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Examination of reviews to establish a proposed model to overcome the challenges of Water Management system in India

Sunita Devi[1*], Sukhvir Singh[2]

[1]*Department of Computer Science, Himachal Pradesh University, India*
[2]*Department of Computer Science, HPU Regional Centre Dharamshala, India*

* Corresponding author. E-mail: sunitadhiman46@gmail.com

Abstract

India's water usage has significantly risen in recent decades due to several socioeconomic variables and demographic changes. To satisfy the demand, supplies have significantly risen as a result of extracting surface and groundwater. Consequently, numerous dry and semiarid areas over exploit their underground water resources, leading to a decline in water levels and a degradation in the quality of groundwater, ultimately culminating in a shortage of groundwater. Surface water resources are frequently depleted in numerous basins due to excessive usage. Surface reservoirs are depleting quickly due to siltation. The increasing menace to freshwater supplies is being caused by the waste generated by urbanization and industrial effluents. India's per capita freshwater availability has declined from 6008 M3 per year in 1947 to approximately 2200 M3 per year since 2000, and further to 1486 M3 in 2021. The projected decrease is expected to reach 1170 cubic meters by 2050. The issue has progressively and considerably evolved. Water scarcity poses a basic challenge in terms of feeding the growing global population, protecting ecosystems, and maintaining social stability and health. Society and the environment face potential hazards due to escalating conflicts and disagreements. This study examines the management challenges, growing issues, and water problems in India. Ultimately, a proposed framework is constructed after using specific measures to tackle the challenges.

Keywords: Smart Water City; Water Resources Availability; Surface Water Problems; Water Scarcity and Management Challenges

1. Introduction

A natural resource that is vital to human survival is water. Both in rural and urban communities, water is necessary to sustain sanitation. Additionally, water is a valuable economic resource. It is essential to industrial production processes and agriculture. In addition, water provides numerous ecological and environmental advantages [1]. Pollutants from domestic sewage and industrial effluents must be assimilated. Global freshwater resource demand is increasing. The amount of water utilized by individuals rose by a factor of five between 1900 and 1980. Seventy-five percent of this expansion happened in the last quarter of the century. Globally speaking, there is a relatively constant total amount of fresh water accessible. On the other hand, on a smaller scale, it is clear that freshwater supply is declining in many locations due to altered water system balances, overuse, and increasing freshwater reserve contamination. There is currently a significant water shortage in several developing countries [2]. The growing scarcity of freshwater is posing a serious threat to the world's expanding population.

The production of food, the preservation of ecosystems, the upkeep of social stability, food security, and interstate peace are all hampered by this scarcity. India faces a major water scarcity crisis that threatens ecological management, social sustainability, and economic growth. A growing population, water-intensive agriculture, and fast urbanization are straining the nation's freshwater supplies. These pressures worsen the issue, making water management a national priority [3].

Indian demographics, with a population exceeding one billion, drive increased water consumption. Water-intensive crops and irrigation in agriculture increase this requirement. India's economy relies on agriculture, which uses a lot of water. The preference for water-intensive crops like rice and sugarcane strains already scarce water supplies. Dependence on agricultural runoff affects water availability and quality, polluting and degrading aquatic bodies. Urbanisation and industrialization complicate water scarcity. As cities grow and industrial activities increase, water demand rises, increasing consumption and waste. Urban regions with dense populations and large industrial operations demand lots of water for home and commercial use [4]. However, fast urban development typically exceeds water infrastructure capacity, resulting in inefficiencies, water losses, and unequal distribution. Industrial processes often pollute water sources, reducing clean water for human and ecological use.

Water scarcity in India affects ecological balance, social stability, and economic development beyond supply. Reduced water supply can degrade ecosystems, harm biodiversity, and disturb natural processes. Competition for scarce water supplies can increase tensions and social conflicts. Water scarcity can limit economic growth, especially in water-intensive sectors like agriculture and industry, jeopardising livelihoods and worsening poverty. Sustainable water management, technical advances, and strong legislative frameworks are needed to solve this complex challenge [5]. Water efficiency, conservation, and alternate water sources must be prioritized. Creating a water stewardship culture requires awareness and community participation. India can minimize water scarcity and safeguard its precious water resources for future generations by developing integrated and effective water management techniques [5].

Indigenous and community-managed water management methods have long existed in India and have done so for millennia. The community's water needs, including those for household water supply, drinking water, and irrigation, have been well satisfied by these systems. Traditional water management strategies that prioritized community involvement underwent a substantial shift during the colonial era. Large-scale barrages and canals were built by the British, but instead of active management, the irrigation systems were governed. Moreover, the communities were too big for any meaningful participation in their administration.

1.1 Water availability, variability and increasing withdrawals.

India is divided into four categories of rivers: [i] rivers originating from the Himalayas; [ii] rivers flowing across the Deccan plateau; [iii] rivers along the coast; and [iv] rivers within the inland drainage basin.1.

In the Himalayan region, precipitation in the form of rain, snow, and glacier melt plays a major role in the formation and maintenance of rivers. The major rivers that come from the Himalayas, such as the Indus, Ganga, and Brahmaputra River systems, depend on this complex hydrological system. Together, these three main Himalayan River systems supply over two-thirds of India's water, making them vital. Precipitation plays a variety of roles. While snow builds up during the winter and eventually melts during warmer months, releasing water into the river systems gradually, rainfall directly feeds the rivers. Particularly in the summer, glacial melt adds to the flow of these rivers, guaranteeing a steady supply of water even in the absence of much rainfall. With certain seasonal changes, the Himalayan rivers are guaranteed to flow throughout the year due to this combination of precipitation sources. Managing the flow of the Himalayan rivers is essential for the purposes of water conservation and mitigating the potential harm caused by flooding to infrastructure and society. The three rivers traversing the Himalayas are transboundary. The rivers in question originate from the neighboring countries of India or from their major tributaries. After traversing India, these rivers go into either

Pakistan or Bangladesh. India alternates between being a downstream nation and an upstream nation. The Mahanadi, Godavari, Krishna, Narmada, Tapi, and Cauvery are prominent rivers within the Deccan region. All of these rain-fed rivers have a significantly lower sediment content compared to the Himalayan rivers. Except for the Narmada and Tapi rivers, the majority of peninsular rivers flow in an easterly direction and eventually reach the Bay of Bengal. The catchment areas and lengths of India's coastal rivers are typically short. The rivers on the West Coast have a high velocity of flow.

