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Analysis of Bed Utilization Efficiency of Intensive Care Units with Pabon Lasso Model

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ABSTRACT

Purpose: This study aimed to evaluate the efficiency of intensive care units in a public university hospital in Türkiye from 2015 to 2024.

***Methodology*:** In this study, the efficiency of the anesthesia, emergency, paediatric, general surgery, ınternal medicine, cardiology, neurology, neurosurgery, neonatal and cardiovascular surgery intensive care units of a public university hospital in Türkiye was evaluated. The efficiency of ICUs for the period 2015-2024 was analyzed using the Pabon Lasso Model. The assessment was conducted using the following indicators: bed turnover rate, bed occupancy rate, and average length of stay.

Findings: The study determined that the highest number of emergency and cardiology intensive care units were found in the efficient region over the years. The bed occupancy rate of the cardiology unit decreased over time and moved to the second region. The bed occupancy rate of the emergency intensive care unit improved over time and moved to the efficient region. However, the cardiovascular surgery unit was found to be in the inefficient region in all years.

Originality: The study evaluated the ten-year effectiveness of a university hospital's intensive care units using the Pabon Lasso model. The fact that no research in this context exists in the literature expresses the study's originality.

Keywords*:* Efficiency, Hospital, Intensive Care, Performance, Productivity.

JEL Codes: I1, I15, I18.

Yoğun Bakım Ünitelerinin Yatak Kullanım Etkinliğinin Pabon Lasso Modeli ile Analizi

ÖZET

Amaç: Bu çalışmanın amacı, Türkiye'de bir üniversite hastanesinin yoğun bakım ünitelerinin 2015-2024 yılları arasındaki etkinliğini değerlendirmektir.

***Yöntem*:** Bu çalışmada, Türkiye'deki bir kamu üniversitesi hastanesinin anestezi, acil, çocuk, genel cerrahi, dahiliye, kardiyoloji, nöroloji, nöroşirürji, yenidoğan ve kalp damar cerrahisi yoğun bakım ünitelerinin verimliliği değerlendirilmiştir. Yoğun bakım ünitelerinin 2015-2024 dönemi etkinliği, Pabon Lasso Modeli kullanılarak analiz edilmiştir. Değerlendirme yatak devir hızı, yatak doluluk oranı ve ortalama kalış günü göstergeleri ile yapılmıştır.

Bulgular: Araştırmada yıllar itibariyle verimli bölgede en fazla acil ve kardiyoloji yoğun bakım ünitelerinin bulunduğu saptanmıştır. Kardiyoloji ünitesinin yatak doluluk oranı zamanla düşerek ikinci bölgeye geçmiştir. Acil yoğun bakım ünitesinin yatak doluluk oranı zamanla gelişerek etkin bölgeye geçmiştir. Bununla birlikte, kardiyovasküler cerrahi ünitesinin tüm yıllarda verimsiz bölgede bulunduğu belirlenmiştir.

Özgünlük: Araştırma, bir üniversite hastanesinin yoğun bakım ünitelerinin on yıllık etkinliği Pabon Lasso modeli ile değerlendirmiştir. Literatürde bu kapsamda bir araştırmaya rastlanmamış olması çalışmanın özgün değerini ifade eder.

Anahtar Kelimeler*:* Etkinlik, Hastane, Yoğun Bakım, Performans, Verimlilik.

JEL Kodları: I1, I15, I18.

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INTRODUCTION

The sustainability of hospitals, which are important building blocks of healthcare systems, depends on their successful management. This reminds me of management guru Peter Drucker's statement, “You can't manage what you don't measure”. This emphasizes the importance of measurement in the management process. The assessment results obtained by measuring the current situation benefit managers by enabling them to identify the aspects of organizations that need improvement. Furthermore, given the increasing demand for healthcare services and the need for financial prudence, the importance of efficiency measurement in hospitals cannot be overstated. Efficiency measurement is, therefore, an essential tool for sustainable hospitals. The efficiency of hospitals can be assessed in terms of all inputs and outputs used in service delivery. For example, the efficiency of health personnel, medical equipment, financial resources, service delivery units such as outpatient or inpatient treatment units, and various health outputs can be measured.

Evaluating the efficiency of hospitals' most critical units is a priority because these units are unable to accept errors. Yiğit (2019) emphasizes that bed utilization is an important indicator of efficiency, as it directly affects hospitals' ability to meet patients' needs. In this context, the efficiency of intensive care units (ICU), one of the most important units, is important. ICU is defined as "service units that aim to improve the care of patients who require intensive care due to serious dysfunction of one or more organs or organ systems, that have a special feature in terms of patient care in terms of physical infrastructure and location, that are equipped with advanced technological devices, where vital indicators are monitored, and where patient care and treatment are provided 24 hours a day without interruption" (Ministry of Health, 2011). According to 2022 data, Türkiye has 57.4 ICU beds per 100,000 population, the highest among OECD countries. The adult ICU Bed Occupancy Rate (BOR) will be 65.7%. (OECD, 2025). Studies show that ICUs consume between 13% and 40% of hospital operating costs (Bauman and Hyzy, 2012; Kim et al., 2015). The need to measure efficiency is understood because, due to their specialized nature, ICU resources are among the most limited in hospitals (Cuadrado et al., 2023).

Lasso (1986) developed the Pabon Lasso model in 1986, which evaluates the efficiency of general hospital and intensive care beds. The Pabon Lasso model is a widely used statistical tool for assessing hospital performance by analyzing specific efficiency indicators. The efficiency indicators used in the analysis are BOR, Bed Turnover Rate (BTR), and Average Length of Stay (ALS). The model uses a graphical method to provide a visual assessment of each hospital's relative efficiency. The graph is divided into four quadrants (Lasso, 1986), which are determined by the average values of BOR and BTR and classify hospitals ranging from under-utilization (low BOR and low BTR) to over-utilization (high BOR and high BTR). The units whose efficiency is assessed are positioned in one of the four regions in the graph according to their relative efficiency status. Thus, the efficiency status of the evaluated units can be easily understood visually. It also allows for comparing units such as evaluated periods, hospitals, and clinics.

