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Physical Environment and Performance Measurement: A Data Envelopment Analysis of Ayushman Aarogya Mandirs in Kanpur Nagar

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Abstract
Under the flagship Ayushman Bharat Mission, the government of India established Health and Wellness Centres (HWCs) as pivotal points for delivering comprehensive primary healthcare, including non-communicable disease (NCD) management, screening, wellness sessions, mental health and so on. Evaluating their operational efficiency is crucial for optimizing resource utilization, process improvement and enhancing service delivery. Suboptimal physical environments—such as poor ventilation, accumulation of waste, inadequate infrastructural facilities including colour-coded bins potentially constrain both access and appropriate delivery of health services.
This study assesses the technical efficiency of 12 HWCs in a district of Uttar Pradesh, employing Data Envelopment Analysis (DEA) to quantify performance variations based on outpatient visits and NCD patient care.
Two DEA models were constructed: Model 1 considered outpatient visits as output with physical infrastructure and ANM personnel as inputs; Model 2 focused on hypertensive and diabetic patient management with ASHA and blood sugar tests as inputs. Efficiency scores were calculated under Variable Returns to Scale (VRS) assumptions. The significant heterogeneity in efficiency underscores the need for targeted interventions focusing on workforce capacity building, on the job training, upgradation of health technology, and strenghtening of the clinical capacity to enhance HWCs' performance. Integrating DEA findings with qualitative inputs can guide policy towards achieving equitable and effective primary care crucial for Universal Health Coverage in India.
Keywords: *Ayushman Bharat,Primary, Health and Wellness Centre, Data Envelopment, UHC, Efficiency*

INTRODUCTION

India's health system has undergone significant transformations in pursuit of Universal Health Coverage (UHC). One of the most ethused mission at the level of primary care is the launch of the Ayushman Bharat Mission in 2018. This initiative aims to rebalance the health sector's orientation from curative to comprehensive, ensuring broad-based coverage and improved access to high-quality care. A central feature of Ayushman Bharat is the upgrading of the existing sub-centres and primary health centres into Health and Wellness Centres (HWCs). These HWCs—also designated as Ayushman Aarogya Mandirs (AAM)—are tasked with expanding primary healthcare services beyond maternal and child health to encompass the management of non-communicable diseases (NCDs), mental health, palliative care, and other emerging priorities((Lahariya, 2020).

These centres aim to overcome barriers including geographic remoteness, lack of provider capacity, and high out-of-pocket expenditure, by positioning high-quality, locally responsive care at the community level. Since its inception, HWCs have reportedly become operational, adopting standards that cover wellness programs like yoga, telemedicine consultations, and population-level disease screening(Tripathi et al., 2024). Efficient functioning of HWCs is key to achieving the goals of UHC, particularly in settings constrained by finite health budgets and rising disease burdens. The assessment of centre-level efficiency helps illuminate operational bottlenecks, guide strategic resource allocation, and empower decision-makers to optimize local health services. With a growing focus on quantitative evaluation, Data Envelopment Analysis (DEA) has emerged as a leading method for comparing performance among healthcare units, including HWCs. DEA's non-parametric framework allows for simultaneous consideration of multiple inputs and outputs without presupposing a specific production function, making it especially suited to diverse and complex healthcare environments.

The assessment of wellness centre's efficiency is essential for identifying the diverse challenges that incumber their capacity to deliver high-quality care within the constraints of limited healthcare budgets. Moreover, such evaluation facilitates informed decision-making aimed at optimizing the allocation and utilization of healthcare resources. Data Envelopment Analysis (DEA) is a widely adopted technique for assessing the efficiency of service organizations, including Health and Wellness Centres (HWCs). Unlike parametric methods, DEA is particularly suitable for healthcare settings because it evaluates multiple

inputs and outputs simultaneously without assuming a specific production function. Each unit assessed,referred to as a Decision Making Unit (DMU), utilizes various resources to deliver multiple services. DEA determines which of the DMUs form the efficient frontier—meaning these units achieve the best performance by either increasing outputs or reducing inputs without negatively affecting other factors. Those operating on this efficient frontier are considered benchmarks for best practices. One key advantage of DEA in the context of HWCs is that it does not require economic valuations for all outputs, many of which are challenging to quantify monetarily. The most efficient units achieve a score of 1, and the most inefficient get 0.