Every year, about 4,000 billion cubic metres [bcm] of precipitation fall on India. With this enormous amount of precipitation, the country has an estimated 1,869 billion cubic metres of potential water resources. However, the functionally available water supply is just 1,137 bcm because of topographical and other natural limitations. 447 billion cubic metres of groundwater and 690 billion cubic metres of surface water make up this accessible resource. The considerable drop in potential to actual water resources emphasises the difficulties brought on by India's varied and frequently difficult geography. Because steep slopes often result in high runoff rates and little infiltration, the amount of water that can be realistically captured and used is reduced. In 2011, India's per capita annual water availability was around 1544 cubic meters. However, this amount has subsequently declined due to population growth. A nation is classified as experiencing water stress when its annual renewable water supply per capita is below 1700 m3, as determined by the Falkenmark Index, a commonly used measure of water shortage. The declining per capita water availability indicates the need for more stringent water management measures, despite the significant differences in lifestyle and water usage between India and Europe and the Americas.

India's water resources exhibit three primary concerns:

[i] India experiences significant temporal variability in water supply, leading to various issues such as floods and droughts.

[ii] There exists a notable geographical discrepancy in the supply and demand of water, where the requirements for various uses are increasing rapidly while the availability remains relatively stable.

[iii] The quantity of water being extracted from surface and underground water sources to meet growing demand is rising and is not environmentally viable.

Water, which makes up more than 50% of the human body and is used in industries, healthcare, agriculture, and food production, is of utmost significance in people's lives. Water resource management has faced several challenges in recent years. Water resources management involves the strategic coordination and optimisation of activities related to the planning, generation, allocation, and effective use of water resources. The limitations in this field include the expansion of the population, problems with infrastructure, climate change, droughts, water scarcity, distribution losses, and insufficient user awareness [6].

The discussion on the sustainability of water delivery systems has become more intense due to the current circumstances. There is a growing global emphasis on tackling water resource management issues, such as reducing distribution losses, predicting user demand, and safeguarding water quality. The German Water Partnership has implemented the concept of "Water 4.0," which entails the incorporation of Industry 4.0 technologies into the sanitation industry. This indicates a positive trend in the adoption of sophisticated technologies in water management [7]. An investigation conducted between 2013 and 2014 examined the adoption of smart metering technologies in water distribution networks in Australia and New Zealand. The results indicated that a combined total of 250,000 intelligent metres were either currently installed or scheduled for implementation. Furthermore, 66% of the water service companies questioned had taken this element into account when developing their strategic plans for the future year. Effective water management is a crucial element of the broader concept of smart cities. Beal and Flynn [8] discovered that smart water management was given less emphasis in the smart cities they studied, highlighting the necessity for increased attention in this domain. However, they failed to furnish comprehensive details concerning particular applications within intelligent water networks. Furthermore, there were no supplementary review articles accessible regarding the implementation of smart water-management systems. These circumstances have generated additional study inquiries in the sector.

Q1: What are the primary challenges confronting India's water management system?

Q2: What type of model may be established to incorporate the entire value chain of public water supply services?
This study focuses on the period after India gained independence and aims to offer a comprehensive analysis of the fresh difficulties and obstacles in managing the country's water resources. The paper consists of two sections. The latest concerns are addressed in the initial section. The second section provides a comprehensive analysis of the challenges related to water management, including data, technology, and institutional obstacles. Ultimately, it proposes a strategy for effectively administering the water management system in India.

2. Literature Review

In January 2020, Stephy Akkara and Thilagaraj Maiman Singh authored a paper titled "Water Leakage Detection and Management System Using IoT" [9]. They suggested a device specifically created to quantify different water quality indicators, including pH levels, water flow pressure, and temperature. The research recommended the utilisation of intelligent interface sensors to oversee water reservoirs, identify water pollution, and trace water pipeline leaks. They employed sensors to monitor the contents of water tanks, identify leaks in pipelines, and assess the pH and temperature. Ultrasonic sensors were used for testing. By implementing these devices in intelligent structures, data may be gathered and examined from residential, medical, and industrial domains to comprehend water consumption patterns and effectively minimise water squandering [10].

Ravindra Parab and Smita Prajapati showcased their project named "Development of Programmable Relay Switch Using Microcontroller" in October 2018. The participants engaged in a conversation about the utilisation of relays and the possible uses they could have. The study emphasised the intimate connection between information technology and various household and industrial activities, noting that controllers are now widely used in several automation applications. The objective of their hardware-based project was to understand the relay control mechanism, which is essential for the analysis and design of automated control systems. Electromagnetic relays have been recognised as a dependable option for controlling the flow of electricity in a wide range of applications. Three relay switching models were constructed, taking into account voltage and temperature. It was determined that all three models demonstrated precise operation and provided a cost-efficient alternative. The suggested project was considered appropriate for industrial applications and might function as a training module in industrial automation [11].

Chetan Sharad Patel and Jitendra Gaikwad introduced their work titled "Design and Development of IoT-Based SMART Water Distribution Network for Residential Areas" in July 2019. The individuals discussed the pressing matter of water shortage, which has been worsened by declining water levels in sources as a result of inadequate rainfall and rising daily water requirements. The exponential growth of residential areas has intensified the need for water. Their project centred on the real-time surveillance of water supply through an Internet of Things [IoT] system, which furthermore regulated a valve to guarantee equitable distribution of water among consumers. The system's objective is to uphold water quality and control water levels in a primary water reservoir, rendering it especially suitable for residential buildings and communities [12].

In 2019, Li et al., introduced a comprehensive system for monitoring water in real-time using inexpensive unmanned surface vehicles. The purpose of this system is to observe and track aquatic ecosystems and offer resources for recognising crucial environmental situations. This will facilitate informed decision-making for the management of lakes, rivers, and coastal regions. The system revolves around a cost-effective Unmanned Surface Vehicle [USV] that is outfitted with a versatile set of sensors for assessing water depth and various physical and chemical properties. In addition, data analytics technologies are integrated to create a full monitoring system that encompasses data gathering, storage, and analysis functions [13].

