

Patient length of stay (LOS) is a key performance indicator (KPI) [2]. It was selected as a key metric for evaluating the quality of care in the ED [1]. The length of stay in the ED begins when the patient enters the unit and extends until the patient is sent home, hospitalized, or moved to another facility. This amount of time reflects how effectively an ED is functioning and performing. A protracted stay is caused by a lack of inpatient beds and the need to wait for specialized consultations and medical test findings [3]. In addition, various variables inside the EDs, such as delayed consult requests, challenging cases, late admission, and congestion, have been among the most common causes of extended LOS [3]. Patients who stayed in the ED for more than 6 hours were classified as having a longer LOS, which was linked to an increased risk of death [10]. Increased LOS in the ED can cause significant expenses and patient safety issues [6]. Moreover, it can have a negative impact on patients and also cause longer hospital stays, greater inpatient costs, and higher death rates [16]; [23].

4.6. Wayfinding

Wayfinding is one of the fundamental characteristics of space that influences the facility's quality of care. Wayfinding considerations in healthcare design lead to a collaborative design by lowering the stress faced by patients, and healthcare facility employees, as well as improving performance. In healthcare facilities, wayfinding is the part of the design that influences efficiency and patient satisfaction [7]. The emergency department's wayfinding system should be connected with the hospital's overall system, using the same styles and norms. Signs should be installed at every important crossroads and location. According to the experts, when a route does not have any crossings or options for diversions, signs should be placed every 30 meters to clarify the path. Electronic navigation and/or information desks are becoming more widely used [7].

5. Emergency department layout typologies

Contemporary ED design concepts are grouped into various forms of "ballrooms", "pods", and "inner-core (linear)" arrangements [18]; [19]. The ballroom layout is the most common ED layout. It enables for received more visibility and departmental management. While in podular, each of the pods requires a complete staff, depending on the patient's number. Patient/staff satisfaction has been improved by enhancing the visibility and accessibility of nurses. But when an ED is designed in a linear layout, employees can be assigned progressively, assisting in the resolution of staffing concerns [26]. The classification of ED layout typologies in this study relies on researching numerous research publications and papers, as well as hospital design guidebooks. The ED patient area and the nurses' station are two key spaces in the ED design that may be arranged in a variety of ways to identify the type of ED. According to [12], various layouts of two areas in a place can create different types of corridors (corridor shapes). So, these three components will select ED layout typology. [19]; [18], depicted the three most basic types of ED layout as described below:

5.1. Podular

This arrangement achieves a good balance between service space and walking distance to the exam room. Because of the view obstruction, multiple nurse's stations must be set up, the full ED is not visible from any of them. Multiple sets of beds with distinct nurse's stations are referred to as "pods,". According to the patient number in pods, each one requires a full rate of staff members, see Fig. 1.

5.2. Ballroom

This layout allows for efficient staff interaction as well as patient visualizations in exam rooms. A center nurse station, or core, is surrounded by beds. From the staff hub in the center of the circle of beds, all of the bedrooms are visible. Clean and dirty utilities and facilities are crammed into the central space. This allows for reduced walking distances to important functions, but it also occupies the central core with concrete walls, obstructing the views that were the ballroom's main advantage point, see Fig. 1.

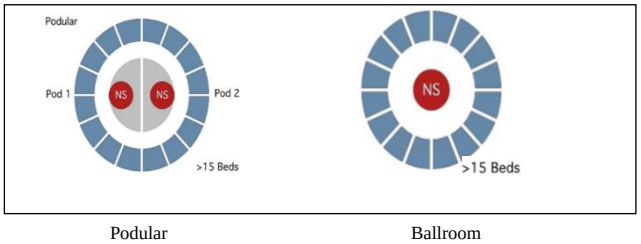

Figure 1. Podular and ballroom emergency department layout typologies. Obtained by Pietrzak and Lennon [19].

