

# Operationalizing Sustainability in Ayurvedic Hospitals: A DEA-based Service Delivery Framework

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## Abstract

*Ayurvedic hospitals face a unique operational challenge: delivering highly personalised constitution-based care while ensuring efficiency, sustainability and scalability. Traditional process variability often leads to resource inefficiencies and limits the ability to benchmark performance. This study proposes a sustainable service delivery framework that strategically integrates operations management principles with Ayurvedic clinical practices. Using a Data Envelopment Analysis (DEA) approach, the study evaluates the operational efficiency of multiple Ayurvedic hospitals, while Structural Equation Modelling (SEM) examines the relationships between process standardization, personalized care, operational efficiency, sustainability performance and patient satisfaction. Results indicate that standardizing non-clinical processes significantly enhances efficiency and sustainability outcomes without compromising personalized treatment, while personalized care remains a strong predictor of patient satisfaction. The study provides a data-driven blue-print for designing scalable, efficient and environmentally sustainable Ayurvedic healthcare services, bridging traditional practices with modern operational insights. These findings offer valuable guidance for hospital administrators, policymakers and researchers seeking to integrate traditional medicine into mainstream sustainable healthcare systems.*

**Keywords:** Ayurvedic Hospitals, Sustainable Service Delivery, Operations Management, Data Envelopment Analysis (DEA), Structural Equation Modelling (SEM), Healthcare Efficiency

## Introduction

Throughout the world, there is an increased focus on how healthcare organizations can become more effective, eco-friendly and patient-focused. Many people are becoming aware of the role that Ayurveda can play in helping people achieve wellness. However, Ayurveda-based health systems are currently experiencing operational difficulties due to the complexity and customisation involved in their treatments. The traditional methods of Ayurveda are different from those used in western medicine. The main difference is that Ayurvedic treatments are made to fit each person's individual needs; this leads to greater variability in process and increases the amount of resources required. Thus, it is the goal of this project to create a new service delivery model that combines both process standardisation and the personalisation of treatment.

## Literature Review

**Service Standardization in Healthcare:** The standardization of services is an important factor that will help to improve the consistency, efficiency, and quality of health care delivery. Han & Ma (2022) propose that by utilising data-driven integrated care pathways, standardising patient-centred services (while still allowing for sufficient flexibility for personalisation) will also eliminate variability in care and enhance continuity of care and patient engagement through the development of a constant, yet flexible, structure of care plans, made possible through the use of real-time data and the utilisation of digital technologies. Wu, Ji, Lu et al. (2018) presented the results from a population-based study to develop a stratification of the standardisation process, whereby the hospitals could be compared based on the indicators of performance (demographic and clinical) through their development of a method to adjust the comparison process for both demographic and clinical confounders (i.e., Length of Stay (LOS) and treatment costs). Overall, it was found that standardising the LOS and Treatment Cost metrics will improve comparability of these metrics, thereby providing a better assessment of the performance level of hospitals and a more informed decision-making process for validating performance assessments. Similarly, Okeke, Agu, Ejike et al. (2022) have developed a proposed Service Standardisation Model (SSM) for health care systems, with a focus on the establishment of standard protocols; the implementation of quality assurance mechanisms; and a systematic performance monitoring system to allow for equitable access to reliable and evidenced-based delivery of health care across various institutions.

**Personalisation and Mass Customisation:** The research around personalization and mass customization has helped people realize that individualized customer experiences can be achieved with operational efficiency. Tihonen and Felfernig (2017) describe how personalization technologies allow customers to easily navigate complex customization environments by helping to lower the level of decision effort necessary to choose them, and to improve the product-service experience. Sunikka and Bragge (2009) differentiate personalization, which focuses on user modeling and technology, from mass customization, which emphasizes flexible product variants and system design. Da Silveira, Borenstein and Fogliatto (2001) define mass customization as delivering individualized offerings at near mass-production cost through flexible processes. Da Silveira, Borenstein and Fogliatto (2012) extend this framework by identifying success factors and implementation strategies. Wang, Ma, Yang and Wang (2017) further introduce industry 4.0 concepts enabling mass personalization through cyber-physical systems and IoT. Taps, Ditlev and Nielsen (2016) highlight limited adoption of these strategies in SMEs and call for focused operational frameworks.

