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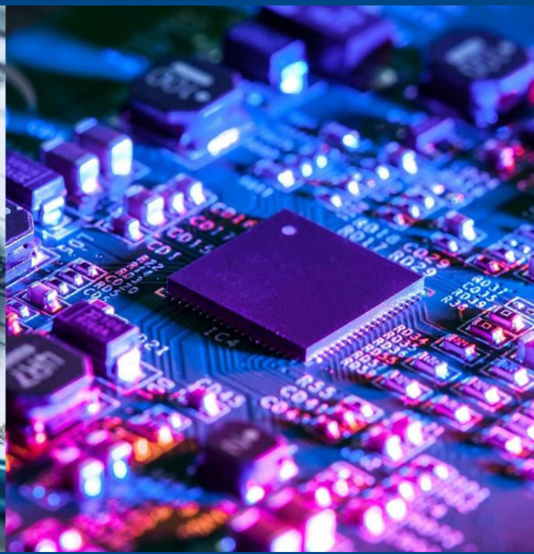

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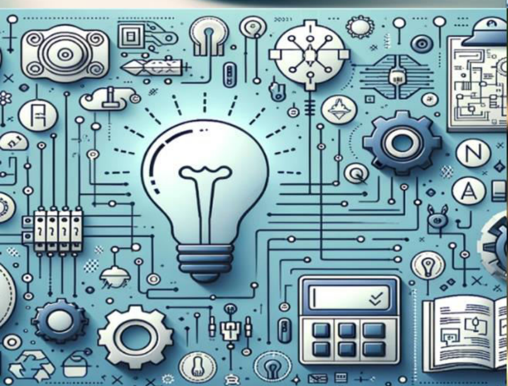

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A Innovative Method of Design and Implementation of Sustainable Water Supply Projects in Chhatrapati Sambhaji Nagar City, Maharashtra

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ABSTRACT: Ensuring a reliable, equitable, and sustainable water supply in rapidly urbanizing cities presents significant engineering, economic, and management challenges. As urban populations surge and city boundaries expand, legacy water infrastructures frequently struggle to keep pace, leading to systemic inefficiencies, intermittent supply, and resource depletion. To address these critical issues, this study, titled "An Innovative Method of Design and Implementation of Sustainable Water Supply Projects in Chhatrapati Sambhaji Nagar City, Maharashtra," proposes a comprehensive, data-driven framework aimed at thoroughly modernizing urban water infrastructure.

The proposed approach seamlessly integrates advanced hydraulic modelling, Geographic Information System (GIS)-based spatial planning, smart monitoring technologies, and energy-efficient system designs to drastically improve overall water supply performance. In this study, rigorous hydraulic analysis and complex network optimization were carried out utilizing industry-standard WaterGEMS and SewerGEMS software. These advanced simulation tools enabled the precise evaluation of fluid dynamics, flow rates, and pressure distributions across the city's network. This technical analysis was deeply supported by GIS-based asset mapping, which provided an accurate, geo-referenced inventory of existing pipelines, reservoirs, and utility nodes, thereby facilitating highly accurate infrastructure planning and informed, data-backed decision-making.

Furthermore, the methodology places a strong emphasis on demand-based zoning and active pressure management to ensure that water reaches all demographic segments equitably, without overwhelming the aging pipes. By integrating real-time monitoring through Supervisory Control and Data Acquisition (SCADA) systems, the framework enhances operational control, allows for immediate fault detection, and significantly boosts overall service reliability. Sustainable engineering strategies—such as aggressive leakage reduction protocols and the deployment of energy-efficient pumping mechanisms—were meticulously incorporated. These interventions are specifically designed to minimize Non-Revenue Water (NRW) and curtail physical and commercial operational losses, which are major financial drains on municipal bodies.

Ultimately, the proposed framework aims to achieve a continuous water supply, highly improved distribution efficiency, and robust long-term resource sustainability. The analytical results indicate substantially enhanced operational performance, notably reduced energy consumption, and deeply improved financial viability for the city's water supply system. Beyond local benefits, the developed model provides a highly scalable and readily replicable solution for broader urban water management. It closely aligns with paramount national policy initiatives, such as the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and the Drink from Tap Mission, actively supporting the transition toward smarter, more resilient, and deeply sustainable urban water ecosystems.

