Keywords
nursing workforce, Saudi Arabia, artificial intelligence, Vision 2030, workforce planning, Saudization

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Received: 11-05-2026
Revised: 15-06-2026
Accepted: 25-06-2026
Doi:10.1922/ejprd.v34i5s.1578

Leveraging Artificial Intelligence to Strengthen Nursing Workforce Management in Saudi Arabia: A Secondary Data Analysis Aligned with Vision 2030

Abstract

Saudi Arabia's Vision 2030 health reforms position the nursing workforce as central to national healthcare transformation, yet workforce adequacy is often assessed through single, national-level indicators that may obscure sectoral and regional variation. This study conducted a secondary, retrospective analysis of Ministry of Health-derived nursing workforce data spanning 2017-2024, combining national sector-year trends with a 2024 regional dataset covering all 13 administrative regions. Descriptive trend analysis, inequality statistics, composite pressure indices, unsupervised clustering, and scenario-based projections to 2030 were applied. The national nursing and midwifery workforce grew from 185,693 to 249,475 personnel, driven disproportionately by private-sector expansion, which nonetheless recorded the lowest Saudization rate (10.7%) among sectors. Regional analysis revealed that high nurse headcounts did not consistently correspond to low workforce pressure; Al Baha, Qassim, and Makkah emerged as recurring high-pressure regions across independent weighting and clustering methods, although sensitivity testing indicated some rank instability. Projections to 2030 showed continued workforce growth across all scenarios, alongside rising service demand per nurse. These findings support a shift toward artificial intelligence-enabled, regional, sector-aware, and scenario-based workforce planning to strengthen forecasting, prioritisation, and targeted intervention in alignment with Vision 2030 objectives.

1. INTRODUCTION

The Kingdom of Saudi Arabia has been implementing an aggressive transformation of the health system as per its Vision 2030 and nurses has been identified as one of the key sectors in the health system transformation (Al-Dossary, 2018; Alsufyani et al., 2020). Although nurses make up the largest professional group in the Saudi healthcare workforce, the sector suffers from a series of structural imbalances such as workforce shortage, unequal distribution of nurses among the regions, high number of expatriates working in health care facilities (Alluhidan et al., 2020). These are not issues that are exclusive to Saudi Arabia; the World Health Organization's latest report on nursing around the world estimates that there are similar problems with shortages and maldistribution in all countries, and that filling the nursing gap will take continued investment in education, employment and leadership into the rest of this decade (World Health Organization, 2020, 2025). In general, the Saudi nursing workforce has been young, and majority of the nurses are expatriates, and the local production of nurses is limited (Alboliteeh et al., 2017).

Over the last decade, however, the government has been trying to come out of this addiction, by Saudization, increasing nursing education, and sector diversification (Alsufyani et al., 2020). Initial assessments reported significant achievements such as Saudization in the private sector not keeping pace with that in the government sector and workforce planning is largely national, lacking sufficient regional level detail (Alluhidan et al., 2020). There is literature on international workforce projection exercise which shows that credible health workforce projection must be a need-driven exercise that considers factors such as population growth and service utilisation and the epidemiological transition (Gailey et al., 2021; Lin et al., 2021). Such multidimensional planning is missing, and, as other parts of the world have seen, while overall figures on growth may be good, there can be very strong regional pressures that can only be remedied by a different approach to workforce expansion (Buchan et al., 2015). Nurse retention in Saudi Arabia is a longstanding issue, to which the above-mentioned structural factors add. Empirical research shows that turnover intentions are related to the job dissatisfaction and occupational stress (Mariano et al., 2023; Shdaifat et al., 2023).

Recent evidence from the region suggests a direct link between the leadership approach, psychological resilience, and intention to leave among nurses, highlighting that workforce inadequacies are not necessarily a numbers issue but also a management-quality and psychological resilience issue (Al-Shomrani et al., 2024; Alasiry et al., 2024). The positive overall growth in the RN workforce in other countries is expected to be unevenly distributed in different regions after the COVID-19 pandemic (Auerbach et al., 2024). Collectively, this literature indicates that there is a need for disaggregated, dynamic, future-oriented analytic tools that can provide information as to where and how pressures build to manage the nursing workforce as a national indicator alone is insufficient. Artificial Intelligence (AI) is proving to be a viable solution to this analytics need. AI-supported staffing systems may strengthen workforce forecasting, optimize nurse deployment, and enable healthcare organizations to respond more effectively to changing service demand (Nashwan & Abujaber, 2023). Traditional retrospective reporting is limited to using historical trends, capacity constraints, and demand signals to forecast, optimise staffing, and alert of early warning, while AI systems can. Reviewing how AI has been used in nurse management through systematic and scoping reviews reveals an increasing body of evidence for the potential benefits of AI in nurse scheduling, predictive staffing, and leadership decision-support, but also highlights the need for data readiness and contextual validation to maximize the potential of AI systems (Gonzalez-Garcia et al., 2024; Kiwanuka et al., 2026).

