A Process-Oriented Balanced Scorecard Framework for Enhancing Managerial Efficiency in Tunisian Hospitals

Zeineb Ben Houria*, Faten Ben Chihaoui

Abstract— **Efficient hospital management plays a critical role in enhancing healthcare system performance, especially in countries with limited resources. In Tunisia, hospital evaluation mainly relies on operational indicators that reflect service use and inpatient efficiency. This study introduces a Process-Oriented Balanced Scorecard (PO-BSC) framework to evaluate regional hospital performance in Tunisia. The model relies on eight operational indicators related to service access, patient flow, resource utilization and clinical outcomes. The indicators are normalized using a structured approach that distinguishes beneficial, non-beneficial and hybrid (threshold-based) measures. Then, a composite PO-BSC score is computed through weighted aggregation, where equal weighting was initially adopted as a baseline assumption. Based on official national hospital statistics, a comparative regional analysis is conducted to identify disparities in performance, utilization imbalances and distinct operational profiles. The analysis reveals significant disparities in operational performance across Tunisian regions. To evaluate the robustness of the model, a Monte Carlo sensitivity analysis based on Dirichlet-distributed random weights was performed. It was confirmed that the regional performance ranking remains stable under different weighting scenarios. The proposed PO-BSC framework provides a practical and reliable decision-support tool for hospital performance benchmarking and regional health policy planning.**

Keywords— Hospital Performance; Process oriented, Balanced Scorecard; operational efficiency; sensitivity analysis, decision support.

I. INTRODUCTION

In most national healthcare systems, hospitals represent a major concentration of financial, human and technological resources. This is why they have to implement a performance management that is oriented to patient satisfaction.

However, evaluating hospital performance remains challenging due to the complexity of healthcare delivery processes and the diversity of services provided. Patient results can be different depending on their medical conditions and how they respond to treatment, which complicates the establishment of standardized performance benchmarks. Qualitative dimensions such as patient satisfaction, staff engagement, and hospital culture are difficult to measure because they depend on subjective assessments. For this reason, hospital managers need to consider these complexities to develop comprehensive performance systems that look at both quantitative outcomes and experiences to get a complete view of hospital performance [1].

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The Balanced Scorecard (BSC) has become an important strategic tool assessing hospital performance within healthcare organizations. It is initially developed for performance management in various business sectors [2]. Then, the BSC has been adapted to healthcare settings to better capture the multiple dimensions of hospital performance [3].

In many developing countries, including Tunisia, hospital planning and performance monitoring are mainly based on standard operational indicators instead of measures focused on patient outcomes. The most common indicators are the Bed Occupancy Rate (BOR), the Length of Stay (ALOS), and the Bed Turnover Rate (BTO). These indicators are widely used to evaluate hospital utilization and operational efficiency.

However, these metrics are often analysed separately or described individually. Only few studies have focused on their combined interpretation to better understand hospital performance and regional differences at the national level.

To address this limitation, this study proposes a Process-Oriented composite index for benchmarking regional hospital operational performance in Tunisia. The proposed framework combines several operational indicators to provide a comprehensive evaluation of hospital performance across different Tunisian regions.

The remainder of this paper is structured as follows: Section 2 outlines the literature review. Section 3 presents the methodological approach and the sample. Section 4 reports the empirical results. Section 5 provides the sensitivity analysis. Finally, Section 6 concludes the paper.

II. LITERATURE REVIEW

The Balanced Scorecard (BSC) is a management tool developed in the early 1990's to balance the impact of financial and non-financial parameters and analyse the organizational performance. The BSC tool has spread to different sectors in the last decades, including healthcare organizations to evaluate hospitalization activities [4].

Balanced Scorecard (BSC) approach has been used in health service sectors, both profit and non-profit, including: Hospitals, Health Service System, University Hospital, Long term Services, Centre for Mental Health, Pharmacy Services, and Health Insurance Company [5].

The literature review shows that the Balanced Scorecard (BSC) is widely used to manage healthcare performance systems through different case studies.