KEYWORDS: WaterGEMS, Distribution System, Hydraulic Modelling, GIS, SCADA, NRW, AMRUT, DMA, Sustainable Water Supply Chhatrapati Sambhaji Nagar.

I. INTRODUCTION

Water is the most critical natural resource for sustaining life, safeguarding public health, and driving socioeconomic development while ensuring environmental equilibrium. In the context of India, rapid urbanization, exponential

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population growth, and industrial intensification have placed unprecedented strain on municipal water supply systems. The escalating demand for safe and continuous potable water necessitates a transition from traditional management to innovative, sustainable urban water management (SUWM) frameworks that prioritize equitable distribution and long-term security.

Chhatrapati Sambhaji Nagar (formerly Aurangabad), a major industrial and educational hub in Maharashtra, epitomizes the challenges faced by Tier-II Indian cities. Over the last decade, the city's expansion has outpaced its infrastructure development. Current municipal data reveals a critical imbalance: the city's daily water demand is approximately 612 MLD, while the current supply capacity is restricted to 186 MLD. This massive demand-supply gap has historically necessitated intermittent supply schedules, forcing residents to rely on private vendors and decentralized storage—practices that exacerbate social inequity and elevate public health risks due to potential contamination in stagnant lines.

The existing infrastructure is hampered by several interconnected technical and operational bottlenecks:

- Physical Losses: Aging pipelines and obsolete networks lead to excessive leakages and high Non-Revenue Water (NRW) levels.
- Capacity Constraints: Existing Water Treatment Plants (WTP) and storage reservoirs are insufficient to meet peak demand.
- Operational Inefficiency: A lack of comprehensive metering, inefficient billing, and the absence of real-time monitoring hinder revenue recovery and infrastructure reinvestment.
- Sustainability Risks: Excessive groundwater extraction in peripheral zones threatens the local water table and long-term environmental viability.

To mitigate these challenges, this research, titled "An Innovative Method of Design and Implementation of Sustainable Water Supply Projects in Chhatrapati Sambhaji Nagar City, Maharashtra," proposes an integrated, technology-driven framework for modernizing urban water systems. This study leverages advanced engineering tools, including hydraulic modelling (WaterGEMS/SewerGEMS), GIS-based asset mapping, and SCADA-based real-time monitoring to optimize network performance and facilitate data-driven decision-making.

The primary objective of this study is to develop a sustainable, data-oriented framework that ensures hydraulic efficiency, minimizes physical and commercial losses, and enhances service reliability. The proposed methodology incorporates District Metered Areas (DMAs) for localized pressure management, energy-efficient pumping configurations, and smart metering to achieve a transition toward a 24×7 continuous water supply. Aligned with national initiatives such as AMRUT and the "Drink from Tap" Mission, this framework seeks to transform Chhatrapati Sambhaji Nagar's infrastructure into a resilient, automated, and efficient system that serves as a replicable model for rapidly growing urban centres across India.

II. METHODOLOGY

The research methodology adopted in this study involves a systematic approach for planning and hydraulic modelling of the distribution network using GIS, AutoCAD, and WaterGEMS software. The methodology includes several stages such as data collection, base map preparation, population forecasting, distribution network design, hydraulic analysis, and model optimization.

2.1. Study Area Assessment

The study focuses on the primary municipal limits of Chhatrapati Sambhajinagar along with its rapidly expanding peripheral regions that have recently been merged under the city's jurisdiction. A comprehensive audit was conducted of the existing infrastructure, ranging from the primary intake structures at the source to the terminal distribution nodes. By evaluating current urban growth patterns, the assessment pinpointed specific zones where service deficiencies and hydraulic bottlenecks are most prevalent. This foundational step allowed for a clear understanding of the spatial constraints and structural weaknesses inherent in the legacy system. Consequently, the study identifies critical areas that require immediate capacity expansion to meet future urban density.