5.3. Linear

The key feature of this layout is the main corridor, which is surrounded by patient rooms and nurse stations placed in a corridor form that is conveniently accessible for both staff and patients. Getting patients into the system as fast as possible helps to reduce corridor traffic while also allowing staff to provide better treatment. Some varieties contain separate passageways for patients and physicians, as well as patients' families. The main corridor is designed in a variety of ways as X, H, T, L, I, and C, see Fig. 2.

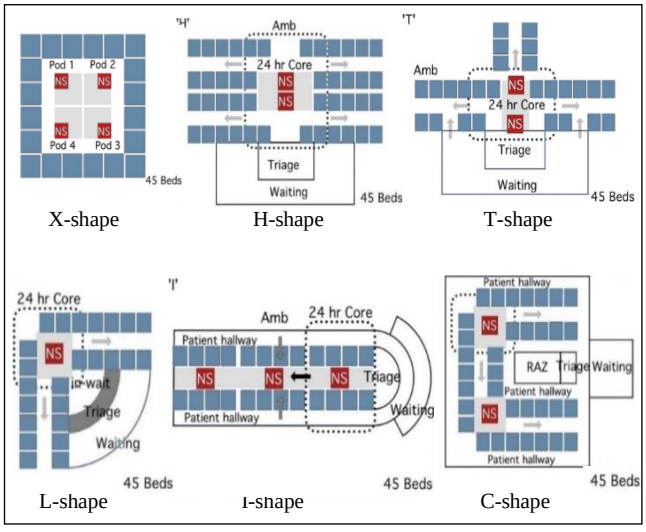

Figure 2. Linear emergency department layout typologies. Obtained by Pietrzak and Lennon [19].

6. Case studies

To identify the case studies a list of statements formed from the terms of each ED layout standard was developed by emphasizing patient rooms, nurse stations, and corridor circulation. Eight EDs from eight Erbil city hospitals were selected as a case study. The EDs are classified according to layout typologies as mentioned below:

6.1. Podular ED hospitals

In podular ED hospitals, the ED is divided into two pods each controlled by its nurse station. Patient rooms are located on the double-loaded corridor. Raparin and Nanakali EDs are examples of podular EDs, see Fig. 3.

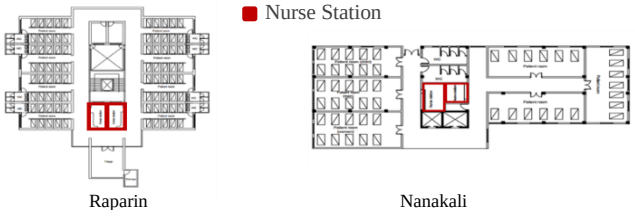

Figure 3. Raparin and Nanakali ED.

6.2. Ballroom ED hospitals

In ballroom ED hospitals, patient rooms are located on double-loaded corridors and controlled by one centralized nurse station. Zanko, PAR, and Rozh-Halat EDs are examples of ballroom EDs, see Fig. 4.

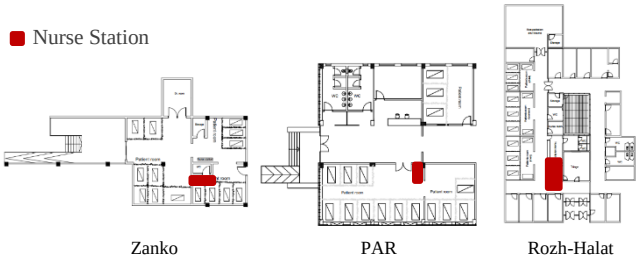

Figure 4. Zanko, PAR, and Rozh-Halat ED.

6.3. Linear ED hospitals

In linear ED hospitals, patient rooms are located on double-loaded corridors and controlled by one or two nurse stations distributed along the (I-L-H) shaped corridors. Sardam, Swedish, and Maternity EDs are examples of linear EDs, see Fig. 5.