Authors in [6] conducted a two-phase study with 200 top managers at Hamad Medical Corporation in Qatar (81 respondents, 40% response rate) to create and validate a five-perspective balanced scorecard framework (adding quality of care to the original four viewpoints). Every measure showed composite reliability and Cronbach's alpha values more than 0.7, indicating discriminant, convergent, and content validity. Senior

managers are able to meaningfully differentiate between the five performance indicators, according to the results.

A conceptual framework for assessing performance in healthcare organizations is presented, with a particular focus on Moroccan hospitals. It consists of three stages: first, a review of the literature on performance measurement systems to find a suitable model; second, the analysis shows that the Balanced Scorecard (BSC) is best suited for hospitals, which leads to the identification of criteria, sub-criteria, and key performance indicators (KPIs); and third, the weights of evaluators are determined using the Analytical Hierarchy Process (AHP) technique. The results point out important evaluation gaps and characteristics, suggesting this model as a helpful tool for comparing and evaluating hospital performance [7].

A combined hierarchical BSC and fuzzy linguistic methods is developed to evaluate the operating room (OR) performance across financial, customer, internal process, learning and growth. Process measurements in OR (throughput, waiting times, and utilization) were shown to support managerial choices and strategy [8].

Other hospital case studies as Indonesian and Chinese apply BSC to measure Bed Occupancy Rate (BOR), Bed Turnover (BTO), Average Length of Stay (ALOS), Turnover Interval (TOI), infection rates, patient satisfaction, employee satisfaction as core internal process and learning metrics for performance management [9] [10].

In order to manage resilience and sustain performance throughout the pandemic, the BSC is implemented at a public hospital with internal procedures such as : innovation and service standards [12].

However, several studies highlight that traditional BSC implementations remain often focused on high level strategic perspectives and may not fully reflect the operational processes of healthcare services. It was shown that many BSC applications in healthcare lack explicit integration of process level indicators to reflect the complexity of healthcare delivery [13].

To address this limitation, this study proposes a quantitative PO-BSC model that integrates several process-based indicators into a composite scoring framework. This framework is used to compare hospital performance across regions and support decision-making.

III. Methodology and sampling

In this study, we used a Process-Oriented Balanced Scorecard (PO-BSC) model to evaluate the operational performance of regional hospitals. The proposed framework contributes to the Tunisian healthcare performance management literature by offering a process-based composite approach for benchmarking hospital performance across different regions.

Unlike the traditional Balanced Scorecard (BSC) model, which integrates financial, customer, internal process and learning perspectives, the proposed PO-BSC focused on process efficiency and service utilization. Beyond performance measurement, the model is intended to support managerial decision-making and strategic planning in hospital.

The methodological approach consists of three main steps:

- ✓ Selection and classification of operational indicators
- ✓ Normalization of heterogeneous indicators
- ✓ Aggregation into a composite performance score.

This study uses quantitative data from official hospital statistics published by the Tunisian Ministry of Health in October 2024. The data cover the period from 2021 to 2023 and include all public hospitals, grouped at the regional level. The dataset includes information on bed capacity, inpatient activity, and population coverage, and other related indicators.

The key elements of BSC-PO for the case study in this paper are revealed in the part that follows.

A. Performance Indicators

The PO-BSC includes eight indicators grouped into two perspectives: stakeholder satisfaction and care process. These indicators were selected based on data availability and their comparability across Tunisian public hospitals.

1. Stakeholder Satisfaction Perspective:

The Emergency department visits per 10,000 inhabitants by governorate and by region: the number of emergency visits in public facilities with an emergency service or unit relative to the population, expressed per 10,000 inhabitants.

The Medical consultations per 10,000 inhabitants by governorate and by region: the number of medical consultations in the public sector during a year, relative to the population of the same year, expressed per 10,000 inhabitants.