Other studies on AI in healthcare also mention the issue of trust, data quality, and readiness of the organisation as common challenges in AI integration into healthcare workflows (Nair et al., 2024). Administrative data disaggregated to the level at which decisions are taken is also a key focus for the World Health Organization's most recent national workforce accounts, with reliable workforce planning depending on these data (World Health Organization, 2026). In spite of this interest, empirical characterizations of the Saudi nursing workforce which integrates both national trend data and sectoral composition and regional pressure indicators within the same analytic frame are limited, and few studies make direct connections between the patterns and AI-relevant management applications. This study aims to fill that void by secondarily analysing statistics of the nursing workforce generated by the Ministry of Health from 2017 to 2024.

The specific objectives were to:

- characterise national and sectoral nursing workforce growth and Saudization trends
- quantify regional variation in workforce capacity, service demand, and localisation
- identify high-pressure regions and workforce clusters using inequality statistics and unsupervised learning
- interpret these findings in relation to AI-enabled workforce management opportunities aligned with Vision 2030

2. Methodology

The design of this study was secondary and retrospective descriptive-analytic based on nursing workforce data obtained from the Saudi Ministry of Health (MoH) Statistical Yearbook 2024 and from 2024 onwards from the Saudi Commission for Health Specialties (SCHS) personnel's data as they are the main source for the nursing workforce in Saudi Arabia. There was no primary data collection made from human subjects and the analysis consisted entirely of administrative statistics which are de-identified and aggregate, so formal ethics approval was not needed. The use of two analytic layers was used. National layer included sector-year observations of the number of nurse, midwife in the Ministry of Health, other governmental sector, and private

sector in the years 2017-2024, as well as the number of Saudi and non-Saudi nurses.

The regional layer included one observation for each administrative region (n = 13) and included counts of MoH hospital and primary healthcare (PHC) nurses, hospital beds, physicians, PHC and outpatient department (OPD) encounters, number of inpatient visits to the private sector and nurse nationality and gender. The regional denominator included all MoH service nurses (MoH hospital plus MoH PHC nurses) and other governmental and private-sector nurses were excluded from regional-ratio calculations due to not being able to attribute them to a facility level. Table 1 presents the results of the two analytic layers and key variables.

Table 1. Data sources and analytic layers used in the secondary analysis

Layer	Time coverage	Unit of observation	Key variables
National sector-year	2017–2024	Sector × year (3 sectors, 8 years)	Nurse/midwife counts by sector; Saudi and non-Saudi nurse counts
Regional	2024	Administrative region (n = 13)	MoH hospital + PHC nurses; beds; physicians; PHC/OPD encounters; private inpatients; nationality; gender

Before analysing the data, the source workbook indicated that there were 22 validation checks done between the extracted data and yearbook tables, all of which were marked as passed. Analytic approach. A six-stage process for analyses was followed which is summarised in Table 2. First of all, descriptive trend analysis was used to measure the workforce growth at the national and sector levels with absolute and compound annual growth rate (CAGR) for the period of 2017-2024. Second, the region's capacity was measured in terms of the two ratios nurse to bed and nurse to physician and Saudization rates for each of the 13 regions.

Third, regional inequality was measured with the coefficient of variation (CV), interquartile range (IQR) and Gini coefficient for five measures of capacity and workload. Fourth, composite regional pressure indices were built based on two different procedures to weight the indicators: equal weighting and principal component analysis (PCA) derived weighting, plus sensitivity analysis on the stability of the ranking of the indices for an alternative indicator definition and an alternative weighting scheme. Fifth, unsupervised cluster analysis (K-means, cross-validated by hierarchical clustering) was used to cluster the regions based on the capacity, workload and Saudization profiles after they were standardised. The optimal number of clusters was determined using silhouette scores when K = 2, 3 and 4. Finally, scenario-based projections were made to extrapolate the national indicators to 2030, under the three types of assumptions: conservative, baseline continuation and accelerated-transformation.