As demonstrated in Table 1, a significant number of studies have employed the Pabon Lasso model to assess the efficiency of various hospitals and healthcare units. However, despite the paucity of studies evaluating the technical efficiency of ICUs (Dedecan and Torun, 2023; Göktaş and Yalçın Balçık, 2024), a range of methodologies has been employed in these studies. Conversely, studies evaluating the effectiveness of the ICU using the Pabon Lasso model are similarly limited in scope.

The present study analysed the effectiveness of ICUs in teaching research hospitals (Esen and Yiğit, 2021; Leblebici et al., 2019). In contrast to the extant literature, the present study focuses on a public university hospital. In this context, the study aims to evaluate the efficiency of the ICUs of a public university hospital in Türkiye for the period 2015-2020 using the Pabon Lasso Model. At this juncture, the study is regarded as original. The study compares the efficiency of intensive care units over the course of the research period. In the following section, the importance of the research is addressed, after which the literature review, methods, findings, and conclusions are presented.

2. LITERATURE REVIEW

Table 1 summarizes the studies evaluating the efficiency of hospitals using the Pabon Lasso model. This model is widely used to measure efficiency in different countries, especially in Iran and Türkiye. The studies found that the Pabon Lasso model has been used to evaluate the bed utilization efficiency of different hospital groups, health groups, inpatient treatment units, health regions, and countries. Several studies have been conducted that analyse changes in the efficiency of hospitals or units over time. The findings of these studies indicate that the efficiency of the units under comparison exhibits a fluctuating trend over time. A review of the extant literature focusing on hospitals has revealed that the proportion of hospitals in the effective region varies between 3% and 50% (Table 1). This finding suggests that the efficiency of hospitals is subject to significant variation.

Table 1. Literature review

Author (year)	*Data Year*	*Scope*	*Result*
Köse (2024)	2020-2021	Hospitals in European Union member states	Hospitals in Germany, Estonia, Italy, Latvia, and Austria are in the efficient region.
Samsudin et al. (2024)	2014, 2018	Hospitals in Malaysia	Thirty-nine percent of hospitals in 2014 and 36 percent in 2018 are in the efficient region.
Malekzadeh et al. (2023)	2019-2020	Hospitals in Northern Iran	Seventeen percent of hospitals are in the efficient regions.
Çırak et al. (2023)	2019	Health regions in Türkiye	The Mediterranean and Southeastern Anatolia Regions in the efficient region.
Leblebici et al. (2019)	2017-2018	Neonatal ICU of a teaching hospital in Türkiye	Neonatal ICU is in the efficient region.
Esen (2023)	2018-2021	Internal and surgical clinics in Türkiye	Neurology, Obstetrics and Gynaecology (O&G), Otorhinolaryngology in 2018; Paediatrics, Gastroenterology, Neurology, O&G in 2019; Gastroenterology, Nephrology, Neurology, Medical Oncology, and Ophthalmology in 2020; Gastroenterology, Neurology, O&G, Ophthalmology in 2021 in the efficient region.
Işıkçelik and Ağırbaş (2023)	2018-2021	Ministry of Health Hospitals in Türkiye	38% of AI group hospitals, 36% of AII group, and 32% of B group hospitals are in the efficient region.
Mahmoodpour-Azari et al. (2022)	2019	Hospitals in Iran	35% of hospitals are in the efficient region.
Roshani et al. (2022)	2015-2019	Hospitals in Iran	33% of hospitals are in the efficient region.
Medaravic (2022)	2019-2020	Hospitals in the former Yugoslavia	The percentage of top-performing hospitals within the territory varied between 20% and 43%.
Yılmaz (2022)	2008-2018	A teaching hospital in Türkiye	The hospital is in the efficient region in 2014 and 2015.
Konca et al. (2022)	2017	Secondary public hospitals in Türkiye	3% of the hospitals are in the efficient region.
Esen and Yiğit (2022)	-	Public hospitals in the Mediterranean Region	32% of the hospitals are in the efficient region.
Shaqura et al. (2021)	2016-2018	Surgical and internal departments of hospitals in Gaza	42.8% of surgical departments and 28.6%-42.8% of internal departments are in the efficient regions.
Esen and Yiğit (2021)	2017-2018	ICUs of a teaching hospital in Türkiye	Of the intensive care units, 30% were in the efficient region in 2017 (Anaesthesia and Reanimation, Surgical, Coronary ICU), and 20% in 2018 (Internal, Coronary ICU).
Aloh et al. (2020)	2011-2016	Teaching hospitals in Southeast Nigeria	Only 10-20% of hospitals were in the efficient region during the survey years.
Taşkaya (2020)	2017	Training and research hospitals in Türkiye	30.5 percent of hospitals are in the efficient region.
Taşkaya (2019)	2014, 2017	Affiliated hospitals in Türkiye	18% of hospitals in 2014 and 29% in 2017 were in the efficient region.
Yiğit (2019)	2017	Pediatric clinics in Türkiye	38% of pediatric clinics (pediatric surgery, urology, pediatric health and diseases, hematology and oncology, endocrinology, and chest diseases) are in the efficient region.
Boz et al. (2018)	2014	Public Hospitals Unions in Türkiye	26% of hospitals are located in the efficient region.
Yiğit and Esen (2017)	2015	Public hospitals in Antalya	50% of hospitals are located in the efficient region.
Yiğit (2017)	2014	Clinics of the Ministry of Health hospitals in Türkiye	23% of clinics (Obstetrics and Gynaecology, Cardiology, Plastic and Aesthetic Surgery, Urology) are in the efficient region.
Yıldız (2017)	2002-2015	Hospitals in Türkiye (Ministry of Health, University, Private)	Ministry of Health hospitals were in the efficient region from 2011 to 2015.
Qodoosinejad et al. (2017)	2009-2013	Hospitals in Tabriz	26% of hospitals are in the efficient region.
Çalışkan (2016)	2014	Public Hospitals Unions in Türkiye	Twenty-five percent of the units are in the efficient region.
Tripathi et al. (2016)	2007-2014	Psychiatric, neurological, neurosurgery services in a tertiary care hospital	Psychiatry and Neurosurgery in 2014 and Neurology in 2007 are in the efficient region.