2. Care Process Perspective:

Hospitalization indicators by governorate and by region such as:

- *Average Length of Stay (ALOS*) is the average number of days patients spend in the hospital. It measured the degree of utilization of available hospital beds. It is calculated by dividing the total number of hospitalization days (NHD) for all patients during a year by the number of admissions (Ad) as following in (1):

$$ALOS = NHD / Ad \quad (1)$$

- *Average Bed Occupancy Rate (BOR)* is the annual average percentage of occupied beds in public facilities. It reflects the average duration of inpatient hospitalization. It is calculated by dividing the total number of hospitalization days (NHD) by the number of active beds (AB), multiplied by 365, expressed as a percentage as following in (2):

$$BOR = [NHD / (AB \times 365)] \times 100 \quad (2)$$

- *Bed Turnover (BTO*) is the average number of patients per day per bed for a year, expressed in percentage. It indicates how many patients are treated per bed during a given period This indicator is calculated using the following in (3):

$$BTO = [(Ad/365) / AB] \times 100 \quad (3)$$

Together, these indicators provide a multidimensional view of hospital activity, including access to care, patient flow, resource utilization and clinical outcome performance.

Surgical procedures per 10,000 inhabitants by governorate and by region is the ratio of the number of surgical procedures in public facilities to the total population for a year, expressed per 10,000 inhabitants.

In-hospital mortality rate by governorate and by region is the number of deaths occurring in hospitals relative to the total number of admissions, multiplied by 1,000.

CT scan examinations per 10,000 inhabitants by governorate and by region is the number of CT scan examinations relative to the population, expressed per 10,000 inhabitants. These indicators jointly describe hospital utilization, patient flow, and overall operational performance.

B. Methodology

The process oriented Balanced Scorecard (PO-BSC) is applied to assess the operational performance of Tunisian public hospitals. The traditional BSC focuses on financial and non-financial dimensions. However, the PO-BSC framework emphasizes internal process, patient flow and resource utilization to be more suitable for public healthcare systems where efficiency is the primary objective.

In this study, the key hospital activity indicators are classified according to the BSC perspectives into two groups (see Table I):

- Stakeholder satisfaction perspective: It focuses on patient access and service utilization to visualize the interaction between the population and hospital services.
- Care process perspective: it represents the core of the PO-BSC and evaluates operational efficiency, productivity and quality of inpatient care.

Both groups reflect patient centred utilization measures and operational efficiency. Each indicator is described via its Key Performance Area (KPA), KPI and source of data used for measurement.

TABLE I. HOSPITAL ACTIVITY INDICATORS (KPA, KPI)

Perspective	KPA	KPI
Stakeholder Satisfaction	Patient	a. Emergency department visits per 10,000 inhabitants
		b. Medical consultations per 10,000 inhabitants
Care Process	Quality, productivity and internal efficiency	c. Average Length of Stay (ALOS)
		d. Average Bed Occupancy Rate (BOR)
		e. Bed Turnover (BTO)
		f. Surgical procedures per 10,000 inhabitants
		g. CT scan examinations per 10,000 inhabitants
		h. In-hospital mortality rate

The regional values of the eight hospital performance indicators are presented in Table II. The data highlights substantial variation across the seven Tunisian regions that justify the need for an integrated performance assessment using the PO-BSC model. Table II's minimum and maximum KPI values are bolded.

TABLE II. REGIONAL DISTRIBUTION OF HOSPITAL PERFORMANCE INDICATORS IN TUNISIAN PUBLIC HOSPITALS

KPI	Regions						
	Grand Tunis	Nord Est	Nord Ouest	Centre Est	Centre Ouest	Sud Est	Sud Ouest
Emergency department visits per 10,000 inhabitants	**3189**	5739	8636	5360	7358	5977	**9883**
Medical consultations per 10,000 inhabitants	10608	8480	12024	11766	10684	**7844**	**12877**
Average Length of Stay (ALOS) per day	5.54	4.71	4.55	**6.01**	3.55	3.46	**3.35**
Average Bed Occupancy Rate (BOR) (%)	59.28	47.26	33.41	**62.06**	41.15	37.47	**27.13**
Bed Turnover (BTO) (%)	10.70	10.04	**7.33**	10.32	**11.60**	10.84	8.09
Surgical procedures per 10,000 inhabitants	**309**	150	149	257	162	**136**	146
CT scan examinations per 10,000 inhabitants	**401**	157	**87**	227	151	138	273
In-hospital mortality rate	**16.2**	21	**25.5**	17.4	17.5	20.1	20.8

C. Mathematical formulation of the PO-BSC Scoring Model

In the following: $r \in \{1, 2,...,R\}$ denotes the regions, where $R=7$ is the total number of regions; $i \in \{1, 2,...,I\}$ denote the operational indicators, where $I= 8$ is the total number of indicators and $x_{ir} \in R^+$ represents the observed value of indicator *i* in the region *r*.