**Sustainability in Healthcare Operations:** Healthcare organizations are resource-intensive and require sustainable operational strategies. Flynn et al. (2025) reveal gaps in organizational support and training for reducing environmental impacts in operating rooms. Dolcini et al. (2025) propose environmental KPIs across energy, waste, water, emissions, transport and site sustainability for hospital benchmarking. Aldafeeri et al. (2024) show that green nursing practices reduce costs and resource consumption simultaneously. Benzidia et al. (2024) demonstrate how big data analytics drives green process innovation in healthcare supply chain, while Mostepaniuk, Akalin and Parish (2023) identify leadership, clinician engagement and rational resource use as key drivers for sustainable healthcare performance.

## Research Gap

Despite the growing emphasis on sustainable healthcare operations, empirical research integrating traditional medicine systems such as Ayurveda with modern operations management frameworks remain limited. Existing studies largely focus either on clinical effectiveness or sustainability practices but lack data-driven models that balance personalization with process standardization and scalability. There is also a scarcity of quantitative benchmarking tools like DEA combined with SEM in Ayurvedic hospital settings. In addition, there is not enough research and documentation linking personalized care, operational efficiency and sustainability performance, and patient satisfaction in Ayurveda. This results in an information gap for developing an effective, measurable and sustainable service delivery system for constitution-based care.

## Research Objectives

- To examine the impact of process standardization on operational efficiency.
- To analyze the effect of operational efficiency on sustainability performance.
- To assess the role of personalized care in patient satisfaction.

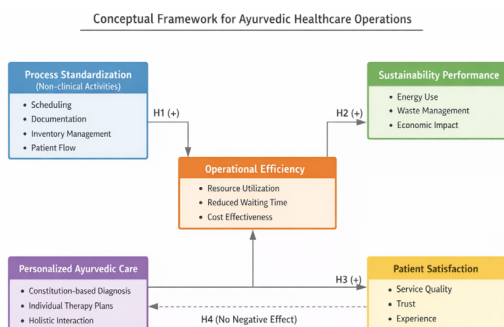
## Hypotheses

- **H<sub>1</sub>**: Process standardization positively affects operational efficiency.
- **H<sub>2</sub>**: Operational efficiency positively affects sustainability performance.
- **H<sub>3</sub>**: Personalized Ayurvedic care positively affects patient satisfaction.
- **H<sub>4</sub>**: Process standardization does not negatively affect perceived personalization.

## Research Methodology

A quantitative, cross-sectional research design was adopted. Data were collected from Ayurvedic hospitals using structured questionnaires administered to administrators, physicians, therapists and patients. Stratified random sampling ensured representation across hospital types.

**Analytical tools used:** (i) Structural Equation Modelling (SEM). (ii) Data Envelopment Analysis (DEA) for efficiency benchmarking. (iii) Multiple Regression for robustness checks. (iv) Reliability and Validity were assessed using Cronbach's alpha, composite reliability and confirmatory factor analysis.



## Conceptual framework

[Image: Conceptual framework diagram showing relationships among process standardization, operational efficiency, sustainability performance, personalized care and patient satisfaction. Source: article manuscript.]

## Data Analysis

An orderly multi-staged approach of analyzing the data for the study was employed to identify how process standardization, operational efficiency, sustainable performance, personalized care and patient satisfaction are related to each other in Ayurvedic Hospitals. The analytical framework integrated descriptive statistics, testing for reliability and validity; Data Envelopment Analysis (DEA), Structural Equation Modelling (SEM) and regression-based robustness checks to provide results with methodological rigor and triangulation of findings.

## Data Screening and Descriptive Statistics

The collected questionnaires were screened for missing values, outliers and normal distribution prior to conducting any statistical analysis. In cases where there were extensive amounts of missing data, the observation was removed from analysis; however, minimal gaps were addressed with mean imputation. Outliers for this study were assessed using the Mahalanobis distance method and box plots as a means to control for potential distortion of results due to outliers in the multivariate analyses performed on the data set.

Finally, the distributional characteristics of the data (as assessed using the values of skewness and kurtosis) indicated that all study constructs met the recommended range. The data were subsequently analyzed to produce descriptive statistics on the types of respondents in this research (i.e., hospital administrators, physicians, therapists, patients) and the key variables of interest in the present study. Among other things, measures of central tendency and variability on the responses indicated a high degree of agreement for items regarding the following: (i) the perceived standardization of current medical practices; (ii) the perceived effectiveness and efficiency of the existing healthcare delivery model; (iii) environmental sustainability initiatives in healthcare; and (iv) personalized care delivery. These descriptive statistics provide preliminary evidence supporting the appropriateness of the sample and data set for conducting further inferential analyses.