One of the earliest applications was done by (González-de-Julián et al., 2021), who performed an analysis that distinguished between rural and urban primary healthcare units in Spain by grouping them into separate clusters. Indian studies have applied DEA to varied health sector settings—from rural Anganwadi centers and district hospitals to state-level technical efficiency analyses (Deka & Mahanta, 2024; Sengar et al., 2022). Mbau et al. (2022) highlighted DEA's capability to assess both service coverage and access, advocating its use in global health systems efficiency research(Mbau et al., 2023).
When applying Data Envelopment Analysis (DEA) to evaluate efficiency in Health and Wellness Centres (HWCs), it is essential to carefully select the appropriate input and output variables as well as the modeling approach. Commonly used inputs in these studies are personnel costs, overall expenditure, referrals, hospital bed-days, pharmaceutical usage, and research activities. Output variables typically include clinical service volumes, patient registrations, and procedural counts, with some studies incorporating quality indicators like adherence to treatment protocols, staff experience, patient satisfaction, and equitable access. In this study, the primary data has been collected from health and wellness centres. The efficiency has been analyzed using the HWCs as decision making units.

MATERIALS AND METHODS

This cross-sectional study was conducted in Ayushman Bharat health and wellness centres located in rural areas of Kanpur district. 12 HWCs were included in the study. The investigator visited the centers and interacted with the CHOs. Human resource, physical infrastructure or environment, drugs and diagnostic facilities were included as input variables, and the number of total outpatient visits, number of people who have taken medicine for hypertension, number of people who have taken medicine for diabetes per 100 population were taken as output variables. In terms of inputs, the number of ANM, asha workers were also taken as per 100 population since these are supposed to be based on the population of the catchment area.

Data and Variables

In evaluating efficiency, input and output variables were derived either directly from the original data sources or specifically constructed for each HWC. To account for variability in population sizes, all measurements were standardized per 100 individuals in the population. The details on the variables used in the analysis are:

Input Variables

Infrastructure: It included the display of clinic timings, outpatient space,medical dispensation, yoga, building, condition of floor, plaster on wellness, labour room, provision of water, electricity,cleanliess,clinic room, examination room,display of materials in local language, AV material, color coded bins, separate utilities for men and women, teleconsultation.

a) Drugs: It comprised the presence of antihypertensive medicine, antidiabetic, vitamins and minerals, electrolyte disturbances,diuretics and antidiabetic.
b) Diagnostics: It included the provision of BP machine-mannual and digital, glucometer, glucometer strips,urine dipstick,weighing machine, haemoglobin check,digital thermometer and measuring.
c) Asha: This was calculated per 100 population.
d) Anm: This was calculated per 100 population.

Output variables

a) Output 1: Number of monthly OPD visits per 100 population
b) Output 2: Number of people who have taken medicine for hypertension per 100 population
c) Output 3: Number of people who have taken medicine for diabetes per 100 population

Factor Analysis

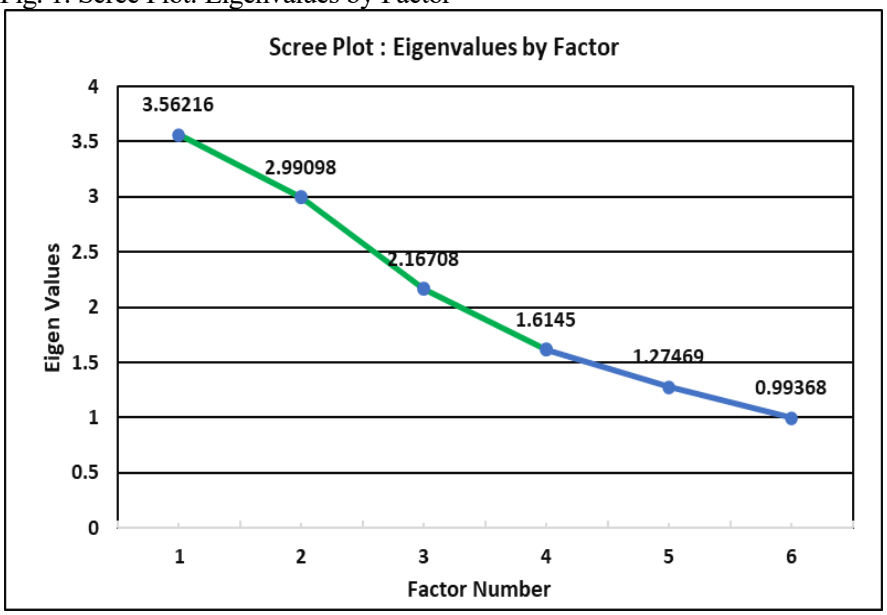
The 12 HWCs served an average population of 5277. Factor analysis serves as an initial step in developing DEA models by identifying variables with strong relationships and high discriminatory power. This approach helps select variables that best represent key dimensions of variability while minimizing redundancy from highly correlated variables. The table 2 shows the eigenvalues. 6 factors are retained with eigenvalues greater than 1, and they cumulatively explain 77.4% of the variance.