2.2. Data Collection and Analysis

Data acquisition involved a hybrid approach, gathering primary field data on current population density, water consumption patterns, and the physical condition of existing pipelines. Secondary data were meticulously sourced from

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Detailed Project Reports (DPRs), historical government records, and high-resolution satellite imagery. This multi-source data was then cleaned and integrated into a centralized Geographic Information System (GIS) database to create a "digital twin" of the city's assets. The resulting database facilitates spatial analysis, allowing for the correlation between topographic variations and service levels. This structured data serves as the empirical backbone for all subsequent hydraulic simulations and forecasting.

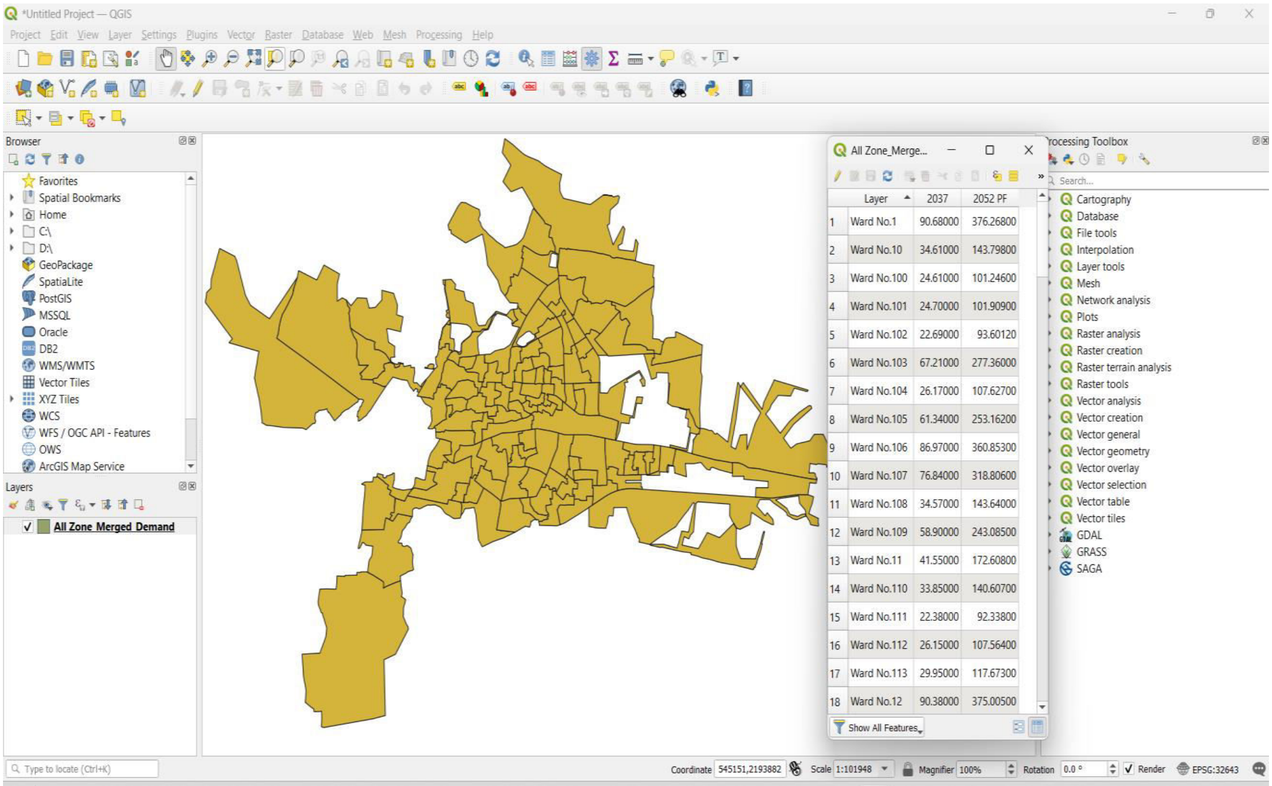

Figure 1: Data Analysis in GIS

2.3. Population Projection and Demand Estimation

To ensure the system's longevity, population forecasting was executed using the Geometric Increase Method, projecting growth trends up to the design horizon of 2055. Water demand estimations were strictly aligned with the CPHEEO (Central Public Health and Environmental Engineering Organisation) norms, accounting for both per capita domestic needs and institutional requirements. The study also factored in fire-fighting demands and industrial water needs to create a comprehensive volumetric profile. Various future demand scenarios were simulated to determine the ultimate peak demand the system must withstand. This rigorous estimation process ensures that the proposed infrastructure is neither under-designed for the future nor inefficiently over-designed for the present.