The indicators are classified into three sets according to their impact on performance: Beneficial indicators (*B),* Non-beneficial indicators *(N)* and Hybrid (thresholds-based) indicators (*H).*

The objective of the indicator's normalization procedure is to transform heterogeneous indicators into comparable scores and construct a composite performance index ($S_r) \in [0, 1]$ for each region.

Normalization of indicators:

The Beneficial indicators: for these indicators, where the score value is higher, this is implying better performance. It is calculated as following in (4):

$$s_{ir}^{(+)} = \frac{x_{ir} - \min_r x_{ir}}{\max_r x_{ir} - \min_r x_{ir}} \quad \forall i \in B \qquad (4)$$

Where $s_{ir}^{(+)} \in [0, 1]$;

The best performing region attains $s_{ir}^{(+)}=1$;

The Non-Beneficial indicators: for these indicators, lower values yield higher normalized scores. It ensures comparability with beneficial indicators. It is calculated as following in (5):

$$s_{ir}^{(-)} = \frac{\max_r x_{ir} - x_{ir}}{\max_r x_{ir} - \min_r x_{ir}} \quad \forall i \in N \qquad (5)$$

Where $s_{ir}^{(-)} \in [0, 1]$;

The best performing region attains $s_{ir}^{(-)}=1$;

The Hybrid (threshold-based) indicators: These indicators are characterized by an optimal operating interval $[L_i, U_i]$. The maximum score is obtained when the indicator value lies this interval, with L_i represents the lower acceptable threshold and U_i the upper acceptable threshold. In this case, the Piecewise linear scoring function is defined as follows:

For each region *r* and indicator $i \in H$, we calculate the score as following in (6):

$$s_{ir}^{(h)} = \begin{cases} 1 - \frac{L_i - x_{ir}}{L_i - \min_r x_{ir}}, & x_{ir} < L_i \\ 1, & L_i \le x_{ir} < U_i \\ 1 - \frac{x_{ir} - U_i}{\max_r x_{ir} - U_i}, & x_{ir} > U_i \end{cases} \qquad (6)$$

The maximum score is obtaining when the performance is within optimal range. The symmetric penalization is for under and over utilization.

A composite PO-BSC is constructed using normalized operational indicators. Beneficial indicators are normalized using a min-max maximization scheme, non-beneficial indicators using

minimization scheme and hybrid indicators using threshold-based piecewise linear function reflecting optimal operational ranges.

The final PO-BSC score is calculated by weighting and aggregating the normalized indicators (Equation 7). This produces a synthetic performance index S_r that ranges between 0 and 1.

$$S_r = \sum_{i\in B} w_i s_{ir}^{(+)} + \sum_{i\in N} w_i s_{ir}^{(-)} + \sum_{i\in H} w_i s_{ir}^{(h)} \quad (7)$$

$w_i \geq 0$ denote the weight assigned to indicator i with:

$$\sum_{i=1}^{I} w_i = 1 \quad (8)$$

In this study, all indicators are assumed to contribute equally to the composite score in order to provide a simple and transparent baseline for policy comparison, as defined in equation (9):

$$w_i = \frac{1}{I} \quad (9)$$

IV. RESULTS AND DISCUSSION

The PO-BSC is applied to evaluate hospital operational performance across Tunisian regions using selected indicators reflecting service utilization, efficiency, throughput and clinical outcomes.

The operational indicators used in the PO-BSC model (see Table III) are grouped according to their impact on performance into three types: beneficial (*B*), non-beneficial (*N*), or hybrid (*H*). This classification ensures methodological consistency during the normalization step and supports the construction of a balanced composite performance index.