Table 1: Factor Analysis based on 12 DMUs using principal component

	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.56216	0.57117	0.2375	0.2375
Factor2	2.99098	0.8239	0.1994	0.4369
Factor3	2.16708	0.55258	0.1445	0.5813
Factor4	1.6145	0.33982	0.1076	0.689
Factor5	1.27469	0.281	0.085	0.774
Factor6	0.99368	0.07112	0.0662	0.8402

Source: Author's Calculations

Fig. 1: Scree Plot: Eigenvalues by Factor



Source: Author's Calculations

Factor 1 explains 23.75% of the total variance and differentiates the HWCs the most. It correlates to OPD consultations, the primary activity of the centre, driven largely by auxiliary nurse availability. Older facilities with established patient networks maintain higher utilization despite aging infrastructure. This also points out to the enhanced role of ANMs and ASHAs given their social proximity with the community.

Factor 2 explains 19.94% variance and correlates to the management of NCDs, particularly hypertension and diabetes. It reflects the screening and case-finding ability, possibly supported by community outreach via ASHA workers. HWCs scoring high here are likely more active in early diagnosis and continuous care for chronic illnesses, in line with India's NCD control program objectives. Factor 3 explains 14.45% and concerns diagnostic services. Laboratory capabilities are characterized by: hemoglobin testing (0.84) and TB case management (0.89), supported by logistics availability (0.46).

Table 2: Matrix of Rotated factor loadings

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Uniqueness
Number of months since HWC	0.0778	-0.1039	-0.1331	0.2603	0.3389	0.7828
% population above 30	-0.2564	0.0985	-0.0174	-0.1266	0.8335	0.2135
distance near CHC	0.1465	-0.2038	-0.1679	0.8461	-0.2804	0.1143
ASHA*	0.0503	0.5527	-0.0732	-0.1231	0.6747	0.2163
ANM*	0.9236	0.0632	0.2143	0.0167	-0.1492	0.0744
OPD cases*	0.9181	0.099	0.1719	0.0137	-0.1539	0.094
Number of people who took medicine for hypertension*	0.0471	0.9456	-0.0096	-0.1156	0.1283	0.0737
Number of people who took medicine for Diabetes*	-0.05	0.9705	-0.0022	-0.0766	0.0433	0.0478
Haemoglobin tests*	0.3748	0.015	0.844	-0.2621	-0.1148	0.0652
Blood sugar tests*	0.4322	0.5148	-0.4559	0.0184	-0.021	0.3396
Number of pregnancies registered*	0.0292	0.3689	-0.1184	-0.1727	-0.3706	0.6819
Immunization<2years	0.1064	-0.0271	0.013	0.9434	0.0451	0.0957
Number of TB patients referred*	0.1579	-0.0716	0.8941	0.0535	0.0355	0.1663
Infrastructure	-0.8443	0.2008	-0.0127	-0.3975	-0.1362	0.0701
Logistics	-0.3584	0.4412	0.4699	0.3029	0.0971	0.3549
*Ratio per 100 population						

Source: Author's Calculation

Data Envelopment Analysis

The variables with the highest rotated factor loadings—number of ASHA workers, ANM, infrastructure index, blood sugar testing—were selected as inputs. Based on the rotated factor analysis results, two DEA models were constructed to evaluate the technical efficiency of HWCs using the most significant dimensions emerging from the factor structure (see Table 3). The factor loadings suggest strong clustering of variables around total outpatient care and NCD management.