A study of Türkiye's regional efficiency, conducted in the context of the Mediterranean and Southeast Anatolia regions, has yielded notable findings (Çırak et al., 2019). A study was conducted to evaluate Turkish hospitals according to ownership and to determine the relative efficiency of different hospital types. The study's findings indicated that Ministry of Health hospitals demonstrated a higher level of efficiency compared to other hospital types (Yıldız, 2017). In single or multi-period studies examining clinics, clinics in effective regions have both similarities and differences (Esen, 2023; Shaqura et al., 2021; Tripathi et al., 2016; Yiğit, 2017; Yiğit, 2019). The extant literature demonstrates a paucity of studies evaluating the efficiency of ICUs, with those that do exist focusing on the ICUs of teaching hospitals (Esen ve Yiğit, 2021; Leblebici et al., 2019). This observation underscores a paucity of data concerning the efficiency of intensive care in university hospitals and other hospital groups, thereby highlighting a substantial research deficit in this domain. In view of the extensive and intricate nature of the treatment services furnished in ICUs, the evaluation of the efficacy of such units assumes paramount importance. University hospitals exhibit a distinct organisational structure when compared to other hospital types. This distinction arises from the advanced healthcare services they provide, in addition to their educational and research functions.

Consequently, the study's emphasis on university hospitals addresses a significant gap in the existing literature by facilitating the evaluation of both patient care and the quality of academic and professional education.

3. METHODOLOGY

In this study, the efficiency of the Anesthesia ICU (I1), Emergency ICU (I2), Paediatric ICU (I3), General Surgery ICU (I4), Internal Medicine ICU (I5), Cardiology ICU (I6), Neurology ICU (I7), Neurosurgery ICU (I8), Neonatal ICU (I9), and Cardiovascular Surgery ICU (I10) units of a public university hospital in Türkiye was evaluated. The efficiency of ICUs for the period 2015-2024 was analyzed using the Pabon Lasso Model, a widely accepted tool for evaluating the efficiency and efficiency of healthcare units. Within the scope of the Pabon Lasso model, the assessment was conducted based on the BOR, BTR, and ALS indicators. This descriptive and cross-sectional study utilised secondary data. The research data was obtained from the hospital information management system in an Excel file. The data concerning the BOR, BTR, and ALS indicators for the ICUs encompassed within the study for the period 2015–2024 are complete, with no data loss. Examining the scope of the data, BOR shows the utilisation rate of patient beds over time. BTR refers to the number of patients using a patient bed. ALS is the average number of days a patient stays in hospital (OECD, 2025). The analysis was conducted on an individual annual basis, with the results visualised through the utilisation of Pabon Lasso graphs. The Pabon Lasso graph, which consists of the BOR, BTR, and ALS indicators, is shown in Figure 1. The X-axis of the graph shows BOR, and the Y-axis shows BTR. The average BOR line is drawn on the X-axis, and the average BTR line is drawn on the Y-axis. These lines divide the Pabon Lasso graph into four quadrants. Region 1 on the graph is inefficient, expressing low BOR and BTR. Region 2 shows low BOR and high BTR. Region 3 is the efficient region, with high BOR and BTR. Region 4 represents low BTR and high BOR. The evaluated ICUs are placed on the graph according to their BOR and BTR values. The lines drawn on the points representing the ICU on the graph are ordered from the left to the right of the graph, from the shortest to the longest.

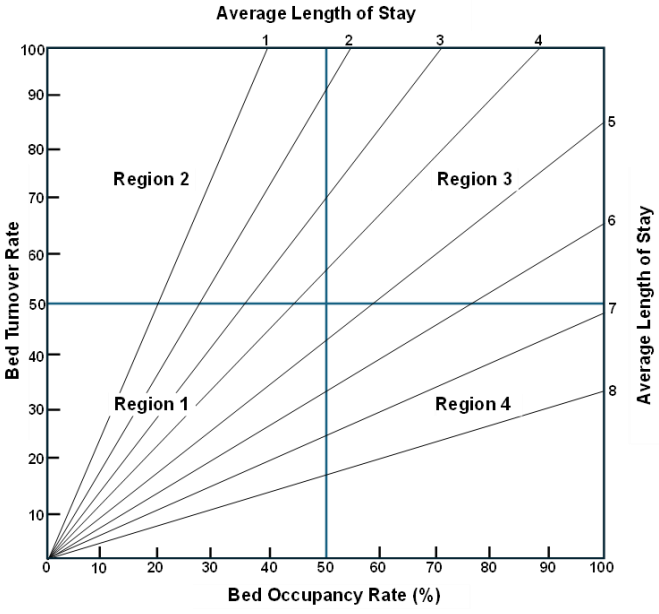


Figure 1. Pabon Lasso modeli (Lasso, 1986)

The Pabon Lasso Model used in this study has certain methodological limitations. The model measures effectiveness relatively and does not reveal absolute levels of effectiveness. In other words, the effectiveness of the ICUs within the scope of the study can be evaluated relative to each other. However, no direct inference can be made about the absolute level of effectiveness of each ICU. Changes in the ICUs addressed in the research may alter the research results. Furthermore, the model is based solely on BOR, BTR, and ALS indicators. It assesses the effectiveness of ICUs within the framework of these three indicators (Lasso, 1986). It is important to consider these limitations when evaluating the research findings.