Table 2. Analytic techniques applied at each stage of the secondary analysis

Stage	Technique	Purpose
1	Descriptive trend analysis (CAGR)	Quantify national and sectoral workforce growth, 2017–2024
2	Ratio analysis	Describe regional capacity (nurses/100 beds; nurses/100 physicians; Saudization)
3	Inequality statistics (CV, IQR, Gini)	Quantify regional dispersion in capacity and workload indicators
4	Composite pressure indices (equal-weight & PCA) + sensitivity analysis	Rank regional pressure and test rank stability
5	Cluster analysis (K-means; hierarchical; silhouette selection)	Segment regions into workforce management profiles
6	Scenario projection (conservative / baseline / accelerated)	Estimate workforce and Saudization trajectories to 2030

This was a secondary (populations) data set and all analyses were descriptive and exploratory in nature no inferential hypothesis testing was conducted. Only administrative counts (aggregated, non-identifiable) were analysed and results are only presented at sector and regional level.

3. Results

3.1 National Workforce Growth and Sectoral Trends

The national nursing and midwifery workforce increased from 185,693 in 2017 to 249,475 in 2024 a net increase of 63,782 nurses, and an overall CAGR of 4.3%. The growth in Table 3 is broken down by sector.

Table 3. Workforce growth by sector, 2017–2024

Sector	2017	2024	Change	CAGR
Ministry of Health	103,990	119,530	15,540	2.0%
Other governmental sector	35,808	49,673	13,865	4.8%
Private sector	45,895	80,272	34,377	8.3%
Total	185,693	249,475	63,782	4.3%

The figures in Table 3 indicate the highest relative growth rate for the private sector as well as the highest absolute growth rate followed by the other governmental sector. The number of jobs in the Ministry of Health has increased the most slowly in relative terms but is still the biggest single employer in 2024. The trend of the country's labour force is presented in Figure 1.

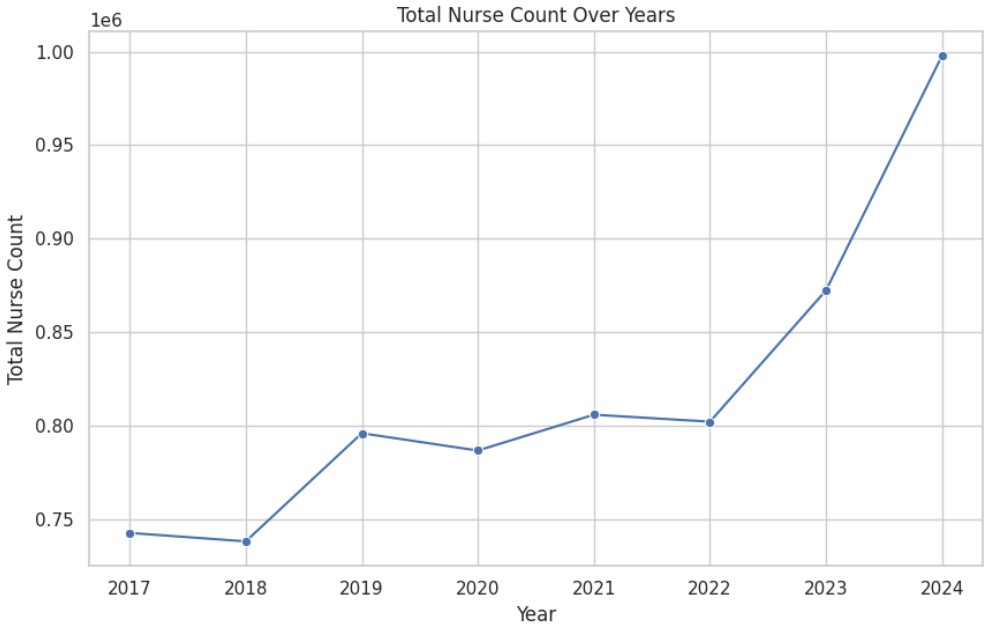

Figure 1. Total nurse and midwife count, 2017–2024.

Growth was non-linear as shown in Figure 1 as growth in the dip around 2018 recovered in 2019 and flattened somewhat in 2021-2022 but experienced a significant increase by 2023-2024. The direction of change is viewed with confidence because it is the last year for which the workforce-source change is documented, but the exact size of the 2023-2024 growth is viewed with caution. Overall, the eight years' pattern suggests a continuous growth amidst a relative stagnation, with direct implications on for planners interested in identifying true structural growth from short-term administrative or reporting artefacts.

3.2 Sectoral Saudization Patterns

National Saudization reached 43.2% in 2024, but sector-level rates diverged sharply, as summarised in Table 4.