### **Reliability and Validity Assessment**

Measurement reliability and the measurement process were also assessed. Reliability was determined through Cronbach's alpha and composite reliability (CR). A value of 0.70 or higher for both types of reliability determined the measurement scale was reliable and the measurements were internally consistent. Convergent validity was determined using factor loadings and Average Variance Extracted (AVE). AVE values of all standard loadings were above 0.50 and factor loadings were all above 0.60; this indicated that the construct had exposed a significant amount of variance in the indicators. Discriminant validity was assessed using the Fornell-Larcker Criterion, wherein the square root of the AVE for each construct had to exceed its correlations with other constructs. The findings validated process standardization, operational efficiency, sustainability performance, personalized care and patient satisfaction as empirically distinct constructs. Confirmatory Factor Analysis (CFA) was conducted using AMOS to analyze and validate the measurement model. The model fit indices — Chi-Square/df, CFI, TLI, RMSEA and SRMR — were all within acceptable ranges, thereby indicating the measurement model had an adequate fit to the observed data.

### **Data Envelopment Analysis (DEA)**

The operational performance of Ayurvedic hospitals was evaluated using Data Envelopment Analysis (DEA), which provided a way to compare the performance of multiple Decision-Making Units (DMUs) on a relative basis using inputs and outputs. Input measures were used to determine how many people worked at each hospital, how much it cost to operate each hospital, how much of the hospital's infrastructure and equipment was being used, and how long it took to treat patients. Output measures of patient in-take, patient satisfaction levels and quality of care were used to compare hospitals against one another. The input-oriented DEA model determined how much more efficient hospitals could be by reducing their use of resources (staff, infrastructure, energy, etc.) while still achieving the same output levels. DEA results support the concept of using quantitative data to develop meaningful benchmarks for hospitals and provide additional evidence that standardization of non-clinical operational processes could improve the efficiency of a hospital's operations without interfering with the personal nature of Ayurvedic treatments.

### **Structural Equation Modelling (SEM)**

To demonstrate the hypothesized associations of process standardization, operational efficiency, sustainability performance, and personalized care with patient satisfaction, SEM was utilized to simultaneously test these relationships and evaluate the causal links among these five constructs. The structural model identified the hypothesized relationships among the constructs, whereby there are paths that extend from process standardization to operational efficiency, operational efficiency to sustainability performance, personalized care to patient satisfaction; however, standardization had a non-negative impact on perceived personalization. To test the hypothesized relationships, path coefficients, t-values, and p-values were calculated for the sample. Bootstrapping methods were used to increase the statistical power. The model produced significant amounts of variance in operational efficiency as well as sustainability performance and

patient satisfaction. The findings support H1 in that the effect of process standardization on operational efficiency is positive and statistically significant. This indicates that providing standardized protocols for non-critical operations such as scheduling, documentation, inventory management, patient flow, etc. has a positive impact on the efficiency of Ayurvedic hospitals. In addition, the relationship between operational efficiency to sustainability performance was positive and statistically significant, confirming H2 and suggesting that when resources are used in a cost-effective manner, they produce environmental and economic sustainability. The results demonstrate H3 in that providing personalized care has a strong positive impact on patient satisfaction. This aligns with the Ayurvedic philosophy that a constitutionally based approach to care through individualized treatment protocols is one of the primary predictors of perceived service quality and therefore patient satisfaction. Moreover, when testing the pathway for H4, it became clear that while process standardization appeared to have no detrimental impacts on individuals' perception of personalization it did offer a neutral to slightly positive correlation between the two; therefore, establishing that operationally streamlining patients would not compromise individualized experiences if clinical autonomy is maintained.

### **Multiple Regression and Robustness Checks**

To validate the findings further, a robustness check was conducted using multiple regression analysis in the form of three separate regressions: first, to check for process standardization's effect on operational efficiency; for sustainability performance, the second regression was done by looking specifically at how operational efficiency affects sustainability; while the last regression assessed how much personalized care influences the patient's satisfaction level. The results produced through each of the three above regressions were found to be in line with each of the confirming SEM results, showing consistency between methods of analysis. The VIF values were also computed to check for multicollinearity; all values were within an acceptable range. Homoscedasticity and linearity were assessed using residual analysis; both analyses confirmed that the overall results remain stable and reliable.