4. RESULTS

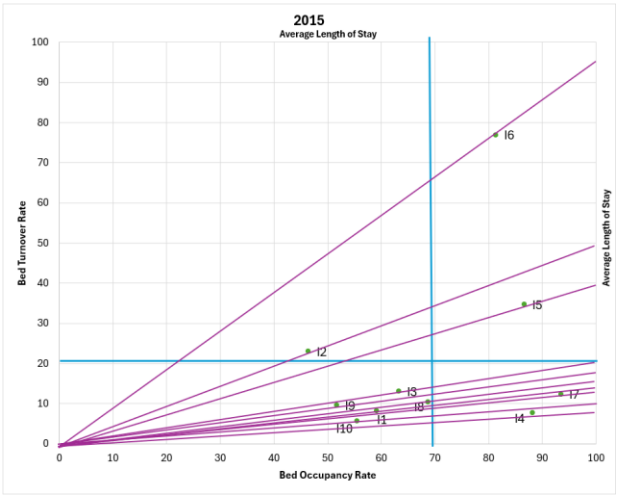
This study analyzed the efficiency of ICUs in a public university hospital. Table 2 shows descriptive statistics of the ICUs' BTR, BOR, and ALS values. The highest average BTR of the hospital was in 2023, while the lowest was in 2015. The highest BTR values of ICUs belong to I6 from 2015 to 2018 and 2024 and I2 from 2019 to 2023. The lowest BTR values were I10 in 2015-2016, I4 in 2017-2018, 110 in 2019-2023, and I3 in 2024. The highest average BOR of the hospital is in 2022, while the lowest is in 2020. The highest BOR values of the ICUs were I7 in 2015, I4 in 2016, I6 in 2017, I2 in 2018-2020 and 2023, and I5 in 2021, 2022, and 2024. The hospital's average ALS is shortest in 2021 and longest in 2019. The ICUs with the shortest ALS were I6 from 2015 to 2019, I2 from 2020, and I5 from 2021 to 2024. The longest ALS ICUs were I4 from 2015 to 2018, I10 in 2019 and 2020, I7 in 2021 and 2022, I9 in 2023, and I3 in 2024.

Figure 2 shows the Pabon-Lasso graphs of the ICUs for the period 2015-2024. In 2015, I1, I3, I8, I9, and I10 were in the first region (inefficient region), I2 in the second region, I5 and I6 in the third region (efficient region), and I4 and I7 in the fourth region. This year's graph shows that the ALS of ICUs is ranked from shortest to longest as I6, I2, I5, I3, I9, I8, I1, I7, I10, and I4. In 2016, II, I9, and I10 are in inefficient region 1, I2 in the second region, I5 and I6 in the efficient region, and I3, I4, I7, and I8 in the fourth region. This year's graph shows that the ALS is ranked from shortest to longest as I6, I2, I5, I3, I7, I9, I8, I1, I10 and I4. In 2017, I1, I3, I9, and I10 were in the inefficient region, I2 in the second region, I5 and I6 in the efficient region, and I4, I7, and I8 in the fourth region. This year's graph shows that the ALS of ICUs is ranked from shortest to longest as I6, I2, I5, I3, I9, I7, I8, I1, I10 and I4. In 2018, I1, I3, I8, I9 and I10 are in the inefficient region, I2 and I6 in the efficient region, I4, I5 and I7 in the fourth region. The ALS of the ICUs this year are I6, I2, I3, I5, I9, I8, I7, I1, I10 and I4 from shortest to longest. In 2019, I1, I3, I5, I8, I9 and I10 are in the inefficient region, I2 and I6 in the efficient region, I4 and I7 in the fourth region. This year's graph shows that the ALS of ICUs is ranked from shortest to longest as I6, I2, I3, I9, I1, I5, I8, I7, I4 and I10. In 2020, I1, I4, and I10 are in inefficient region, I2 and I6 are in the efficient region, and I3, I5, I7, I8, and I9 are in the fourth region. This year's graph shows that the ALS is ranked from shortest to longest as I2, I5, I1, I6, I4, I3, I9, I8, I7 and I10. In 2021, I1, I3, I4, I8, I9 and I10 are in inefficient region, I2 and I6 are in the efficient region, I5 and I7 are in fourth region. This year's graph shows that the ALS of ICUs is ranked from shortest to longest as I5, I2, I6, I4, I1, I8, I3, I9, I10 and I7. In 2022, I3, I7, I9, and I10 are in the inefficient region, I6 is in the second region, I2 is in the efficient region, and I1, I4, I5, and I8 are in the fourth region. This year's graph shows that the ALS of ICUs is ranked from shortest to longest as I5, I2, I4, I6, I9, I1, I3, I8, I10 and I7. In 2023, I3, I4, I8, and I10 are in the inefficient region, I6 is in the second region, I2 is in the efficient region, and I1, I5, I7, and I9 are in the fourth region. This year's graph shows that the ALS of ICUs is ranked from shortest to longest as I5, I2, I8, I1, I4, I6, I3, I7, I10 and I9. In 2024, I3, I4, I9, and I10 are in the inefficient region, I6 in the second region, I2 in the efficient region, and I3, I5, I7, and I8 in the fourth region. This year's graph shows that the ALS is ranked from shortest to longest as I5, I2, I4, I1, I6, I9, I8, I10, I7 and I3.