Table 4. Sector nurse composition and Saudization, 2024

Sector	Total nurses	Saudi	Non-Saudi	Saudization
Ministry of Health	119,530	77,216	42,314	64.6%
Other governmental sector	49,673	22,104	27,569	44.5%
Private sector	80,272	8,589	71,683	10.7%
Total	249,475	107,866	141,609	43.2%

The Ministry of Health had the largest Saudization percentage, followed by other governmental sectors, while the private sector had the lowest percentage and yet it added the most to the growth of the workforce. The changes in this sectoral gap over the study period are shown in figure 2.

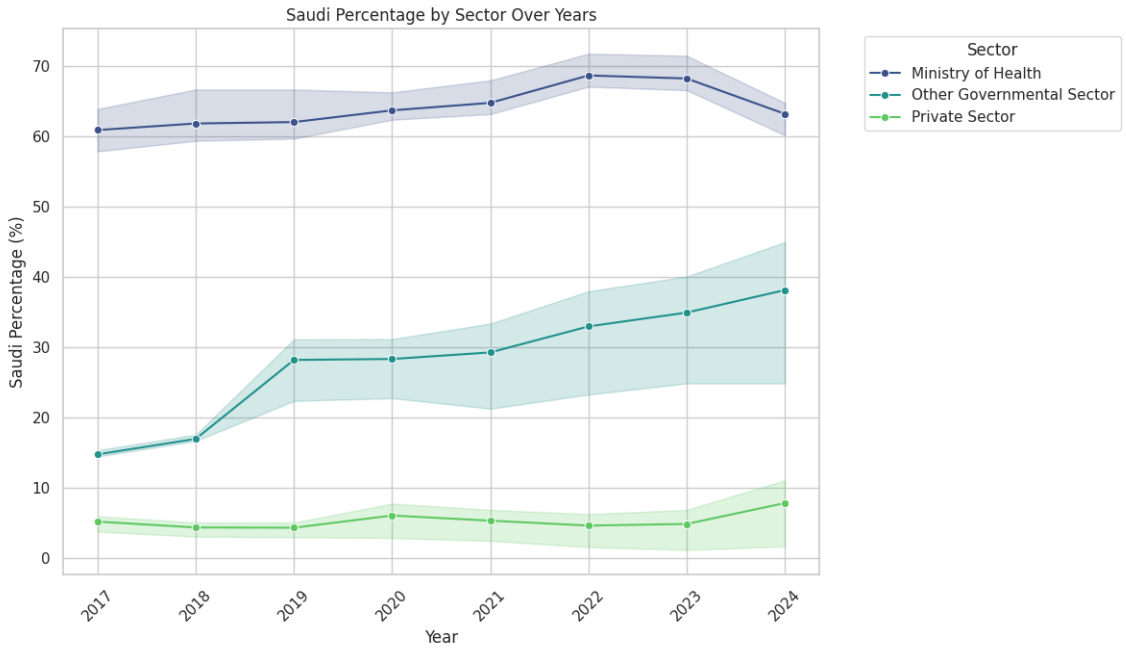

Figure 2. Saudi percentage by sector, 2017–2024.

As can be seen in Figure 2, the average level of localisation in both public and governmental activities remained higher than in private activities over the study period and the level of localisation steadily increased with the fastest growth in employment in the private sector. This gap is proof that the statistics for Saudization of the health sector are insufficient to reflect the extent of the localisation mission still to be achieved in private hospitals and clinics which now employ a significant portion of all the nurses working in the Kingdom.

3.3 Regional Capacity and Distribution

Workforce distribution across the 13 administrative regions was highly concentrated. Table 5 presents regional MoH service-nurse counts alongside capacity ratios for 2024.

Table 5. Regional capacity indicators, 2024

Region	MoH service nurses	Nurses/100 beds	Nurses/100 physicians	Saudization
Riyadh	26,540	313.8	175.8	52.8%
Makkah	21,308	231.0	160.4	59.4%
Eastern	18,327	281.5	187.3	75.6%
Madinah	8,199	263.0	186.0	74.7%
Asir	8,100	238.2	183.6	69.1%
Qassim	7,452	224.2	185.8	48.8%
Jazan	6,531	224.0	256.7	85.1%
Al Jouf	5,301	273.2	255.5	81.9%
Tabuk	4,325	225.3	195.8	71.5%
Hail	4,021	207.3	196.2	73.8%
Najran	3,777	269.8	207.9	52.0%
Northern Borders	3,156	216.2	212.2	74.6%
Al Baha	2,493	192.5	170.4	40.6%

Riyadh had the highest number of MoH service-nurses followed by Makkah and Eastern Province, while Al Baha, Northern Borders and Najran had the lowest numbers of service-nurses. Interestingly, absolute numbers did not match with the capacity ratios: Riyadh had the highest number of nurses per 100 beds and Al Baha had the lowest; while Jazan and Al Jouf had the highest numbers of nurses per 100 physicians, even though their absolute numbers were relatively low. The total number of nurses in regions are graphically represented in figure 3.