In April 2016, Imam et al., aims to tackle the increasing recognition of water management issues, with a particular focus on the necessity of data about the movement and distribution of groundwater. The authors emphasise the constraints of current water monitoring network architectures and suggest implementing a SCADA monitoring system utilising radio telemetry technique. This system is specifically engineered to oversee the dispersion and movement of water from its origin to different locations, enabling the supervision of both the quality and quantity of water. It is capable of identifying potential hazards and issuing timely alerts in the event of unforeseen contamination or overflow [14].

In 2018, Simmhan et al., introduced a paper titled "Automated Irrigation System Based on Soil Moisture Using Arduino". The objective of this project is to automate the process of farm irrigation and control soil moisture levels. This will be achieved by utilising an Arduino microcontroller, a soil moisture sensor, and an L293D module. The system detects the level of moisture in the soil and autonomously controls the activation or deactivation of the pump. This automated system is especially beneficial in arid regions with limited precipitation, as it guarantees effective irrigation of plants while minimising water loss. The device enables farmers to remotely oversee and control irrigation, rendering it a vital instrument for enhancing agricultural efficiency [15].

Neirotti et al., [16] aims to tackle the problem of water wastage caused by leaks in distribution lines. These leakages frequently result from deteriorating infrastructure or construction activities. The system created in this project utilises Internet of Things [IoT] technology and incorporates sensors at both the source and destination points to accurately detect water flow rates. The technology can identify leakages by analysing the disparity in water volume between the initial and final sites. This information is crucial for doing additional study and enhancing water distribution management.

The incorporation of cutting-edge technology across several domains has resulted in substantial enhancements in safety, productivity, and resource allocation. Kartakis et al., [2015] investigates the application of Arduino-based systems for improving fire safety. This system utilises a variety of sensors and components, such as LM35, MQ2, and GPS modules, to automatically identify the presence of fire or smoke. Once detected, the system promptly initiates safety actions, such as deactivating the MCB and activating water spraying, to ensure a swift and efficient reaction to fire dangers. Shahanas et al., [14] put forward a proposal for a "Water Level and Leakage Detection System with its Quality Analysis based on Sensor for Home Application." This system utilises microcontrollers to monitor the amounts and quality of water in tanks. It sends alerts through SMS and reduces wasting of water and electricity by using sensors to detect leakage. This encourages the effective use and preservation of water in home environments. Simmhan et al., [15] showcased notable progress in resource management with their presentation on "Wireless Transmission of Acoustic Emission Signals for Real-Time Monitoring of Leakage in Underground Pipes." This system utilises wireless technology to identify and pinpoint leaks by analysing acoustic emission signals. It provides a cost-efficient and easily manageable method for monitoring underground pipes. Together, these examples exemplify the revolutionary capability of incorporating intelligent technologies into daily systems, improving safety, productivity, and environmental friendliness in diverse applications.

Geographic Information Systems [GIS] provide a strong foundation for combining spatial data with analytical functions, greatly improving the management of water supply systems. Water supply managers can utilise Geographic Information Systems [GIS] to visually represent and examine intricate datasets in order to tackle a range of operational difficulties. GIS allows for the development of real-world maps that precisely identify regions with low water pressure or water quality problems, making it easier to quickly detect and resolve these issues. The utilisation of this spatial analytic capability enables managers to effectively distribute resources and carry out specific maintenance or repair tasks. In addition, Geographic Information System [GIS] models can utilise historical data to forecast potential future problems, allowing for proactive efforts to reduce risks and improve the resilience of the system [18].

GIS may be used for real-time monitoring, which greatly lowers the time needed to analyse and manage water supply networks. The real-time capabilities of the technology allows management to quickly identify and resolve any abnormalities in the water delivery system. In addition, GIS incorporates statistical metrics such as water demand, supply levels, water quality, and network efficiency, offering a thorough assessment of the system's performance. These insights are crucial for optimising the placement of new water sources, improving network efficiency, and discovering discrepancies between supply and demand [19].

In addition, the integration of GIS technology with GPS for tracking wastewater and mapping sewer lines to Sewage Treatment Plants [STPs] improves planning and decision-making processes. Managers can utilise digital maps and reports to visually represent regions with strong demand and limited supply, monitor performance metrics, and examine long-term patterns. This comprehensive strategy facilitates the anticipation of future problems and the organisation of maintenance and repair tasks, therefore guaranteeing a more dependable and effective sewer system. GIS models utilise data queries to produce digital maps and reports, enabling thorough analysis and the discovery of ideal sites for new infrastructure, hence enhancing the overall efficiency of the water and sewer networks [20].

GIS is an essential tool for managing water supply. It provides real-time monitoring, predictive modelling, and data-driven decision-making capabilities. The usefulness of this system lies in its capacity to identify and resolve problems connected to water demand, supply, quality, and network efficiency, as well as optimise the selection of new resource locations. This ultimately leads to the creation of more efficient and sustainable water supply systems [21]. Utilising statistical indicators, sewage network maps, GPS technology, and GIS software can offer significant insights into sewer network issues and assist in formulating efficient planning policies. Through the examination of data on several factors and the generation of digital maps and reports, managers may detect problematic regions, forecast future issues, and formulate strategies to improve the overall efficiency of the sewage network [22].

The quality of water is a crucial element in the management of water resources since it has a direct influence on the health and welfare of populations and ecosystems. Through the analysis and assessment of tap water quality and groundwater hydrogeochemistry, it is feasible to ascertain the water's quality and hardness. This information may then be used to make informed judgements regarding suitable water treatment technologies or strategies for water usage. Ensuring optimal water quality is crucial for promoting sustainable development and safeguarding the long-term well-being of both individuals and the ecosystem [23]. Geographic Information Systems [GIS] and other data-driven technologies are essential for efficient water supply management. They are particularly useful in monitoring and predicting the performance of water networks and determining the best locations for additional water sources. Monitoring the quality of water and assessing the chemical composition of water are crucial measures to guarantee the safety and cleanliness of water for populations and ecosystems [25]. Effective water resource management is crucial for achieving sustainable development and ensuring the long-term welfare of the planet. Advanced technologies such as Geographic Information Systems [GIS] facilitate well-informed decision-making and the creation of efficient planning strategies. These technologies enhance the performance of water supply networks and tackle challenges with water demand, supply, quality, and network efficiency [27].