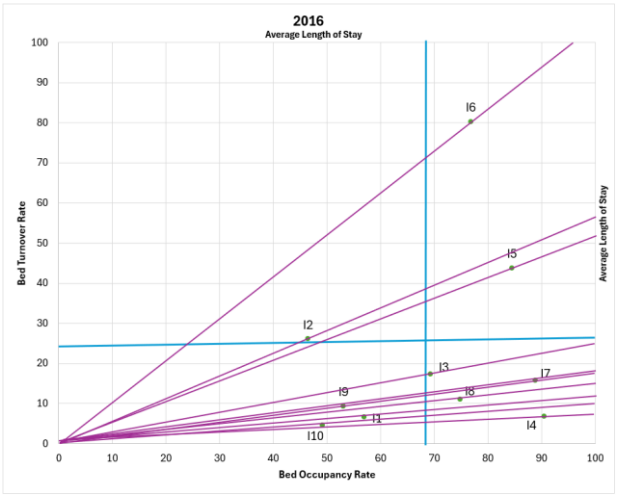
Table 2. Descriptive statistics

Year	*ICU*	*I1*	*I2*	*I3*	*I4*	*I5*	*I6*	*I7*	*I8*	*I9*	*I10*	*Minimum*	*Maximum*	*Mean*	*Standart Deviation*
2015	ALS	26.28	7.39	17.76	42.07	9.13	3.86	27.67	24.21	19.77	36.39	3.86	42.07	21.45	12.44
	BTR	8.22	22.94	13.00	7.65	34.63	76.90	12.33	10.36	9.55	5.57	5.57	76.90	20.12	21.78
	BOR	59.18	46.45	63.27	88.16	86.61	81.37	93.49	68.74	51.71	55.53	46.45	93.49	69.45	16.82
2016	ALS	31.08	6.51	14.65	48.19	7.05	3.50	20.71	24.61	20.80	39.14	3.50	48.19	21.62	14.65
	BTR	6.69	26.06	17.25	6.85	43.75	80.20	15.67	11.09	9.31	4.59	4.59	80.20	22.15	23.54
	BOR	56.99	46.45	69.25	90.49	84.45	76.79	88.89	74.79	53.05	49.18	46.45	90.49	69.03	16.64
2017	ALS	32.98	5.29	12.79	76.65	10.84	4.11	21.27	22.19	20.74	43.52	4.11	76.65	25.04	21.83
	BTR	6.13	37.12	16.81	4.11	26.38	79.11	15.22	12.64	11.16	4.48	4.11	79.11	21.32	22.76
	BOR	55.43	53.76	58.90	86.33	78.32	89.16	88.71	76.81	63.43	53.42	53.42	89.16	70.43	14.96
2018	ALS	37.72	4.36	16.68	85.83	23.62	3.56	33.08	28.44	23.88	42.00	3.56	85.83	29.92	23.44
	BTR	3.89	76.35	14.06	3.15	11.00	88.67	6.61	9.45	8.49	3.98	3.15	88.67	22.56	31.91
	BOR	40.22	91.27	64.28	74.00	71.19	86.45	59.87	73.67	55.51	45.75	40.22	91.27	66.22	16.44
2019	ALS	30.96	3.42	18.73	82.48	31.78	3.24	41.17	37.61	26.23	87.67	3.24	87.67	36.33	28.73
	BTR	6.13	102.06	13.19	4.08	7.67	100.78	7.25	5.83	7.99	2.00	2.00	102.06	25.70	40.01
	BOR	51.99	95.52	67.69	92.08	66.75	89.56	81.78	60.11	57.41	48.12	48.12	95.52	71.10	17.40
2020	ALS	18.02	2.66	20.48	20.73	12.62	3.45	25.86	31.91	18.92	33.12	2.66	33.12	18.78	10.37
	BTR	8.11	122.59	11.17	5.87	18.94	68.63	10.99	7.00	14.52	3.68	3.68	122.59	27.15	38.51
	BOR	40.07	89.38	62.65	33.32	65.47	64.95	77.88	61.20	75.24	33.36	33.32	89.38	60.35	19.14
2021	ALS	16.27	3.54	20.82	25.46	16.92	3.25	17.93	29.23	16.67	27.76	3.25	29.23	17.79	8.93
	BTR	16.89	98.29	12.08	9.78	22.17	92.15	19.29	9.56	15.81	3.92	3.92	98.29	29.99	34.81
	BOR	75.28	95.42	68.93	68.20	99.22	82.15	94.79	76.53	72.20	29.81	29.81	99.22	76.25	19.91
2022	ALS	16.16	3.23	19.41	17.60	17.67	2.85	23.24	33.43	15.47	29.05	2.85	33.43	17.81	9.70
	BTR	19.04	109.29	12.42	21.58	22.20	92.08	11.52	10.83	17.45	6.93	6.93	109.29	32.33	36.59
	BOR	84.29	96.62	66.03	91.03	99.79	71.84	73.37	99.22	73.95	55.11	55.11	99.79	81.12	15.37
2023	ALS	23.74	2.54	26.40	30.85	17.33	1.94	17.28	29.18	17.64	30.40	1.94	30.85	19.73	10.62
	BTR	13.17	179.09	10.08	6.76	17.50	101.29	17.74	7.56	15.63	6.17	6.17	179.09	37.50	57.30
	BOR	85.70	97.89	72.92	57.13	83.09	53.80	83.99	60.40	75.53	51.42	51.42	97.89	72.19	15.80
2024	ALS	17.65	3.61	36.63	18.38	16.36	2.00	18.85	32.38	15.55	23.93	2.00	36.63	18.53	10.85
	BTR	20.75	92.12	6.53	11.12	20.91	114.89	15.77	11.33	16.47	7.65	6.53	114.89	31.75	38.50
	BOR	92.64	91.04	65.57	56.00	93.71	63.10	81.41	86.18	70.14	50.14	50.14	93.71	74.99	16.05