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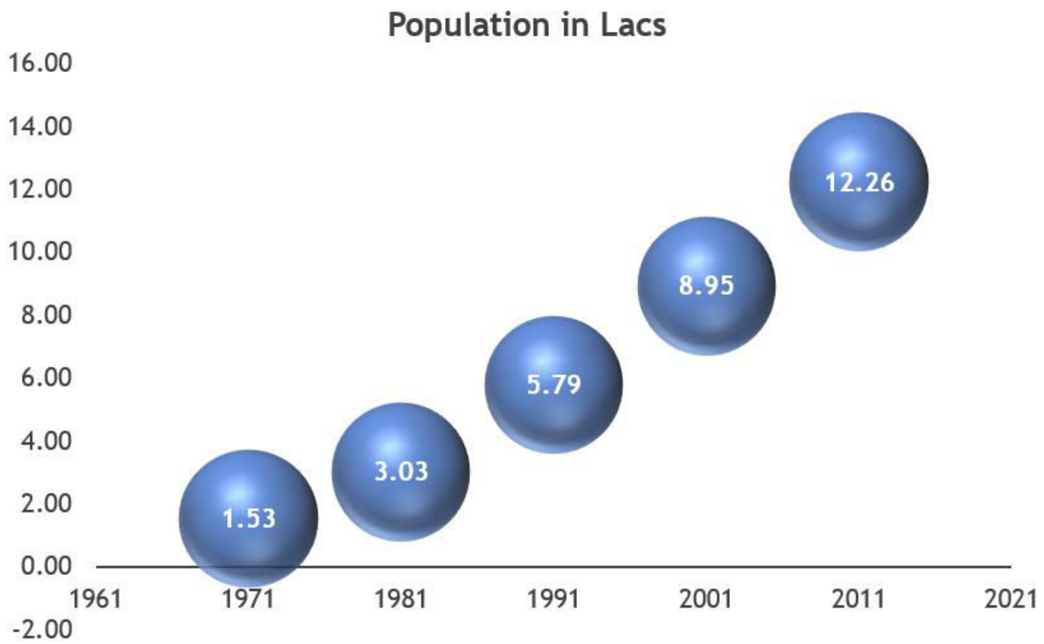

Figure 2: Population – Historical Data

2.4. Hydraulic Modelling and Network Optimization

Advanced hydraulic simulations were conducted using Bentley WaterGEMS and SewerGEMS to analyze the behavior of the network under varying flow conditions. The model successfully identified critical hydraulic failures, such as chronic low-pressure zones, excessive head losses, and areas of high stagnation. Optimization was achieved through iterative simulations, where pipe diameters were resized and network looping was introduced to enhance system redundancy. The formation of District Metered Areas (DMAs) was integrated into the model to facilitate better pressure management and easier leak detection. These refinements ensure that the distribution network operates at peak efficiency while maintaining equitable pressure across all topographical elevations.