3. Challenges in Managing Water Management

After achieving independence, India faced the dual obstacles of augmenting foodgrain production and ensuring access to safe drinking water. Investing in irrigation infrastructure became a key priority in the five-year plans. India has made significant advancements in this field since 1951. Tzagkarakis [20] found that the total area of land that is being irrigated increased by about two times, from 21 million hectares in 1951 to 45.6 million hectares by 1991. As a result, there was a significant increase in yearly foodgrain output, from only 50.8 million tonnes in 1951 to 198 million tonnes in the period of 1996-

1997. Significant enhancements in water provision have been made possible through the utilisation of both surface and groundwater resources. Only 6.15 percent of the population had access to clean drinking water at the time of independence, according to TERI 1998. In 1997, the percentage of the population had significantly risen to more than 81 percent [CSE 1997]. These technological improvements have revealed numerous medical, social, and administrative obstacles. The purpose of this debate is to examine the main water-related problems that may hinder the satisfaction of future water supply requirements in India.

Despite the limited utilization of natural runoff, there is minimal capacity for further exploitation due to various constraints. To begin with, almost all appropriate sites have already been utilized, and the utilization of those locations is quite extensive [21]. The construction of a new water storage facility is more likely to provide a mechanism of allocating the current water resources among various applications than it is to increase the overall quantity of resources that are available. Subsequent exploitation will have significant socioeconomic and environmental consequences. Massive human communities have been forcibly displaced and relocated due to the construction of large dams, resulting in the loss of people's customary means of earning a living and their ability to sustain themselves, notwithstanding the enormous flooding created by the dams [22]. The problem of displacement, despite the fact that it is a substantial one, is overshadowed by the more fundamental concerns that are inherent in these patterns of development. These concerns include human rights, fairness, and social justice. The underlying concept is that the individuals who reap the advantages of advancements are not always the ones who bear the associated costs.

In addition, there is a growing scrutiny from environmentalists and social justice advocates about large-scale water projects in India [23]. Large dams are recognized to pose hazards to ecosystems and the environment. Extensive submergence caused by large dams is believed to have negative impacts on the ecosystem, which goes against common assumption. On the other hand, irrigation is known to have positive benefits on the environment and ecology [24]. Furthermore, there is uncertainty regarding the availability of funds for substantial water initiatives. International relief organizations are facing increased public scrutiny because to the growing global knowledge of the adverse social and environmental impacts associated with large-scale dam projects. This has also resulted in a decrease in the amount of international financial support that is being provided for big dam projects in India. As of right now, there are four hundred dam projects in India, both major and minor, that have been put on hold because of a lack of finance or resistance from environmental advocacy groups [25].

3.1 Diminishing the Potential of Current Supply Systems

Several challenges plague the implementation of major reservoir projects in India, potentially jeopardizing the feasibility of existing water supply strategies. One of the issues is the increased rate of soil erosion in the catchment areas, leading to faster accumulation of sediment in reservoirs. This is a significant problem for hydrologists. The hydrologists' calculations consistently underestimated the true rates of soil erosion and siltation. During the early design phase, it was expected that the Dharoi reservoir, located on the Sabarmati River, would experience an annual silt accumulation rate of around 1.6 million cubic metres [MCM] [26]. However, later evaluations of the watershed undertaken in 1994 unveiled a substantially increased sedimentation rate of almost 10 million cubic metres per year. As a result, the increased sedimentation has caused the reservoir to have a shorter lifespan and a decrease in its storage capacity. Large reservoirs often lead to reduced water flow in the lower sections of the river, thus impacting the replenishment of underground water sources. Each of these characteristics has a detrimental impact on future supply. The insufficient efficiency of irrigation systems that are dependent on these reservoirs is another significant problem that has to be addressed. These irrigation schemes exhibit substandard construction quality, poor maintenance, unreliable and subpar irrigation services, inadequate system supervision, limited farmer participation in irrigation management, low levels of water fee collection, and inefficient distribution of resources. The identified factors have significant negative impacts on both current achievements and the possibility for future investment [27].

It is evident from recent data that the effectiveness of Major and Medium irrigation schemes has increased significantly. By the predicted timeframe of 2021-2022, this canal network is expected to supply irrigation to approximately 64.7 million hectares of land. Mudumbe [28] emphasises the crucial significance of seepage from canals and the return of water from irrigation in reducing the decrease of groundwater levels in areas where groundwater pumping for irrigation is common. However, due to the significant financial, economic, social, and environmental hazards associated with building major dams, there is a limited ability to increase the current water supplies. There is a noticeable decrease in the future capacity of the existing resources [29].

3.2 Depleting Reserves of Untreated Freshwater

The ramifications of decreasing groundwater levels and the exhaustion of economically feasible resources can have significant social, economic, and environmental consequences. As the groundwater levels decrease, shallow wells run out of water, forcing impoverished farmers to leave their wells. As a result, only individuals who have the financial means to dig deeper wells or buy water from surrounding well owners at higher prices are able to obtain access. From an economic standpoint, decreasing water levels amplify the amount of energy needed to extract a particular amount of water, thereby raising the extraction costs and lessening the economic feasibility of irrigated agriculture [30].

Groundwater has a critical role as a storage system during droughts, making it an essential resource from an environmental perspective. During prolonged periods of drought, groundwater reserves are utilised to protect crops, alleviate the impacts of drought, and fulfil many socioeconomic and environmental requirements. Gradually, the reduction of resources presents a significant threat to the ability of India to ensure food security and withstand droughts. Impoverished farmers who return to rain-fed agriculture are at risk of crop failure, which leads to reduced crop yields and increased susceptibility to drought, even before a severe depletion occurs [31]. Groundwater is crucial in influencing the movement of rivers in different river basins, especially during periods that are not part of the monsoon season. Continued decreases in groundwater levels can have a lasting impact on the movement of water into rivers, causing negative effects on river flow and the ecosystems in the surrounding areas [32].