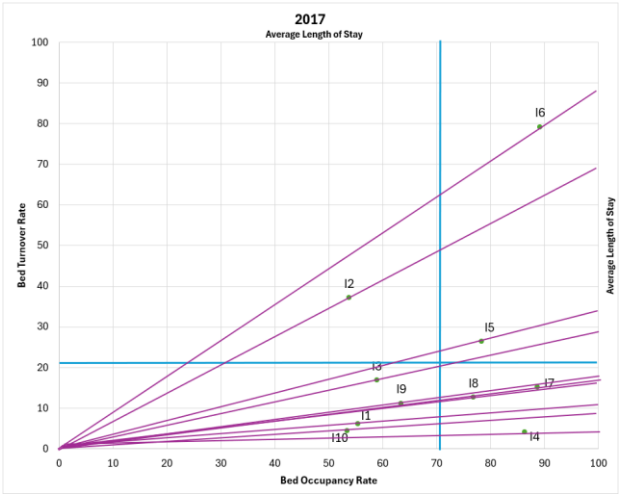
ALS: Average Length of Stay, BTR: Bed Turnover Rate, BOR: Bed Occupancy Rate



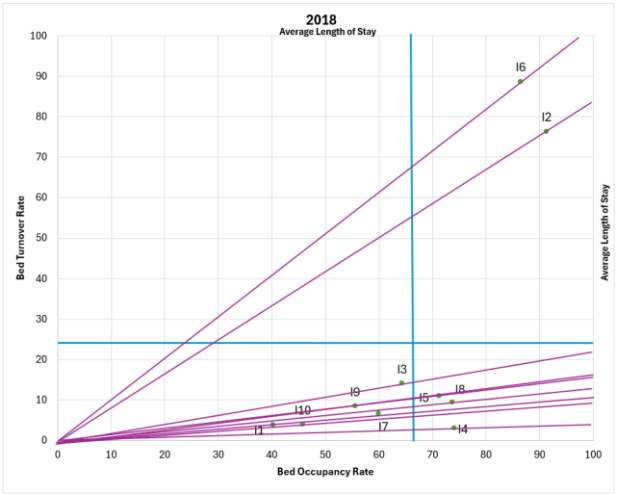
(a) 2015



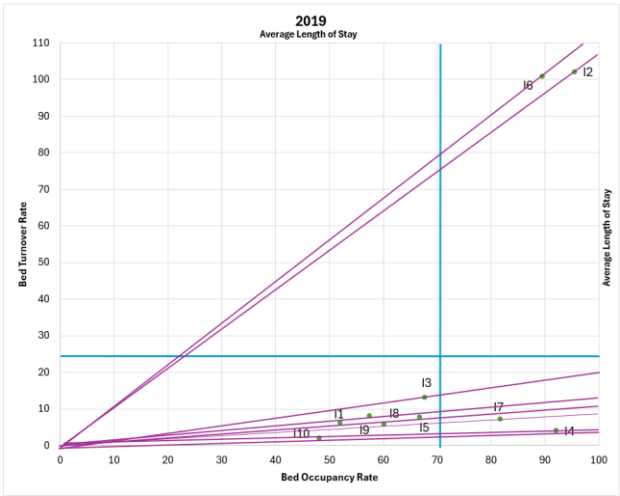
(b) 2016



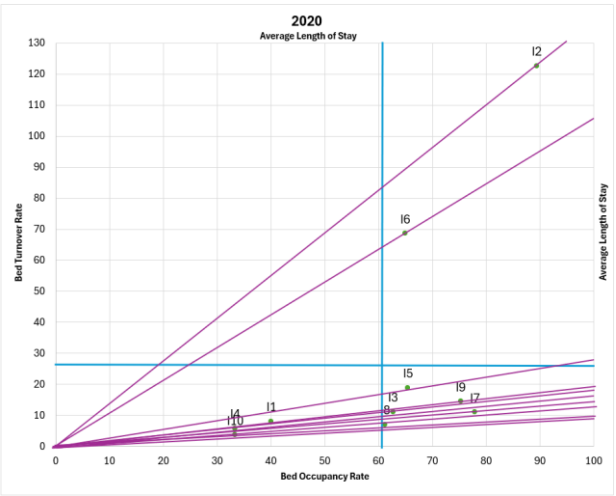
(c) 2017



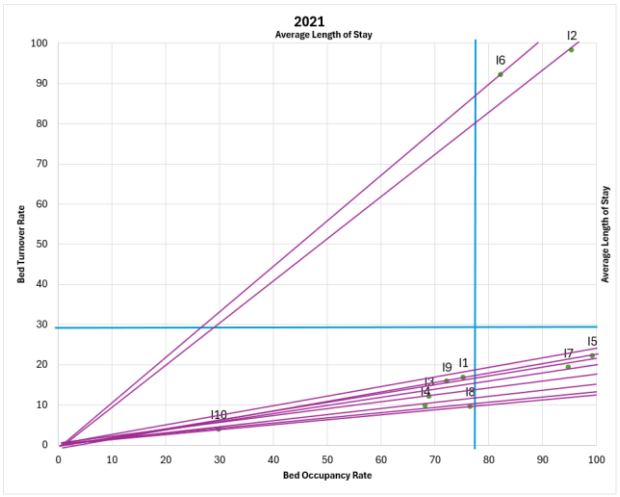
(d) 2018



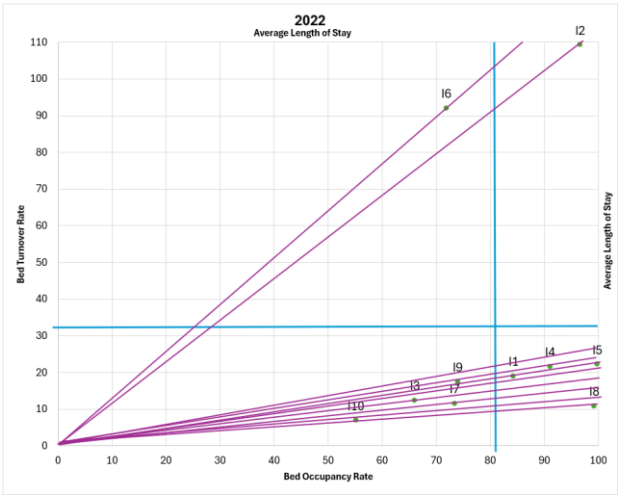
(e) 2019



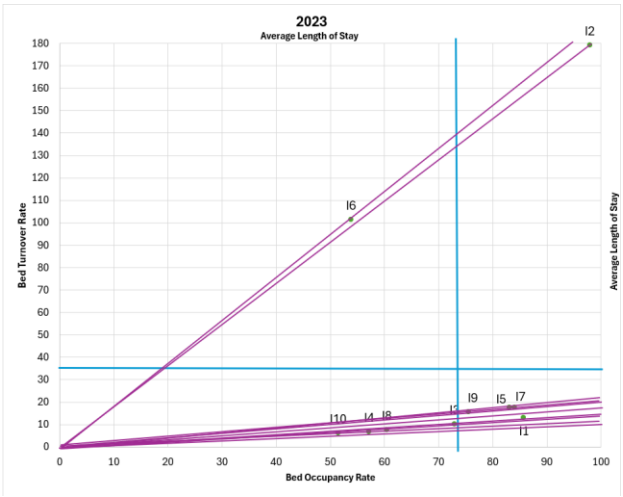
(f) 2020



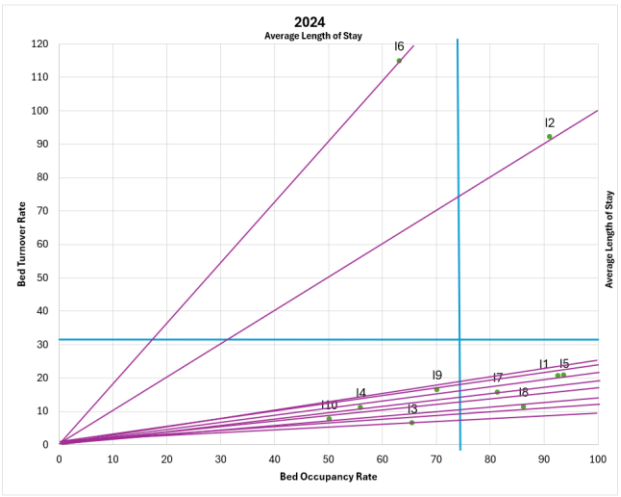
(g) 2021



(h) 2022



(ı) 2023



(i) 2024

Figure 2. Pabon Lasso graphs for 2015-2024

5. DISCUSSION and CONCLUSION

As healthcare services advance, the role of ICUs continues to grow. The management of acute conditions and the increasing prevalence of chronic diseases, coupled with an aging population, have heightened the demand for intensive care (Duke et al., 2014). The presence of ICUs contributes to reducing overall healthcare costs by enabling effective management of complex cases and preventing complications. Effective intensive care interventions can decrease the need for long-term rehabilitation following critical illnesses, thereby reducing long-term healthcare expenditures (Costa et al., 2019; Ely, 2004). Therefore, the efficient and sustainable provision of critical care services in ICUs is of paramount importance.

This study evaluated the efficiency of the ICUs of a university hospital in Türkiye from 2015 to 2024. The average ALS in the hospital fluctuated between 17.79 and 36.33 days over the years. The shortest ALS values are in 2021 and 2022 when the Covid-19 pandemic was effective. It is likely that the reduction in the length of patients' hospital stays due to protective measures during the pandemic will impact this situation. On a branch basis, the longest ALS belongs to the general surgery ICU, cardiovascular surgery ICU, neurosurgery ICU, and anesthesia ICU. The shortest ALS belongs to the cardiology ICU and emergency ICU. Surgical ICUs have the longest ALS, while medical ICUs have the shortest. Patients typically take longer to stabilize in surgical ICUs, so a longer ALS is expected. A study evaluating the ICUs of a training and research hospital found that the longest ALS is in the Neurology and Neonatal ICUs (Esen and Yigit, 2021). In this study, Neonatal ICU ALS of university hospital was 15-26 days, while the same value was calculated as 10.6-10.1 days in a training and research hospital (Leblebici et al., 2019).

The average BOR of the hospital was at its lowest in 2020 (60.35%) and at its highest in 2022 (81.12%). The low BOR in 2020 was largely due to the postponement of healthcare services for non-COVID-19