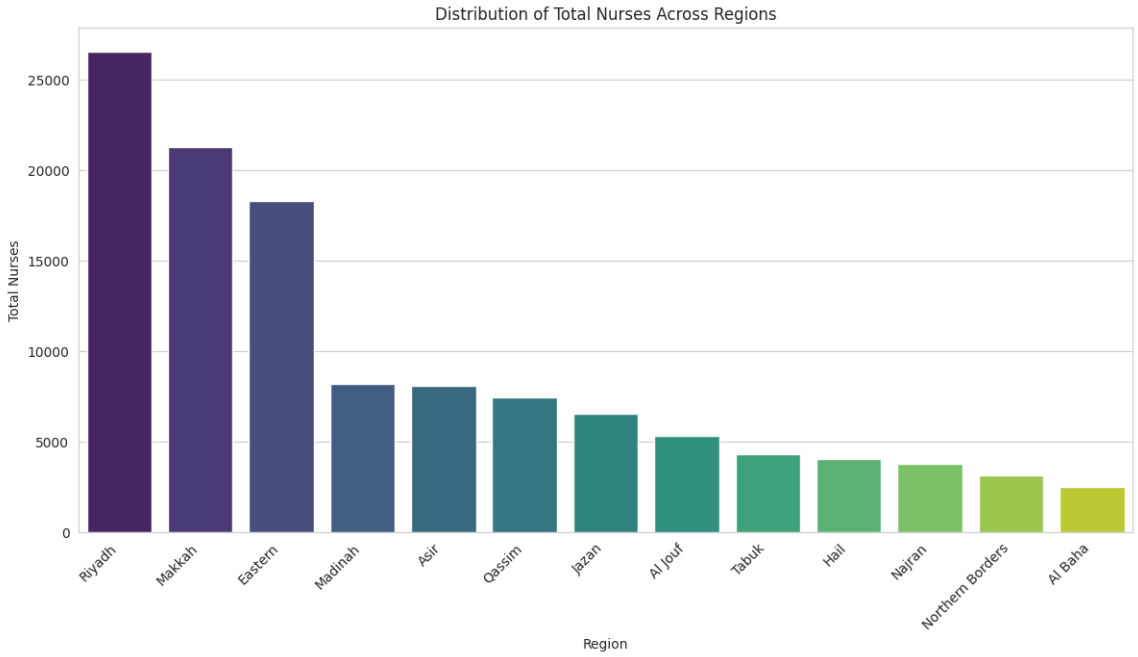

Figure 3. Distribution of total MoH service nurses across administrative regions, 2024.

This can be seen from Figure 3 as the focus is on the concentration, which suggests that a focus on individuals can lead to a failure to identify problems in smaller regions, thus advocating for ratio-based and workload adjusted indicators in regional workforce planning. The capacity ratio in regions with intermediate-sized nurse counts (e.g., Al Jouf and Najran) were similar to or equal to that of much larger regions, which shows that the size of the population and facilities is not a factor on its own to the relative sufficiency of the nurse count.

3.4 Regional Inequality and Pressure Prioritisation

Table 6 reports inequality statistics across five capacity and workload indicators.

Table 6. Regional inequality statistics

Indicator	CV (%)	IQR	Gini
Nurses per 100 beds	14.2	45.7	0.076
Nurses per 100 physicians	14.8	24.3	0.075
Saudization rate	21.0	21.9	0.112
PHC encounters per nurse	38.9	803.4	0.204
OPD encounters per nurse	26.5	50.2	0.140

The indicators of service workload had the highest variation by region, with the highest coefficient of variance being for PHC encounters per nurse followed by OPD encounters per nurse and Saudization rate, with less variation in the static indicators of capacity ratio. Table 7 shows the highest five regions that were found to have high pressure in two different weighting methods.