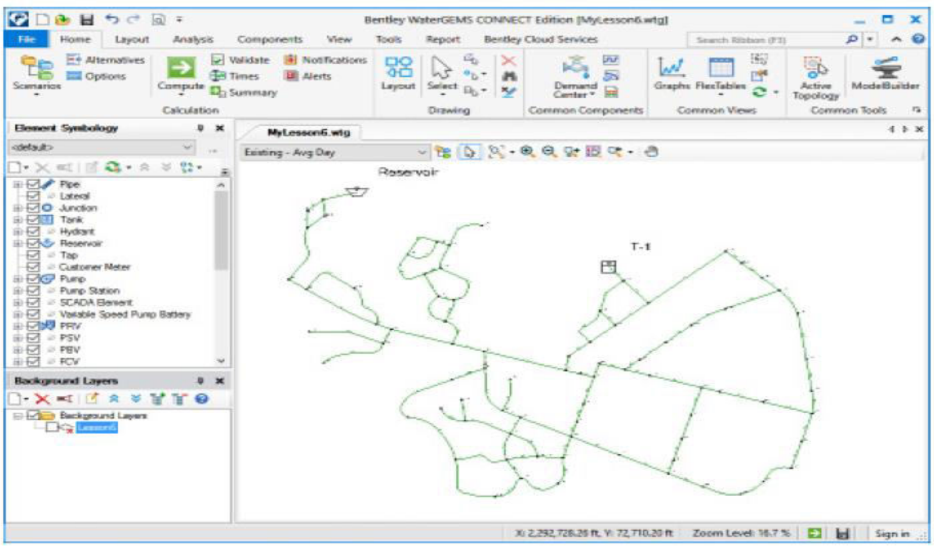

Figure 3: Hydraulic Modeling Analysis in WaterGEMS

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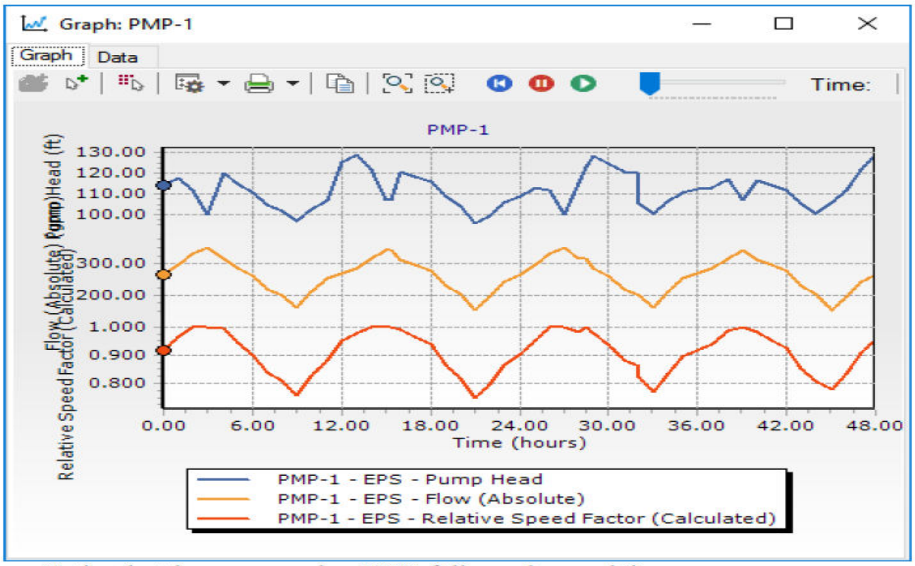
2.5. Sustainable Design Interventions

Sustainability was integrated into the design through the selection of energy-efficient pumping systems and the use of corrosion-resistant, high-durability pipeline materials. The framework proposes a SCADA-based smart monitoring system to provide real-time data on flow rates and pressure fluctuations, allowing for immediate corrective actions. To reduce the burden on surface water sources, the methodology incorporates rainwater harvesting and localized groundwater recharge as conjunctive use strategies. These interventions are specifically designed to lower the carbon footprint of water delivery while simultaneously reducing operational expenditures. By focusing on long-term viability, these measures ensure the project remains financially and environmentally sustainable over its entire lifecycle.



Notice that the pump reaches 100% full speed several times.

Figure 3: Extended Period Simulation (EPS)

2.6. Tools and Analytical Techniques

The research utilized GIS tools for complex spatial analysis, enabling the precise mapping of infrastructure components against the city's digital elevation model. AutoCAD was employed to generate detailed engineering drawings, technical layouts, and cross-sections necessary for the implementation phase. Statistical validation techniques were applied to calibrate the hydraulic models against observed field data, ensuring high accuracy in the design outcomes. This rigorous analytical approach minimizes the margin of error between simulated results and real-world performance. Collectively, these tools provide a robust technical framework that validates the reliability of the proposed sustainable water supply model

III. RESULTS AND DISCUSSION

The implementation of the proposed sustainable design and planning framework is projected to fundamentally transform the operational landscape of the urban water supply system in Chhatrapati Sambhaji Nagar. Through the application of optimized hydraulic designs, the system achieves a substantial reduction in both physical and commercial water losses. By utilizing WaterGEMS to identify and eliminate high-stress nodes, the study minimizes the probability of pipe bursts, while the integration of District Metered Areas (DMAs) enables granular monitoring to proactively address leakages. This systematic approach directly targets the reduction of Non-Revenue Water (NRW), ensuring that a higher percentage of treated water reaches the end consumer, thereby improving the overall volumetric efficiency of the network.