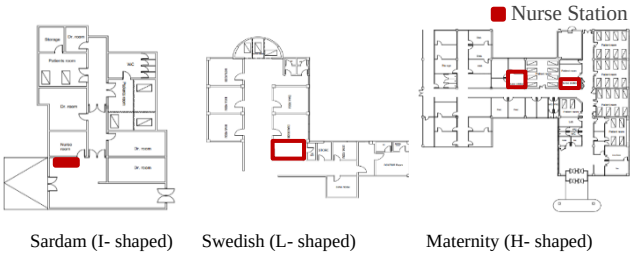

Figure 5. Sardam, Swedish, and Maternity ED.

7. Discussion

As mentioned previously, data and results were collected from the questionnaire survey based on feedback from ED patients in eight Erbil city hospitals. the one-way analysis of variance (ANOVA) of the SPSS program was carried out to demonstrate the variation in means among the eight EDs and prove the research hypotheses. The key factors/variables used in analyses were wayfinding, accessibility, privacy, visibility, time spent-length of stay (LOS), and corridor circulation. The following is a review of the results obtained from questionnaire analyses to indicate the impact of the spatial layout of ED in Erbil city hospitals on its functional performance efficiency in terms of its variables. Based on evaluations and feedback collected from patients in each ED, due to the availability of functional performance variables, in comparison between the eight case studies, Zanko and Swedish EDs are the best for having most of the factors, Zanko has (accessibility and corridor circulation), and Swedish has (time spent and privacy) factors. Moreover, PAR ED has good visibility and Maternity hospital has good wayfinding inside its ED. Furthermore, the remaining EDs contain functional performance factors, but to a varying degree. In comparison between the eight case studies in each typology, all cases of podular layout have all factors in varying degrees, but none of them has the highest value of any of the factors as shown in Table 1 and Fig. 6 below.

Table 1. Mean of podular ED's factors based on patient feedback.

Podular layout typology hospitals			
Factors	**Hospital**	**Mean**	**Std. Deviation**
Privacy	Raparin	3.39	0.437
	Nanakali	2.12	0.301
Accessibility	Raparin	3.86	0.385
	Nanakali	4.14	0.250
Corridor Circulation	Raparin	3.00	0.384
	Nanakali	3.13	0.281
Visibility	Raparin	3.89	0.454
	Nanakali	3.75	0.235
Time Spent	Raparin	3.56	0.357
	Nanakali	4.10	0.316
Wayfinding	Raparin	4.19	0.492
	Nanakali	3.92	0.312

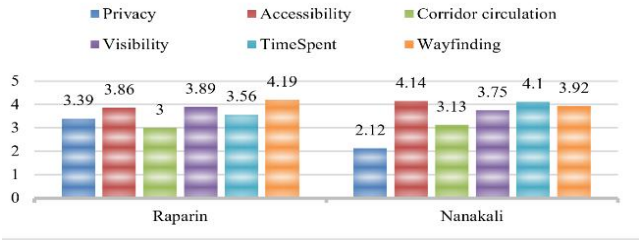

Figure 6. Podular ED's factors mean.

While Table 2 shows that in ballroom typology, Zanko ED has the highest value of (4.52) regarding accessibility with (4.01) in the corridor circulation factor, this will indicate the ease of circulation in this layout. Also, PAR ED has the highest value of (4.52) in the visibility factor, see Fig. 7.

Table 2. Mean of ballroom ED's factors based on patient feedback

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Ballroom layout typology hospitals			
Factors	**Hospital**	**Mean**	**Std. Deviation**
Privacy	Zanko	3.28	0.340
	PAR	3.25	0.273
	Rozh-Halat	2.12	0.417
Accessibility	Zanko	4.52	0.281
	PAR	4.44	0.346
	Rozh-Halat	4.16	0.360
Corridor Circulation	Zanko	4.01	0.274
	PAR	3.37	0.293
	Rozh-Halat	2.88	0.455
Visibility	Zanko	3.16	0.294
	PAR	4.52	0.366
	Rozh-Halat	3.85	0.481
Time Spent	Zanko	4.19	0.281
	PAR	4.30	0.314
	Rozh-Halat	3.31	0.462
Wayfinding	Zanko	4.08	0.492
	PAR	4.34	0.321
	Rozh-Halat	3.25	0.397

As shown in Table 3, in the linear typology, Swedish ED has the highest value of (4.52) in the privacy factor with (4.71) in the time spent factor, which proved that patients spend less time with high privacy in Swedish hospital. Also, in this layout Maternity ED has the highest value of (4.53) in the wayfinding factor, see Fig. 8.