Table 7. Top five high-pressure regions under two weighting approaches

Rank	Equal-weight region	Index	PCA-weighted region	Index	Tier
1	Al Baha	3.15	Qassim	0.76	High pressure
2	Qassim	2.86	Makkah	0.73	High pressure
3	Makkah	2.71	Al Baha	0.73	High pressure
4	Tabuk	2.36	Tabuk	0.66	High pressure
5	Eastern	2.32	Eastern	0.65	High pressure

Al Baha, Qassim and Makkah were among the top three high pressures areas in both weighting methods and Tabuk and the Eastern Province also came up in the top five. However, the sensitivity analysis revealed that individual region ranks were not always the same: Tabuk's rank changed from 4 to 10 and Riyadh's rank changed from 12 (equal-weighting) to 7 (PCA-weighting), suggesting that using pressure to prioritise regions should be used as an indicator signal rather than a definitive ranking. Nevertheless, there is a reasonably strong agreement between the two weighting methods in the top three regions to provide a good indication of where to start the process of prioritizing a region for initial diagnostic review and stakeholder engagement. **3.5 Cluster-Based Regional Segmentation**

Silhouette scores were used to select the optimal cluster count, with K = 3 (silhouette = 0.384) outperforming K = 2 (0.356) and K = 4 (0.282). Table 8 summarises the resulting cluster profiles using mean scaled feature values

Table 8. K = 3 cluster profiles using mean scaled features

Cluster	Nurses/100 beds	Nurses/100 physicians	PHC enc./nurse	OPD enc./nurse	Saudization
0	-0.191	0.828	-0.865	-0.297	0.890
1	0.355	-0.452	0.716	-0.110	-0.362
2	-1.526	-0.978	-0.688	2.260	-1.917

The clusters were: Cluster 0 with comparatively higher Saudisation, nurse-to-physician ratio and lower PHC workload (Al Jouf, Madinah, Jazan, Hail, Northern Borders); Cluster 1 with higher nurses-per-100-beds and PHC workload and lower Saudisation and nurse-to-physician ratio (Asir, Makkah, Eastern, Tabuk, Najran, Qassim, Riyadh); and Cluster 2 with lower scaled capacity, Saudisation, and higher disproportionately high OPD workload with lower nurse-to-physician ratio (Al Baha, which was an outlier). The solution with K = 3 is shown in Figure 4 in the form of a projection of the solution onto the principal components.

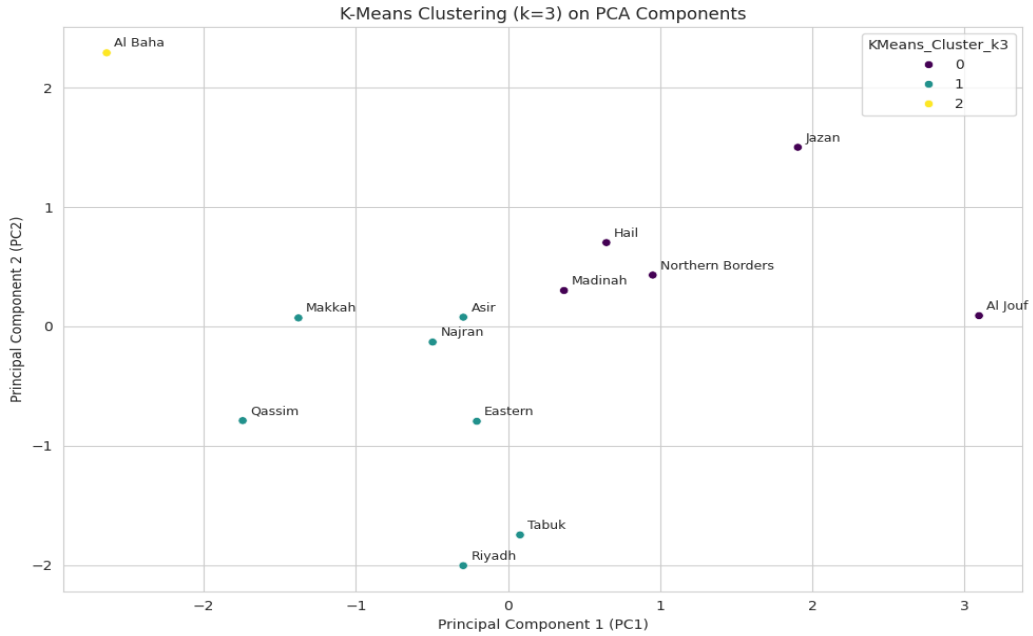

Figure 4. K-means clustering (K = 3) of regions projected on principal components.

Each of the three clusters has a clearly different representation in the component space (as illustrated in Figure 4) and this is an indicator of their value as a tool to segment into differentiated interventions to workforce for each peer region, rather than a uniform national intervention. Notably, Cluster 2 was only made up of Al Baha, which also was included in the top high pressure regions in Table 7, providing convergent evidence using different analytic approaches to the unique characteristics of the workforce in this region.