3.3 Growing Water Scarcity

The surge in demand for water can be attributed to a diverse range of demographic and socio-economic factors, including population expansion, urbanization, industrialization, shifts in agricultural techniques, and cultural changes. Since gaining independence, the country's population has increased by almost 250 percent, from a paltry 400 million to about one billion. The correlation between population expansion and water demand is not linear. Nonetheless, the spatial arrangement and demographic trends of the population are more vital than the mere numerical expansion of the population. Urbanization has a substantial impact on the way water demand changes over time. Urban regions generally have a greater per person need for essential goods and services related to the environment [33]. Urban population increase has a greater impact on demand than rural population growth, mainly because of the consequences of urbanisation on waste management. By 1994, urban regions constituted almost 25% of India's overall population, marking a substantial rise compared to the proportion during the time of Independence. The rise of urban population has significantly exceeded the growth of rural population. According to predictions from the UN Population Division, India's urban population is expected to reach 600 million by 2025, accounting for approximately 45% of the country's overall population. The swift process of urbanisation has caused a rise in population density in some cities, leading to higher rates of urban population growth and an increased demand for water per person [34].

The growing population is anticipated to put pressure on the supply of food grains, requiring an increase in food grain production to sustain the current per capita supply levels. In recent years, there has been a significant increase in the amount of food grains consumed per person in India, including cereals and pulses. This can be attributed to improved economic conditions and a decrease in poverty levels. Consequently, the foodgrain production growth rate must surpass the population growth rate by a significant margin. Based on a prediction by the United Nations, the population of the country is expected to reach 1.5 billion by 2025. At that time, the country will require a total food supply of 350 million tons [35].

3.4 Surface Water

Pollution is significantly endangering the integrity of surface water bodies, which are crucial sources of natural freshwater supplies. The Central Pollution Control Board report identifies 20 sites along the banks of major rivers in the country that are seriously contaminated. The pollution levels in these places exceed the capacity of the rivers to naturally absorb and neutralize it [36]. Finally, they are at the proximity of thriving industrial clusters and prominent cities in the country.

The implementation of pollution control measures by competent agencies in India is largely insufficient, with significant firms regularly disregarding these regulations. Nevertheless, the presence of administrative and structural shortcomings within regulatory organisations, combined with restricted legal jurisdiction to enforce penalties, contributes to this problem. Moreover, identifying the origins of contamination presents a substantial difficulty. Court judgements frequently impede ministries and agencies' efforts to close non-compliant industries, leading to significant delays and transferring decision-making authority to the courts. In addition, a significant proportion of enterprises that cause pollution are small-scale businesses that do not have the necessary financial means to invest in expensive facilities for treating waste water [37].

The storage capacity and longevity of multiple significant and insignificant reservoirs in India are decreasing at rates that exceed the initial projections. This presents a substantial obstacle to large urban areas and municipalities that depend on these reservoirs for their water supply. The rapid increase in population in metropolitan areas intensifies the pressure on water supplies, making shortages worse and increasing the disparity between the amount of water available and the amount needed. Currently, several cities, including Ahmedabad, are facing a significant shortage of drinking water [38].

The United Nations estimates indicate that by 2025, India's water demand would equal its total available freshwater resources, highlighting the seriousness of potential water scarcity. Mahmoud et al., [39] corroborate the expectation that per capita freshwater availability will decrease as a result of population expansion and dwindling supplies. The unequal distribution of wealth intensifies the problem of water access, as affluent persons control the majority of resources, further marginalizing the less privileged and potentially resulting in social tensions and conflicts [38].

3.5 Growing Competition and Conflicts

The demand for municipal water supplies rises significantly as a result of the high population density in metropolitan regions. Not only is this object of superior quality, but it also occupies a highly significant position. Due to difficulties in satisfying their supply needs, urban areas are taking resources from rural areas, which causes tensions with other competing demands in those locations. Industry disperses throughout rural areas, creating a situation where the total water demand in such areas rises quickly. As a result, industry quickly compete for the limited freshwater supplies with irrigation and drinking needs [40].

As commodities become harder to come by, rivalry heats up between various industries and between users within each industry. In the end, to meet their demands, the wealthier and more powerful groups dominate the already limited freshwater resources, often at the expense of the most significant uses [41]. Municipal administrations in several Gujarati cities and towns are requesting more water from agricultural surface reservoirs to fulfil rising demands. Since irrigation supplies have always decreased, these allocations have caused conflicts. Many Indian river basins are seeing more tension between irrigation, drinking water, urban, and industrial use [42].

In the growing scenario, there will be intense competition among consumers within the water sector in addition to rivalry and conflicts between various industries. In the event that there is no appropriate institutional framework in place to meet more general societal goals, it is possible that the affluent and privileged may monopolize the resources at unreasonably high economic and social costs as economically accessible water resources become scarcer. This could lead to a progressive worsening of the population's water scarcity, making it more difficult for them to obtain water for basic needs. Tensions and disputes within society could result from these conditions [43].

4. Research Objectives and Data Analysis

Vijai and Sivakumar [44] highlighted the significance of considering wider societal aspects when assessing excessive exploitation of groundwater in the context of limited availability. The factors encompassed in this context are economic efficiency, equality, environmental considerations, drought resilience, long-term option preservation, and the supply of drinking water supplies as essential entitlements. Consequently, he alters the criteria used to assess if India's groundwater resources have been over used [45]. This argument advocates for revising the criteria and objectives used to assess water development, with the aim of encouraging the inclusion of broader goals pertaining to technical, social, political, economic, and environmental sustainability.

4.1 Resource Availability and Assessment Variables

The criteria for determining whether water is available or whether there is a water scarcity scenario are likely to vary as the aims of data gathering and interpretation continue to evolve. At now, the assessment of excessive water development and scarcity relies solely on the water balance criterion. From a sociological standpoint, it is crucial to ascertain the adequacy of the water supply in the basin to meet essential survival requirements, particularly for drinking purposes. From an economic perspective, a crucial factor in evaluating scarcity is the level of investment required by communities to acquire water for different purposes, as well as determining whether water is economically within reach or not [46]. Decreasing groundwater levels can lead to higher expenses for drilling wells and extracting groundwater due to increased investment and energy costs. Hence, it is crucial to incorporate measurements of pumping depths and yield levels as significant characteristics [44].
Moreover, attempting to evaluate the comprehensive water conditions in a river basin just based on quantitative data regarding the total water supply and demand would be very impractical. The data regarding the quality requirements for meeting different sectoral as well as the quantitative estimates of the volume of demand in each area, should be readily accessible. Similarly, the data on the quality of the current supplies should also be available.