A critical outcome of this research is the achievement of balanced pressure distribution across the entire transmission and distribution infrastructure. By simulating various flow scenarios, the proposed methodology ensures that topographical variations do not lead to service disparities. This results in the elimination of chronic low-pressure zones in peripheral areas and prevents excessive-pressure conditions in lower-elevation zones that typically lead to

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infrastructure fatigue. Consequently, the system provides an equitable water supply to all service zones, fulfilling the core mandate of social inclusiveness in urban utility management.

From an economic and environmental perspective, the adoption of energy-efficient pumping systems and optimized operational scheduling leads to significant energy savings. By matching pump performance curves with real-time demand data via SCADA systems, the city can drastically reduce its electricity consumption and associated carbon footprint. This operational optimization translates into reduced recurring costs, enhancing the financial viability of the municipal water board. Furthermore, the transition toward a 24×7 continuous water supply ensures consistent availability, significantly reducing the public health risks and the economic burden associated with private water storage and vending.

Comparative analysis highlights that this integrated methodology performs with markedly higher efficiency than conventional, fragmented water supply planning practices. Unlike traditional methods that often overlook long-term resource security, this framework integrates sustainability principles with real-time digital monitoring. The synergy between infrastructure planning and smart technology provides a resilient solution capable of adapting to future urban growth. Ultimately, these results demonstrate that a data-driven, sustainable approach not only optimizes current resource usage but also establishes a scalable blueprint for the future of urban water security in India

The hydraulic modelling of the sewer network was carried out using SewerGEMS software to evaluate the performance of the proposed sewer system. The simulation results provided important hydraulic parameters such as pipe diameter, flow velocity, discharge, and hydraulic grade line.

The analysis showed that the optimized sewer network maintains adequate self-cleansing velocity, which helps prevent sediment deposition and blockage in sewer pipes. The selected pipe diameters and slopes ensure smooth wastewater conveyance through gravity flow without the need for extensive pumping systems.

The results also indicate that the integration of GIS and hydraulic modelling tools significantly improves the accuracy and efficiency of sewer network design. The optimized network layout reduces construction costs while ensuring long-term operational reliability. The study demonstrates that the proposed methodology can be effectively applied to other small towns facing similar wastewater management challenges.

IV. CONCLUSION

The findings of this research demonstrate that the integration of sustainable engineering principles during the Detailed Project Report (DPR) preparation phase is not merely an optional enhancement, but a critical necessity for the long-term viability of urban infrastructure. By transitioning from traditional, reactive planning to a proactive, data-driven framework, the study proves that cities can significantly enhance the hydraulic performance and structural reliability of their water supply systems. The comprehensive approach—centering on demand-based zoning, real-time monitoring via SCADA, and GIS-based asset management—effectively resolves chronic urban challenges such as intermittent supply, pressure imbalances, and high Non-Revenue Water (NRW) levels.

Furthermore, the methodology emphasizes that financial and environmental sustainability are deeply interconnected; energy-efficient pumping and optimized distribution logic reduce operational expenditures while simultaneously conserving vital natural resources. This research provides a robust, scalable, and technologically advanced blueprint that aligns with national mandates like AMRUT and the “Drink from Tap” Mission. Given its success in Chhatrapati Sambhaji Nagar, this framework is highly replicable and can serve as a definitive model for other medium-sized Indian cities striving to modernize their utility networks. Ultimately, the study concludes that adopting such innovative design and implementation strategies is the most effective pathway toward achieving water-secure, resilient, and "smart" urban ecosystems across the country.

V. ACKNOWLEDGEMENTS

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