3.6 Workforce Projections to 2030

The scenario projections showed that nurse numbers, Saudisation and service-utilisation indicators in all three (conservative, baseline-continuation and accelerated) scenarios showed an increase between 2024 and 2030, with the greatest increase under the accelerated scenario. The estimated trajectory of the number of nurses in the country is shown in figure 5.

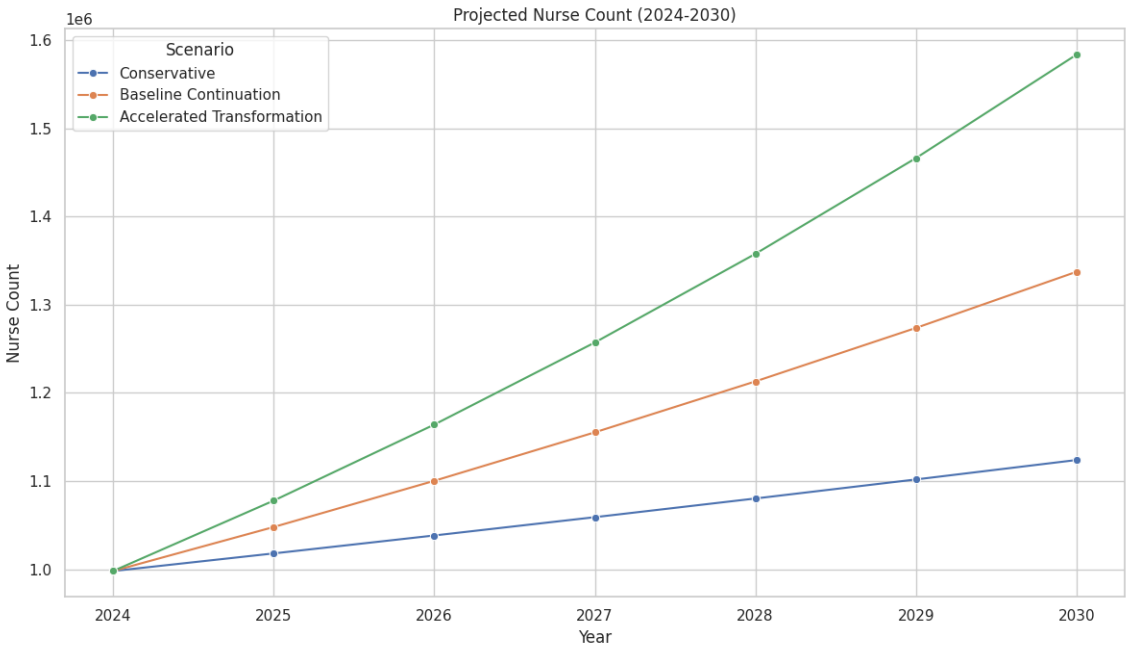

Figure 5. Projected national nurse count, 2024-2030, across conservative, baseline, and accelerated scenarios.

The increasing trend in all scenarios in Figure 5, suggests forward looking recruitment and training-capacity planning. Given, however, that the number of encounters a nurse is likely to see is increasing in a progressive manner across the scenarios, workforce increase alone seems to be an inadequate means of keeping up with the growing pressure from increased demand for services and complementary means of increasing productivity and appropriate skill-mix need to be considered.

4. Discussion

This secondary analysis validates the results of a growing number of nurses working in Saudi Arabia since 2017, as described in the overall trends of the country's workforce planning literature (Gailey et al., 2021; Lin et al., 2021). There are three findings, however, that can give context to this growth story relevant to AI-based workforce management. First, sectoral divergence, with the private sector expanding fastest, but least Saudiised, resonates with previous worries that Vision 2030 reforms have not touched all sectors of employment equally (Alluhidan et al., 2020; Al-Dossary, 2018). This trend is similar to what has been observed in the past, with the workforce in the country being highly dependent on expatriates who are not employed by the government (Alboliteeh et al., 2017), and is consistent with international evidence which suggests that reducing localisation gaps is not something that can be addressed simply by supply-side workforce growth without a deliberate policy targeted at sectors (Buchan et al., 2015).