Table 3: Composition of models

Role	**Model 1**	**Model 2**
Input	ANM, Infrastructure	Asha, Blood Sugar Tests
Output	Outpatient visits(OPD visits)	Number of people who took medicine for Hypertension and Diabetes

* Ratio per 100

Model 1 evaluates overall outpatient performance. It uses OPD consultations per 100 population as the output, reflecting patient volume. The inputs are ANM availability and infrastructure scores of centres. Model 2 evaluates NCD screening efficiency for hypertension and diabetes using medication uptake as outputs. Their joint use is justified by strong factor co-loading, reflecting a unified screening process. To maintain the DEA's discriminatory power, models include a maximum of four variables. Several models with different combinations of inputs and outputs were implemented, but we only show the results of the two models that obtained the best results, separately for total OPD and NCD patient care. After applying the selected models (Table 3), the efficiency value is obtained (Table 4).

In Model 1, the range of efficiency is between 0.522 and 1. Those units that are inefficient need to reduce their consumption of inputs proportionally between 10.9% and 47.8% for their level of outputs. The best performing HWCs as per model 1 are 3, 9, and 11. On the other hand, low performing ones are HWC 4,7 and 8. With the addition of hypertension and diabetes care, efficiency scores widened in model 2, averaging 0.502 and ranging from 0.254 to 1. The top performers were HWCs 6 and 1, while HWCs 7, 10, and 12 ranked lowest. Notably, HWC 1 was efficient in both models, whereas HWC 7 was consistently among the lowest.

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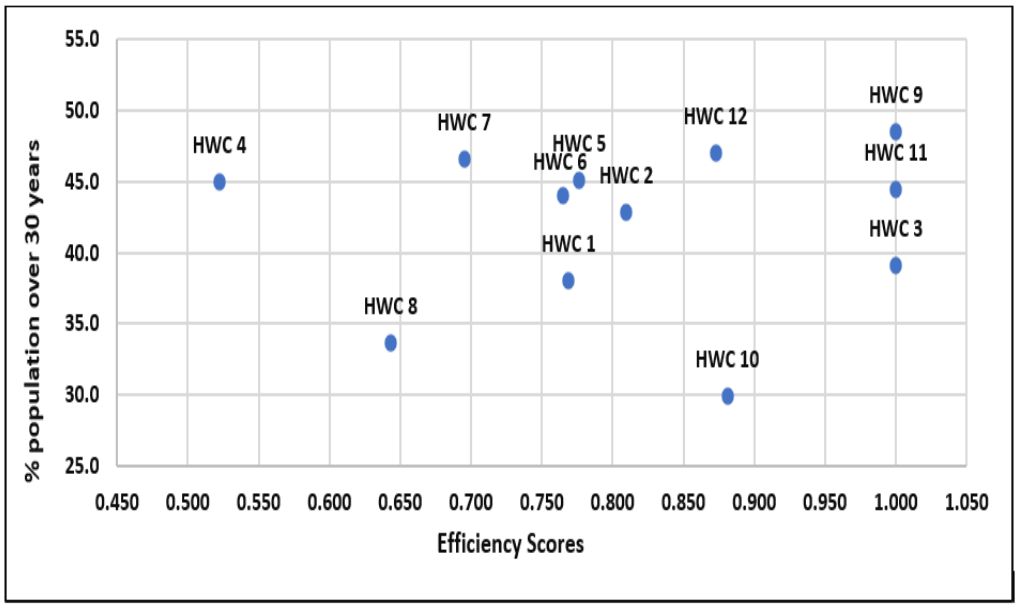
Table 4: Efficiency obtained with models 1 and 2 for variable return to scale (VRS)

	MODEL 1		**MODEL 2**	
	rank	theta	rank	theta
HWC 1	8	0.769	2	1.000
HWC 2	6	0.810	9	0.388
HWC 3	1	1.000	3	0.583
HWC 4	12	0.522	5	0.568
HWC 5	7	0.776	7	0.469
HWC 6	9	0.765	1	1.000
HWC 7	10	0.695	10	0.313
HWC 8	11	0.643	6	0.480
HWC 9	1	1.000	4	0.571
HWC 10	4	0.881	12	0.004
HWC 11	1	1.000	8	0.394
HWC 12	5	0.873	11	0.254