TABLE III. NORMALIZED SCORES BY INDICATORS AND REGION

KPI	Type	Explanation
Emergency department visits per 10,000 inhabitants	B	Higher access reflects stronger service capacity
Medical consultations per 10,000 inhabitants	B	Higher outpatient activity indicates availability
Surgical procedures per 10,000 inhabitants	B	Higher technical activity
CT scan examinations per 10,000 inhabitants	B	Higher diagnostic capacity
Bed Turnover (BTO) (%)	B	Higher turnover then better bed use
Average Length of Stay (ALOS) per day	N	Shorter stay then better efficiency
In-hospital mortality rate	N	Lower mortality then better quality
Average Bed Occupancy Rate (BOR) (%)	H	Optimal interval required

According to [14], standard benchmark for the optimal mean bed occupancy rates typically range between L_i= 80% and U_i= 85%. This range reflects a balance between efficient resource utilization and operational flexibility. In our study, all Tunisian regions present a structural underutilization of inpatient resources. Normalized scores and the resulting composite PO-BSC index for each region are presented in the following Table IV.

The PO-BSC scores reveal a regional variation in hospital process performance (see Table V). The synthetic scores range from 0.298 to 0.640, show significant disparities in hospital operational performance across the Tunisian regions reflecting structural inequalities in hospital resource utilization and operational efficiency.

The Grand Tunis, with the highest overall score (0.640), demonstrates strong operational balance characterized by maximum scores in surgical procedures (normalized score -1) and CT scan activity (normalized score=1) combined with the lowest mortality rate (normalized score =1) and relatively high bed turnover (0.79) and average bed occupancy rate (0.61). Although, the average length of stay remains moderate (0.18). This pattern suggests a balanced integration between service capacity and operational efficiency.

TABLE IV. NORMALIZED SCORES BY INDICATORS AND REGION

KPI	Regions						
	Grand Tunis	Nord Est	Nord Ouest	Centre Est	Centre Ouest	Sud Est	Sud Ouest
Emergency department visits per 10,000 inhabitants	0	0.38	0.81	0.32	0.62	0.42	**1**
Medical consultations per 10,000 inhabitants	0.55	0.16	0.83	0.78	0.56	0	**1**
Average Length of Stay (ALOS) per day	0.18	0.49	0.55	0	0.92	0.96	**1**
Average Bed Occupancy Rate (BOR) (%)	0.61	0.38	0.12	0.66	0.27	0.20	0
Bed Turnover (BTO) (%)	0.79	0.63	0	0.70	**1**	0.82	0.18
Surgical procedures per 10,000 inhabitants	**1**	0.08	0.08	0.70	0.15	0	0.06
CT scan examinations per 10,000 inhabitants	**1**	0.22	0	0.45	0.20	0.16	0.59
In-hospital mortality rate	**1**	0.48	0	0.87	0.86	0.58	0.51

A moderate performance is shown in the Centre Ouest (0.574) and Centre Est (0.560). These regions show stable operational balance with efficient bed turnover (normalized score = 1 and 0.70) and acceptable mortality rate (normalized score = 0.86 and 0.87).

The Sud Ouest (0.542) despite it presents high service utilization levels with maximum normalized scores for emergency visits (normalized score = 1) and consultations (normalized score = 1). This decrease in performance due to a very low average bed occupancy rate (normalized score =0) and a moderate bed turnover (normalized score = 0.18). This suggests potential underutilization of hospital infrastructure despite high demand intensity.

The Nord Est (0.354) and Nord Ouest (0.298) present the lowest composite scores, showing the weakest operational efficiency. Nord Ouest presents the minimum CT activity, the highest mortality rate and the lower bed turnover (normalized score=0). Nord Est shows moderate mortality rate (normalized score= 0.48) and limited diagnostic activity as medical consultations (normalized score = 0.16) and surgical procedures (0.08).

The observed regional disparities highlights that differences in operational processes such as admission management,

discharge planning and resource allocation could conduct to measurable variations in performance outcomes.