Second, regional analysis shows that absolute numbers of people in the workforce are not a good measure of workforce needs. If looking at capacity and demand in combination with localisation, Riyadh, Makkah and Eastern Province are the areas with the most nurses, but statistics and pressure indices show that Al Baha, Qassim and Makkah are areas of persistent high pressure. The sensitivity analysis also reveals that the rankings of regions in terms of pressure are not constant, with some regions achieving significant shifts in their rankings in response to the other definitions and/or weighting schemes. This instability is consistent with the literature on the projections about the workforce, which cautions against the use of needs-based workforce models as settled conclusions or judgements, but rather as inputs for decision-making while accounting for the underlying assumptions (Gailey et al., 2021; Auerbach et al., 2024).

Thirdly, a single country and/or single region view cannot offer a segmentation layer that the cluster analysis does. The K = 3 solution (chosen on the basis of silhouette score) identifies a cluster of higher level of Saudization, a cluster of higher workload and an outlier region that needs to be reviewed individually. This descriptive segmentation aligns with the understanding of the logic underlying AI-enabled decision-making tools for nurses, which focus on integrating multiple streams of structured data to generate actionable signals, and context-specific signals, as well as automation, are key to delivering value (Kiwanuka et al., 2026; Gonzalez-Garcia et al., 2024). These data should be combined with the retention/leadership literature. Therefore, the workforce adequacy measure (in this study, it is represented by capacity ratio) does not reflect whether the nursing workforce available in the hospital is stable as indicated by the high turnover intention related to occupational stress and job dissatisfaction in Saudi hospitals (Mariano et al., 2023; Shdaifat et al., 2023). Therefore, territories that were found to be at risk in this analysis might be at risk in terms of leadership or retention due to the weak leadership or retention conditions in that region, as evidenced by the recent Saudi study that directly correlated leadership style and resilience with intention to leave (Al-Shomrani et al., 2024, Alasiry et al., 2024).

The segmentation in this study would be further enhanced if indicators of retention, and leadership were incorporated into future dashboards that were AI-enabled, in conjunction with the indicators of supply and demand. Implementing the results, the findings indicate that AI can

be used in various real-world applications: sector/region-specific demand forecasting using trend and projection data; dynamic pressure-index dashboards that surface, instead of masking, the underlying assumptions in the light of the sensitivity findings; and cluster-informed intervention design, which avoids a one-size-fits-all national policy. This aligns with implementation-science evidence that beyond the sophistication of the algorithm, data quality, disaggregation, and organisational readiness are key factors in the success of such tools (Nair et al., 2024; World Health Organization, 2026).

The nursing workforce shortage identified by the World Health Organization (2025) also highlights the importance of precision forecasting at a regional level (not just national) for the planning of Vision 2030. There are some limitations of the study. It is descriptive and cross sectional at the regional level, does not show causality or individual nurse workload, turnover and vacancy rates and skill mix. It is important to note that the workforce-source transition for 2024 introduces measurement uncertainty into the latest year of data, while clustering is statistically preferred at K = 3, it needs to be validated with operational stakeholders prior to using it as the basis for policy targeting.

5. Conclusion

This secondary analysis of data from 2017 to 2024 derived from the MOH, reveals that the Saudi nursing workforce has increased significantly, from 185,693 to 249,475 nurses and midwives but this general increase in the country conceals important variation at the sector and regional levels. Although the private sector's employment growth was the fastest, it is far less Saudised than employment in the government sector and analysing employment data at the regional level, it is clear that high nurse counts do not necessarily mean low workforce pressures, when taken in the context of capacity ratios and demand for services. Rankings of inequality statistics and pressure indices, and cluster analysis, all point to the same higher-pressure areas (Al Baha, Qassim and Makkah) and sensitivity testing shows that these rankings are sensitive to the analytic assumptions that are made and should not be used to supplant the expert judgement. To 2030, projections of the scenarios indicate that without productivity and skill-mix planning in combination with workforce expansion, the workforce is unlikely to reduce the pressure on services, by itself, under any of the trajectories tested. Together, these results suggest a paradigm change from nursing workforce management to national level planning using a single indicator to AI-assisted, regional level planning with sector awareness and scenario modelling. The underlying dataset already combines the signals of supply and demand at the national and regional level, making it a solid basis for the applications of AI in the forecasting, the prioritisation at the regional level, the design of interventions based on clusters, and the early-warning dashboards. This potential will need to be realised through an emphasis on data quality, consistency of sources, and a validation by stakeholders, as well as by including additional indicators for retention, leadership and skill-mix that are not currently covered in the current analysis. A more equitable and resilient nursing workforce is within reach as Saudi Arabia moves towards a more integrated approach to planning by incorporating these analytic capabilities in routine planning effort, as it works towards achieving its Vision 2030 health workforce targets.

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