conditions during the peak of the pandemic, whereas the high BOR in 2022 reflects the renewed demand for these services and the treatment of previously deferred cases (Ministry of Health, 2023). Cardiovascular surgery ICUs had the lowest occupancy, while internal medicine ICUs had the highest. The high occupancy in the latter is attributable to the primary treatment of patients infected with the COVID-19 virus in the ICU for Internal Medicine. The average occupancy rate for adult intensive care in Türkiye's ICUs in 2023 was 65.7 (Ministry of Health, 2023), with higher rates observed in the Anesthesia, Emergency, Internal Medicine, and Neurology ICUs in the same year. A study of the ICUs of a tertiary hospital revealed that the BOR of the Surgical ICU was higher than that of the Internal ICU (Esen and Yigit, 2021). Leblebici et al. (2019) found the BOR of the Neonatal ICU in a training and research hospital to be between 85.24% and 66.19%. However, in this study, the BOR varies between 51-75% according to years. This study revealed a general trend of higher BORs for ICUs belonging to internal medicine departments. The BTR of the hospital demonstrated variability over the years, ranging from 20.12 to 37.50. The lowest BTR was observed in 2015, while the highest BTR was in 2023. The observed increase in BTR over time can be attributed to the shortening of treatment times due to improvements in medical care. The units with the highest BTR are Cardiology, ICU, and Emergency ICU, while the lowest is Cardiovascular Surgery ICU. Yiğit and Esen (2021) found that the internal ICU had a higher BTR. The discrepancy likely reflects the different diseases treated in each ICU and their associated mortality rates. In this study, the Neonatal ICU of the university hospital was between 7 and 17, while another study found that it was between 30.06 and 40.12 in a training and research hospital (Leblebici et al., 2019).

According to the Pabon Lasso results, the anesthesia ICU was in the inefficient region from 2015 to 2021. However, its BOR improved from 2022 to 2024, moving it into the fourth region and indicating an overall improvement in efficiency over time. It was determined that the Emergency ICU was in the second region, which was efficient in BTR but inefficient in BOR from 2015 to 2017, and moved to the efficient region in 2018 and later. The position of the pediatric ICU has varied between the inefficient region and the fourth region over the years. The ICU experiences performance changes from time to time in terms of BOR. While General Surgery ICU was in the fourth region in 2015-2019 and 2022, it was in the inefficient region in 2020, 2021, 2023, and 2024. This situation is due to the change in BOR. While the internal medicine ICU was in the efficient region in 2015-2017, BOR activity decreased in 2018, and the ICU was in the fourth region. In 2019, BOR activity also decreased and moved to the inefficient region, and in 2020-2024, it is again in the fourth region. While the cardiology ICU was in the efficient region from 2015 to 2021, the BOR activity decreased from 2022 to 2024, and the unit moved to the second region. The neurology ICU is in the fourth region in all years except 2022. Compared to other years, it is inefficient for all indicators in 2022. In 2015, 2019, 2021, and 2023, the neurosurgery ICU was in the inefficient region. In other years, the BOR was found to be active and moved to the fourth region. The neonatal ICU was in the fourth region in 2020 and 2023 but was in the inefficient region in other years. The cardiovascular surgical ICU has been inefficient for all years**.**

Over the years, the ICUs most frequently in the efficient region were the Emergency ICU and the Cardiology ICU. While the Cardiology ICU's efficiency in terms of LOS declined over time, placing it in the second region, the Emergency ICU improved its BOR and entered the efficient region. Notably, the Cardiovascular Surgery ICU remained in the inefficient region throughout all years. Neonatal ICU and Neurology ICU were in the inefficient region 8 times, and the Anaesthesia ICU was in the inefficient region 7 times during the ten-year study period. Neonatal ICU was in the fourth region in some years (2020 and 2023), as in the study by Leblebici et al. (2019). In the study of Yiğit and Esen (2021), internal and coronary ICUs were in the efficient region, while general and neonatal ICUs were in the inefficient region. Differences in ICU efficiency among institutions providing the same level of services may be due to regional differences, periodic differences, and details of services provided.

As a result, this study evaluated the bed utilization performance of a university hospital using the Pabon-Lasso model. As mentioned in the research text, intensive care units are the most specialized units in hospitals. As such, they need to operate efficiently to provide continuous service. To this end, it is important to identify areas for improvement through efficiency analyses. A limited number of studies in the literature evaluate the efficiency of ICUs. It would be helpful to increase research in this area. For this purpose, it is recommended that the efficiency of ICUs be evaluated using both Pabon-Lasso and different analysis methods. The employment of alternative efficiency measurement models to the Pabon Lasso model has the potential to engender more comprehensive and holistic results about the efficiency of the ICU. Given that Pabon Lasso is founded on relative efficiency measurement and is thus incapable of performing absolute efficiency assessment, it is necessary to conduct research employing methods that facilitate absolute efficiency measurement. Nevertheless, absolute efficiency measurement necessitates the determination of standard effectiveness indices. Standard efficiency values for ICUs can be established based on findings obtained from an increasing number of studies on different types of effectiveness measurement. Furthermore, given that the Pabon Lasso model assesses effectiveness within the

framework of the BOR, BTR, and ALS indicators, it is important to utilise methods that also consider different indicators. In this context, the employment of varied models for the measurement of efficiency serves to enhance methodological diversity and contributes to the establishment of standard values. In addition, conducting studies in a range of hospitals or hospital groups in future research and increasing the number of studies that compare these groups will strengthen the generalisability of the findings and the validity of policy recommendations.

The findings of this article provide policymakers with important information for determining the level of efficiency of ICUs. The analyses reveal relative differences in efficiency between units and indicate potential inefficiencies in resource utilisation. Accordingly, it is recommended that bed and staff distribution in ICUs be optimised, process improvements be implemented in low-efficiency units, performance monitoring systems be regularly applied, and efficiency data be used in health policy decision-making processes. Such efficiency-focused policies will support the effective use of ICU resources, maintain service quality, and support the sustainability of the healthcare system.

Author Contributions
Ferda Işıkçelik: Literature review, Conceptualization, Methodology, Data Curation, Analysis, Writing-original draft *Derya Engin*: Modelling, Writing-review and editing

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It was declared by the authors that the tools and methods used in the study do not require the permission of the Ethics Committee.

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It was declared by the author(s) that scientific and ethical principles have been followed in this study and all the sources used have been properly cited.

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