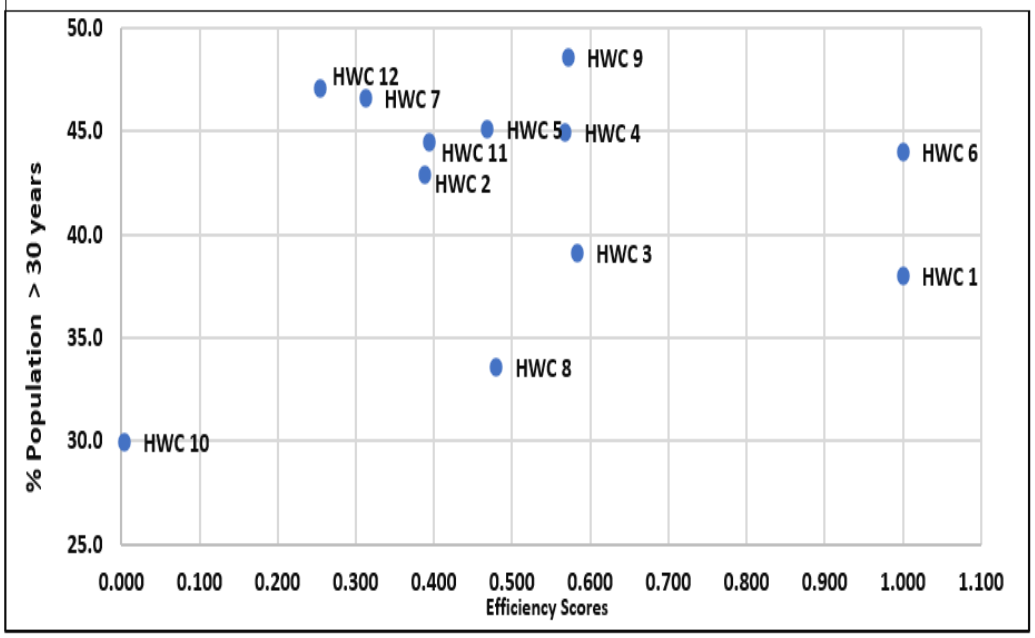
Source: Author's calculations

Fig.2: Efficiency frontier of Model 1 corresponding to % of population above 30 years.



The Data Envelopment Analysis (DEA) results provided are based on a variable returns to scale (VRS), output-oriented model that evaluates the technical efficiency of Health and Wellness Centres (HWCs) using selected inputs and outputs. Each decision-making unit (DMU) receives an efficiency score, where a score of 1 indicates efficiency. Scores less than 1 reflect varying degrees of inefficiency, suggesting that the unit could potentially increase output or reduce input to achieve parity with best-performing units. Model 1 considered total outpatient visits as the output while model 2 considered the patients coming for dibates and hypertension only, as output. In Model 1, several DMUs (specifically DMUs 3, 9 and 11) have achieved an efficiency score of 1, denoting that they could serve as benchmarks for others in the sample. The figure 2 showcases the efficiency of the centres in model 1 graphically.

Fig.3: Efficiency frontier of Model 2 corresponding to % of population above 30 years.



The figure 3 showcases the efficiency of the centres in model 2 graphically. Inefficient units can be analyzed through reference to their peer set, guiding targeted interventions such as increased staff training, improved supplies management, or realignment of service processes. DEA not only quantifies inefficiency but also identifies specific reference units that inefficient DMUs should emulate to enhance productivity. The presence of efficient units suggests that best-practice performance is feasible even within existing constraints, and the significant proportion of inefficient units signals opportunities for systemic enhancement. Integration of DEA into management and quality improvement strategies can foster an environment of data-driven optimization, ultimately contributing to more equitable and effective primary care delivery in low-resource settings.