TABLE V. PO-BSC SCORES BY REGION

	Regions						
	Grand Tunis	Nord Est	Nord Ouest	Centre Est	Centre Ouest	Sud Est	Sud Ouest
PO-BSC score	**0.640**	0.354	**0.298**	0.560	0.574	0.392	0.542

The results show that hospital performance is not determined only by service volume, but by the balance between utilization, efficiency and clinical outcomes. The results also suggest a relationship between service demand and operational efficiency. Regions with high activity levels such as the Sud Ouest do not necessarily achieve the highest operational efficiency. For the Grand Tunis, that presents the strongest performer, combines high technical capacity, acceptable occupancy and strong clinical outcomes. However, low performing regions show weakness in technical infrastructure, efficiency and mortality.

Decision makers can improve hospital performance by adjusting capacity in regions with low occupancy rates and by improving patient flow in regions with moderate occupancy and longer stays.

V. SENSITIVITY ANALYSIS

To assess the robustness of the proposed PO-BSC composite index, a Monte Carlo simulation was conducted in MATLAB using stochastic weights generated from a Dirichlet distribution. The weights are obtained through exponential transformation and 10,000 iterations were performed to allow strong perturbations in indicator importance. The weight vector follows:

$$w \sim Dir\ (\alpha_1, \alpha_2, \dots, \alpha_8) \qquad (10)$$

With $\alpha_i = 1\ \forall\ i = 1,2, \dots 8$

This corresponds to a uniform distribution over the simplex as following in (11):

$$\{w\ \in R_+^I : \sum w_i = 1\ \} \qquad (11)$$

Where R_+^I denotes the I dimensional non negative space and w_i represents the weight assigned to indicator *i*.

The objective is to examine whether regional rankings remain stable when indicator weights are changed randomly. This helps determine if the differences between regions are real and stable, or simply driven by the equal-weight assumption. The simulated score statistics are presented in Table VI. For each region, we compute the mean score, the standard deviation (*Std Dev*) and the coefficient of variation (*CV*). The *CV* is used to assess stability: a low value indicates that the results are more stable and structural robustness.

For the Grand Tunis, the Centre Est, the Centre Ouest and the Nord Est, the *CV* presents a moderate variability (16-18%). This indicates that their performance profiles are relatively balanced across indicators. However, the Nord Ouest exhibits very high variability (*CV*=38%) revealing that its composite performance highly depends on which indicators receive higher weights. For both the Sud Est (29.03%) and the Sud Ouest (24.57%) show also a significant dispersion.

This analysis shows that variability is not the same across all regions, which reflects differences in operational coherence. The ranking probability heatmap (Fig.1) provides a clearer view of how stable each region's position is.

TABLE VI. SIMULATED SCORE STATISTICS

	Regions						
	Grand Tunis	Nord Est	Nord Ouest	Centre Est	Centre Ouest	Sud Est	Sud Ouest
Mean	0.6408	0.3530	0.2988	0.5596	0.5729	0.3931	0.5432
Std Dev	0.1185	0.0578	0.1142	0.0901	0.1053	0.1141	0.1335
CV (%)	18.50	16.38	38.21	16.10	18.37	29.03	24.57

The Grand Tunis maintains a dominant position with 1st rank in 53% of simulations. This confirms that its position is not impacted by specific indicator weighting and has a balanced operational performance. The Nord Ouest shows a high probability (64%) to occupy the last position. Combined with its highest CV (38.21%), this reveals structural weakness rather than temporary underperformance. Even under strong random weight changes, the region remains at the bottom of the ranking hierarchy. The Centre Est and the Centre Ouest exhibit dispersed ranking probabilities between the 2nd to 4th positions. Their moderate CV values (16-18%) confirm a relative stability but also competitive proximity. Their rankings are sensitive to strategic priority changes, meaning that targeted improvements could shift their relative positions. The results of the Sud Ouest present a distinctive pattern, with ranks between the 1st and the 4th positions. This indicates a strong performance in certain indicators but insufficient consistency across all dimensions. Finally, the Sud Est shows an important dispersion across ranks 4 to 7, revealing sensitivity to weighting assumptions.