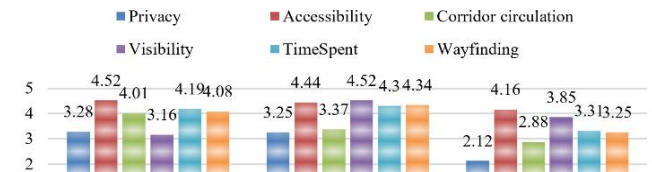

Figure 7. Ballroom ED's factors mean.

Table 3. Mean of linear ED's factors based on patient feedback.

Linear layout typology hospitals			
Factors	**Hospital**	**Mean**	**Std. Deviation**
Privacy	Sardam	3.11	0.290
	Swedish	4.52	0.353
	Maternity	2.48	0.408
Accessibility	Sardam	4.12	0.201
	Swedish	4.10	0.370
	Maternity	4.30	0.206
Corridor Circulation	Sardam	3.26	0.297
	Swedish	3.41	0.388
	Maternity	3.14	0.298
Visibility	Sardam	3.11	0.661
	Swedish	4.20	0.353
	Maternity	2.63	0.530
Time Spent	Sardam	4.21	0.377
	Swedish	4.71	0.160
	Maternity	3.31	0.309
Wayfinding	Sardam	3.82	0.432
	Swedish	4.15	0.399
	Maternity	4.53	0.899

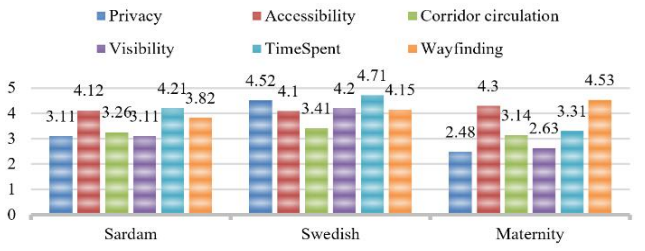

Figure 8. Linear ED's factors mean.

In comparison between the ED typologies, Table 4 shows the mean of each factor for each ED typology, where the greater factor for each ED typology is chosen. Based on the patient questionnaire, the ballroom ED layout typology has a high degree of (accessibility, visibility, and corridor circulation). As the accessibility values obtained from questionnaire analysis, have the highest value in the ballroom layout (4.37), and the lowest was in the podular layout (4.0), the visibility factor has the highest value in the ballroom and podular layout (3.83), and the lowest was in linear layout (3.31). Furthermore, the corridor circulation factor has the highest value in the ballroom layout (3.42), and the lowest was in the podular layout (3.1). While the podular and linear ED typology both has a high degree of two variables. In podular typology, privacy and visibility variables have the highest degree of (4.45) (3.83). In linear typology, time spent and wayfinding variables have the highest degree of (4.04) (417).

Table 4. Mean of ED layout typology factors based on patient feedback.

Factors	Typologies	Mean	Std. Deviation
Privacy	Podular	4.45	0.37
	Ballroom	2.88	0.34
	Linear	3.37	0.35
Accessibility	Podular	4.0	0.32
	Ballroom	4.37	0.33
	Linear	4.17	0.26
Corridor Circulation	Podular	3.1	0.33
	Ballroom	3.42	0.34
	Linear	3.27	0.33
Visibility	Podular	3.83	0.34
	Ballroom	3.83	0.38
	Linear	3.31	0.51
Time spent	Podular	3.83	0.48
	Ballroom	3.93	0.35
	Linear	4.04	0.282
Wayfinding	Podular	4.0	0.40
	Ballroom	3.89	0.40
	Linear	4.17	0.58

In comparison to other ED layout typologies, the ballroom typology is considered to be the best typology, while podular and linear both came in second place due to their similar number of available factors, see Fig. 9.