5. Solutions to overcome the challenges of water management system

5.1 Smart Water Networks

Smart water networks are an innovative method of improving water delivery systems by combining physical and virtual elements to boost performance, resilience, and user engagement [47]. Benítez et al. define smart water networks as systems with multiple instruments to continuously assess variables like pressure, flow, and totalized flow. These devices can detect losses and estimate demand using metre data. Siddiquee and Ahamed [48] define smart water networks as efficient integration of water distribution system elements. The networks have physical, measurement and control, data gathering and transmission, data monitoring, and data processing layers. Concrete pipes, reservoirs, valves, pumps, and tanks form the physical layer. The measuring and control layer includes field equipment that measures flow, pressure, reservoir level, turbidity, and conductivity. Control devices like PLCs are included. Data is collected and transmitted using SCADA systems, telemetry equipment, and communication networks. The data management and monitoring layer manages data storage, processing, and accessibility. Finally, the data analysis layer uses various technologies to achieve various goals, which are classified by function.

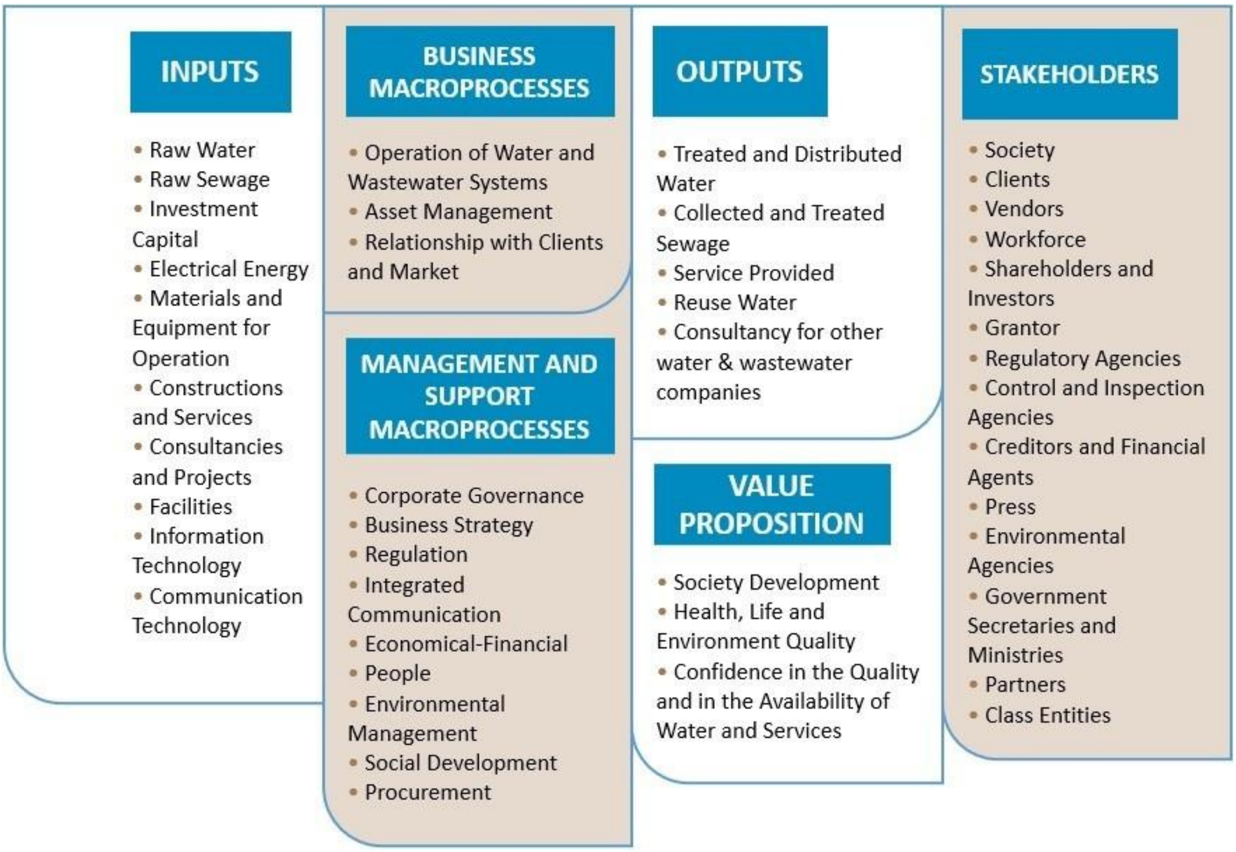

Figure 1. Value Chain [adapted from [25].

5.2 Smart Water Management

Smart water management, along with smart grids, urban mobility, garbage collection, citizen services, healthcare, and safety, is an important part of smart cities. Tzagkarakis et al. [20] show that "intelligence" is linked to smart city service efficiency. Smart water management uses IoT technology to achieve goals, according to Slany et al. [21]. These aims include water quality and accessibility, loss reduction, infrastructure maintenance, and user water conservation. Thus, smart water management uses intelligent water networks to provide sustainable, efficient, and high-quality services.

5.3 Water Value Chain and Supply Management

Smart water management is a subset of smart cities with specialised applications. It can also be used in specific domains, with the value-chain idea as an analytical tool. A value chain describes a company's activities and how it distributes its final product to clients [45]. Thus, examining the water value chain identifies areas where smart water-management technologies could be deployed, providing requirements for their implementation. Sao Paulo Basic Sanitation Company [Sabesp] built the value chain in Figure 1 in its Sustainability Report. Sabesp serves the sixth most people worldwide and is the leading sanitation firm in the Americas. The corporation provides sanitation services to 28 million people in 375 municipalities in São Paulo, Brazil.