Then, the Monte Carlo results reveal three structural clusters:

- Stable leader (the Grand Tunis),
- Competitive middle group (Centre Est, Centre Ouest and Sud Ouest)
- Structurally vulnerable regions (Nord Est, Sud Est and Nord-Ouest)

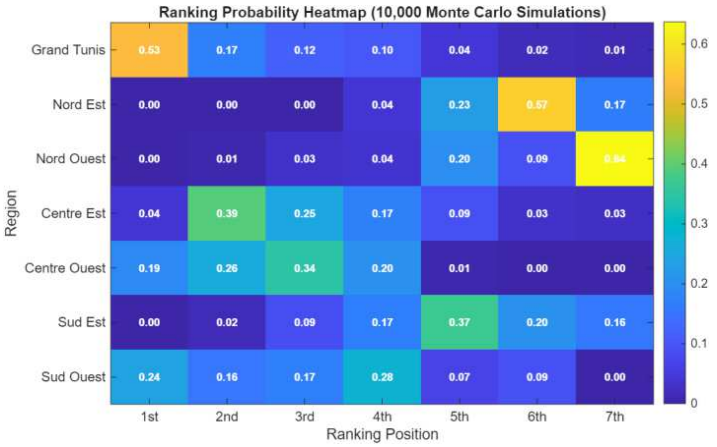

Figure 1. Ranking Probability Heatmap

The sensitivity analysis based on Monte Carlo simulation indicates that the composite PO-BSC index is relatively stable under different weighting scenarios. The results suggest that the framework can be used as a benchmarking tool for hospital performance evaluation across regions, while also highlighting structural imbalances that require targeted managerial attention.

VI. CONCLUSION

This study proposes a Process-Oriented adaption of the Balanced Scorecard (PO-BSC) framework for Tunisian regional

hospital benchmarking. It uses a composite normalized index to assess hospital operational performance across Tunisian regions.

The framework combines eight operational indicators reflecting key aspects of hospital activity, including service access (such as admission rates), patient flow efficiency (average length of stay, bed turnover rate), resource utilization (bed occupancy rate), and clinical outcomes (mortality rate). The aggregation of these indicators into a normalized score between 0 and 1 makes it easier to compare hospital performance across regions.

Methodologically, the proposed model contributes by introducing a hybrid normalization approach tailored to healthcare indicators. It takes into account beneficial, non-beneficial and threshold-based measures. This helps provide a more realistic representation of hospital performance and supports the creation of a consistent composite index for regional comparison

The empirical results show meaningful differences in hospital performance across the seven Tunisian regions. PO-BSC scores range approximately from 0.30 to 0.64, highlighting significant differences in operational efficiency and resource utilization. Regions with shorter hospital stays and higher bed turnover rates tend to perform better, emphasizing the importance of efficient patient flow and bed management practices in improving hospital performance.

The Monte Carlo sensitivity analysis, based on 10,000 simulations with Dirichlet distributed random weights, confirms the robustness of the proposed index. Despite substantial perturbations in indicator weights, the overall ranking remains stable, with the best and worst performing regions keeping their relative positions in most cases. This confirms that the observed differences are structural rather than driven by the weighting method.

The approach is also computationally efficient, relying mainly on normalization and weighted aggregation operations. The Monte Carlo simulations were implemented in MATLAB and executed efficiently, showing that the method could be applied to larger hospital datasets in future studies.

From a policy perspective, this framework can help the Ministry of Health identify underperforming regions and support decisions on resource allocation, hospital planning and healthcare improvement policies.

However, this study presents some limitations. It uses aggregated regional data, which may hide differences between individual hospitals. Also, while robustness was tested through simulations, the equal-weight assumption gives the same importance to all indicators, which may not always reflect reality. Alternative weighting mathods could produce small variations in rankings.

Future research could apply this framework at the hospital level, include risk-adjusted clinical indicators and explore other weighting techniques such as Analytic Hierarchy Process (AHP) or entropy methods to further strengthen the framework.

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