### **Integrated Interpretation of Results**

Integrating DEA and SEM produced both benchmarking information and an explanation of how managerial practices and care philosophy predict sustainability- and satisfaction-related factors. Using DEA determined how hospitals measured the relative efficiencies of one another while SEM explained why managerial practices and care philosophy produced sustainable and satisfactory outcomes. Combining DEA's analytical hybrid approach added to the methodological strength of the study and provided a wealth of data entries for those administrators and policymakers wanting action based on this information.

An overall evaluation of the data demonstrated Ayurveda hospitals can optimally create efficiencies in both sustainable operational performance and patient-centric performance by strategically combining how they apply standardisation to their support processes and individualising their patient clinical care.

The results of this evaluation indicate that standardisation of processes can positively influence an Ayurvedic hospital's operational efficiencies as a result of standardisation and support for H1. Standardising non-clinical processes (i.e., scheduling, charting, inventory management, patient flow) eliminates excessive variances and wasted resources without negatively impacting physician autonomy or efficient use of resources. As indicated in the benchmarking data, considerable variation existed between various hospitals, with the most efficient hospitals using staff more effectively, reducing patient wait times and decreasing overall resource usage associated with hospitals' use of physical facilities.

Operational efficiencies are very likely to contribute positively and significantly to sustainable operational performance in Ayurvedic hospitals, thereby supporting H2. Hospitals that have greater operational efficiencies have reduced resource use, introduced better waste management practices and achieved greater economic and environmental outcomes. Therefore, operational efficiencies are an essential strategy for attaining and achieving sustainable healthcare practices in any culture employing traditional techniques and methods.

The evidence supports H3 because of how positively the personalized Ayurvedic approach impacted patients' overall satisfaction levels, as well as their appreciation of the diagnostic method based on their individual characteristics (constitution), the tailored treatment plan for each patient and the overall holistic approach to patient interaction. Furthermore, H4 was also validated through the findings, showing that regardless of where standardization occurs in the healthcare process, the application of process standardization will not diminish the perception by the patient of being personalized, as well as increasing the efficiency of individualized care whereby clinicians devote a significant amount of time to developing treatment regimens based on the patients' needs. This indicates the potential for all Ayurvedic hospitals to grow and sustain themselves over time while still maintaining very high levels of patient satisfaction due to the combination of process standardization and personalized care.

### **Discussion**

The study's conclusions provide greater insight into how traditional health care systems, such as Ayurveda, can effectively integrate and apply the principles of modern business operations without compromising their foundational values. The positive correlation between the standardization of processes and operational efficacy indicates that a great deal of inefficiency within Ayurvedic hospitals is attributable to variability in the performance of non-clinical processes. The standardization of such activities as patient scheduling, patient documentation, inventory management, and resource allocation leads to improved coordination and increased throughput, which is consistent with the service operations theory. Additionally, operational efficiency's strong influence on sustainability performance indicates that the two objectives — economic and environmental — are interconnected within the health care industry. Moreover, an efficient use of manpower, energy, and materials leads to lower costs and environmental impacts directly. Finally, the strong connection between patient satisfaction and personalized care reaffirms the idea that Ayurveda values the constitution-based approach to treatment, and therefore, personalization remains a key factor in determining service quality. Finally, the non-negative impact of process standardization on perceived levels of personalized service challenges the assertion that efficiency-driven systems reduce the delivery of individualized care; in actuality, clinical autonomy and operational discipline can coexist.

### **Managerial Implications**

The results offer a data-driven approach for hospital administrators to achieve optimal personalization and scalability in their operations and highlight areas of measurable improvement that result from investing in digital health records, workflow automation, standard operating procedures, and performance dashboards to assist hospitals with operational efficiency and benchmarking. Efficiency audits using data from the DEA enable hospitals to identify unused/underutilized personnel and best practices among their peers and promote the integration of Ayurvedic hospitals into mainstream sustainable healthcare strategies by creating operational accountability and supporting clinical excellence.

### **Conclusion**

The present work presents an innovative, quantitative framework that integrates Ayurvedic philosophy into contemporary service operations management by utilizing the combination of DEA and SEM to show how process standardization, operational efficiency, sustainability performance and personalized care are connected through a single model. Ultimately, the results demonstrate that it is possible to sustainably scale up and provide patient-centered Ayurveda Healthcare Delivery Systems through a combination of operational rigor and personalized treatment, providing important guidance for researchers, practitioners and policymakers as they work toward responsible, modernizing practices within their respective, traditional healthcare systems.

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