The water value chain is closely interconnected with the natural water cycle. Prisciandaro et al. [23] suggest a self-contained water system that encompasses water collection, purification, storage, distribution, wastewater treatment, and reuse of treated wastewater. The authors' depiction of the water cycle provides a more thorough and precise illustration of the key processes emphasised in reference [46]. As a result, it was chosen as a benchmark for examining the extent to which smart water management systems are used across the water value chain. The water value chain is closely interconnected with the natural water cycle. Lalle et al., [47] propose a closed water cycle that includes water capture, treatment, storage, distribution, sewage treatment, and effluent reuse. These authors developed a more complex water cycle to describe the fundamental mechanisms. Thus, it was used to analyse water value chain smart water-management system application coverage.

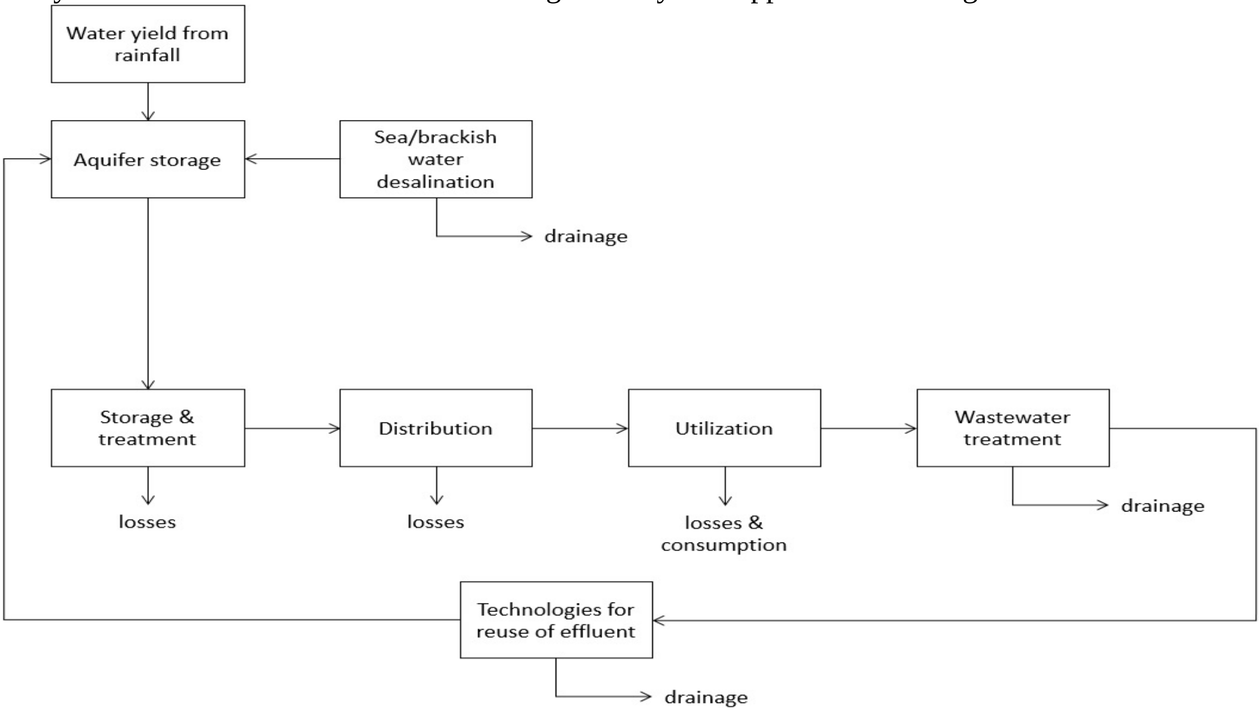

Figure 2. Closed water cycle [adapted from][26].

5.4 Structure of Water-Supply Systems

The distribution of water that satisfies the established criteria for quality, quantity, and pressure is the primary function of a water supply system. It includes the infrastructure capable of delivering this water supply. It is crucial that the water quality remains uncompromised within the pipelines. Furthermore, in order to efficiently handle fire emergencies, it is crucial for the water supply system to have the capacity to distribute water to all specified areas with adequate pressure and the necessary amount of water [54]. Figure 3 depicts the fundamental arrangement of a water distribution system.

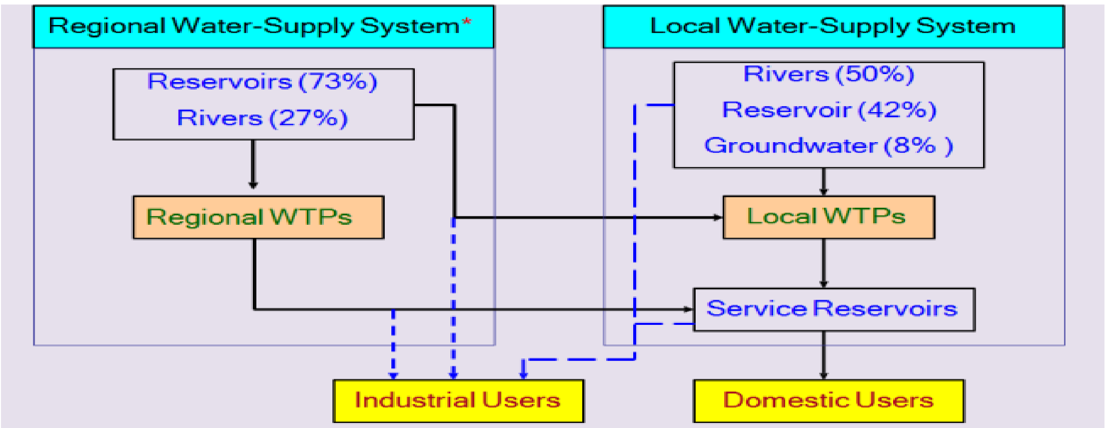

Figure. 3. Structure of water supply management system

The presence of microorganisms and other contaminants in drinking water poses health concerns to both humans and animals. To enhance the microbiological quality of drinking water and prevent the spread of diseases, it is imperative to avoid this. As a result of the rapidly increasing demand for water supply, the management of water resources has become more intricate. The functioning of the system is impacted by external influences and aims to minimize costs for the public [48]. The urban water supply system faces three significant challenges, namely:

- Exhaustion of water resources
- Declining water distribution
- Rapid urbanization

Water resources can pose hazards to the public through both natural disasters and deliberate acts of aggression. The quality of fresh drinking water is significantly impacted by the waste discharged by factories and enterprises [49, 57]. Providing secure and hygienic, dependable water supply to urban areas necessitates the implementation of numerous innovative technologies and substantial financial commitments. Water treatment and desalination plants are the most advantageous applications of these new technologies due to their high efficiency and lower costs. This innovative technology also monitors water quality management and detects leaks in pipelines [50]. Sustainable Urban Drainage Systems [SUDS] is an approach that facilitates the enhancement of green spaces and the environment by managing and improving their quality. The objective is to preserve stormwater by decreasing the amount of runoff and improving water filtration rates through the collection and temporary storage of water [51, 58].