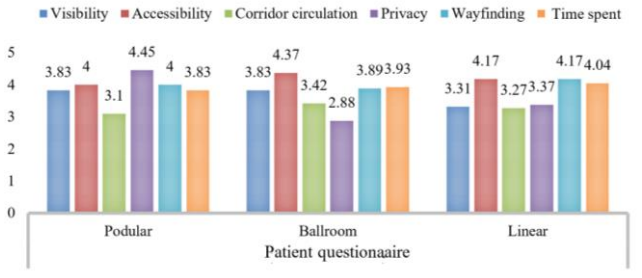

Figure 9. Mean of ED layout typology factors based on patient feedback.

8. Conclusion

The design of floor plans and circulation systems for effective privacy, accessibility, wayfinding, and many other factors within the building is both a difficult and complex task, which requires great importance in architectural design. For this, the design of ED built according to effective systems and typologies plays a major role in facilitating patients to achieve their treatment easily and provide higher satisfaction levels, thus contributing to the creation of an efficient and developed healthcare system. The current research focused on the spatial configuration of ED in Erbil city hospitals and analyzed three different ED layout typologies with the assessments obtained from the patient survey. Findings obtained from the assessments of patients' feedback effectively contributed to indicating the impact of the spatial layout of ED on its functional performance efficiency. Based on the patient feedback analysis, the following findings were obtained:

- The analyses showed a clear preference for the ballroom layout typology compared to podular and linear typologies due to the achievement of high values in most factors adopted for measurement in the research. Ballroom layout is a more functionally efficient typology due to the high accessibility, visibility, and corridor circulation value compared to podular and linear typologies. This means that this typology is less deep and is the easiest layout to reach. Also, in terms of visibility, this typology has more visibility between patients and staff which enhances staff awareness of patient conditions and prevents unsafe behaviors. The high level of corridor circulation in this typology indicates its ease of circulation. On the contrary, we see that podular typology has the least accessibility and corridor circulation among all cases, and linear typology has the least visibility among all cases.

- Assessments regarding the other two typologies, podular and linear, are considered similar in the number of factors achieved, as each has two factors and is considered the second typologies in making ED more functional to improve patient satisfaction.

- The podular typology has the highest value of privacy and visibility, this means that this layout allows for greater visibility between the staff and patients than linear typology, and patients have more privacy. On the contrary, the ballroom typology has the least value of privacy and linear typology has the least value of visibility among all cases.

- As for time spent and wayfinding factors, the linear layout typology has the highest value of both factors which proved that patients spend less time in linear layout because of its easy wayfinding.

- As indicated by the outcomes of the one-way ANOVA test in (Tables 1,2, and 3). The availability of functional performance factors in eight EDs was accepted by patients but to varying degrees, this proves the first hypothesis (The factors of functional performance are available in the EDs of Erbil hospitals to varying degrees due to their different spatial configurations). Thus, this difference in value causes the difference between hospitals in their outcomes based on their factor's value, this proves the second hypothesis (Considering the ED functionality, various ED layout typologies provide different outcomes).
- Data derived from the patient questionnaires analysis can be used to measure factors and variables associated with the spatial configurations of ED layout typologies, such as wayfinding, accessibility, privacy, visibility, time spent-length of stay (LOS), and corridor circulation. In terms of giving satisfaction and making the department more functionally effective.

- Overall, research findings show the significance and effectiveness of the PBBD approach and functional performance serving as its main criterion in demonstrating the impact of spatial configuration and organization of ED on its functional efficiency.

In conclusion, the research findings indicate that there is a direct correlation between the layout typology of the ED and its functional performance and efficiency, as it showed that the variation in the configurations creates a difference in their functionality, based on the study factors. The study results provide a wonderful guide for healthcare designers in their future works, especially in ED areas, provided the influential role of ED typology in creating a safe, comfortable, and healthy indoor environment for the staff working and patient satisfaction, as well as preventing space overcrowding.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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