Many DMUs display substantial differences in efficiency between the two models. In particular, Model 2 generally yields lower efficiency scores across DMUs compared to Model 1. This suggests that while some HWCs efficiently manage general outpatient care, they may lag in providing effective diabetes and hypertension services. Such discrepancies reveal specific performance gaps in chronic disease management, likely tied to variations in staff training, diagnostics utilization, and clinical protocols. Most DMUs fall below the efficiency frontier in both models, with a considerable spread of efficiency scores. This dual-model visual presentation underscores the importance of tailored strategies in HWC management. It highlights not only the overall resource conversion capability but also the specialized capacity for NCD (Non-Communicable Disease) care, which is critical for long-term public health impact in rural settings. However, it is also important to note that DEA is sensitive to sample size and selection of variables. This study was cross-sectional, and there could be a potential measurement error. A variation in the inputs and outputs can lead to a different spread of efficiency.

DISCUSSION

This study combines Factor Analysis, Data Envelopment Analysis, and qualitative fieldwork to evaluate rural Health and Wellness Centers' efficiency. While DEA is valuable for benchmarking, the findings reveal limitations and contextual challenges to consider. The primary advantage of DEA lies in its ability to distinguish efficient from inefficient centres by constructing an efficiency frontier. In this analysis, three HWCs were identified as fully efficient in outpatient service delivery, while two centers demonstrated optimal performance in managing hypertension and diabetes, thereby serving as benchmarks for underperforming facilities, particularly those within the same or adjacent blocks. It is important to recognize that these efficiency assessments are relative to the sample of 12 HWCs included in this study; the efficiency frontier and rankings may vary substantially if HWCs from additional districts or states are incorporated.

The inclusion of some key intercepts from the qualitative findings further elaborated the key pillars behind the sound working and upkeep of health and wellness centres. The important factors are the availability of medicines, positive management, and mutual trust. Cojoined with an output-oriented approach, our study reflects the reality that most inputs in public healthcare systems - including staff allocation, equipment, and facility infrastructure - are largely predetermined at the HWC level and not easily modifiable in the short term. Consequently, our analysis focused on how HWCs could maximize their health service outputs given these relatively fixed inputs. Our results suggest that in the context of Uttar Pradesh's HWCs, improving efficiency requires better utilization of existing resources rather than simply reducing inputs.

The selection of input and output variables potentially impacts DEA outcomes. To address this, preliminary factor analysis was conducted to identify the most relevant variables. Our findings suggest key policy implications for HWC management in Uttar Pradesh. Expanding ASHA-led hypertension and diabetes screening could enhance chronic care outcomes statewide. The observed negative association between infrastructure and efficiency warrants reevaluation of investment priorities, potentially shifting focus from physical infrastructure to workforce development and community engagement. Additionally, marked efficiency disparities among HWCs highlight opportunities for peer learning, with high-performing centers serving as benchmarks for lower-performing facilities.

Future research should address current limitations by incorporating longitudinal data to enable dynamic efficiency analysis and including quality metrics—such as patient satisfaction, treatment adherence, for a more comprehensive evaluation of HWC performance beyond absolute service volume. While CMO office targets aim to improve accountability, this study highlights that these top-down targets can lead to unintended consequences, such as skewed priorities and data inflation when detached from ground-level realities. Reforms should prioritize audit of data quality over rigid output quotas, ensuring HWCs are equipped to deliver quality care. This is an important insight triangulated by the qualitative insights.

In conclusion, as India advances its primary healthcare system via the HWC initiative, continuous efficiency monitoring using DEA, supplemented by qualitative evaluations, is critical to optimizing resource use and achieving universal health coverage.

CONCLUSION

The discussion underscores that integration of both quantitative DEA findings with qualitative insights from frontline workers and users is vital for evidence-driven health system reform. The findings advocate for continued monitoring and capacity building within HWCs, and point to the need for further multi-site studies to validate and generalize these results for broader healthcare system improvement in India. Health system requires financial investments, physical infrastructure as well as resilient workforce strategies, on-the-job refresher training sessions, and performance incentives—especially for rural HWCs serving high-need populations.

Future research should embrace mixed-methods frameworks and extend analyses across broader geographic settings to inform robust interventions. Overall, technical efficiency in Indian HWCs is both measurable and improvable. By leveraging DEA results as a starting point for targeted management and policy intervention—alongside a people-centered focus—the health system can move closer toward the universal, high-quality care envisioned in the national health mission.

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