The disadvantage of the current system is as follows:

- There is excessive water usage occurring when individuals wash their vehicles or water their plants, resulting in the unneeded depletion of water resources [52].
- Water leakage is unavoidable as a result of deteriorating pipes over a period of time.
- The corporation is uncertain about the presence of water overflow in any of the houses.
- The firm is unaware of the water use of the dwellings.

5.5 Smart City Water Supply Management System Design Concept

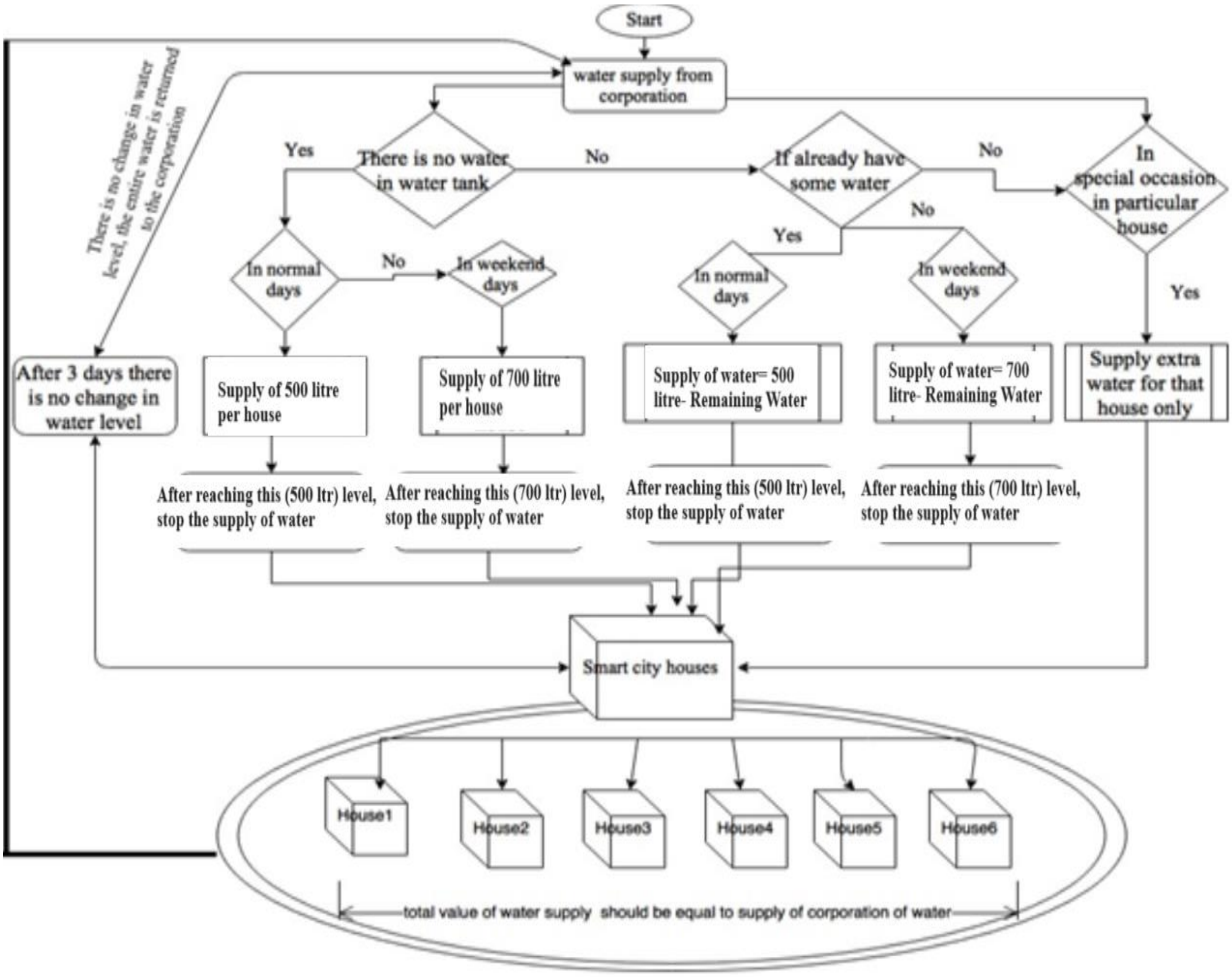

Figure. 4. Flow diagram for proposed system

A Smart city comprises several residential dwellings. Water is a fundamental necessity. The water consumption in each household varies depending on the specific needs of its occupants. Water usage fluctuates depending on the season [53, 59]. Specifically, water consumption is rising on Sundays due to activities such as laundry and home cleaning, especially when both members in a household are employed. Similarly, during the summer season, there is a higher demand for water. During the cold and wet seasons, there is a decrease in water usage [54]. Considering these factors, users should assume responsibility for water management. The proposed approach is specifically designed for the purpose of water management and is controlled by sensor devices [55]. The technology is designed to guarantee that no user experiences water scarcity at any point throughout the system's repair. For example, every household demands roughly 300 litres of water. The Corporation will provide a sufficient amount of water for a smart city, which is regulated by a sensor gadget. This sensor system regulates the movement of 300 litres of water for a solitary residence. The water tank has a volume of 500 litres. Once the tank reaches a capacity of 300 litres, it should be immediately redirected to the next residence. The water tank can be marked at each 100-liter interval. At the beginning, there is a volume of water measuring 100 litres, which completely occupies the first line. Every water tank is equipped with a sensor chip specifically designed to monitor the water level inside the tank. To entirely fill the tank, an extra 200 litres of water must be added to the present 100 litres remaining. The sensor chip possesses the capacity to manage this process.

On weekends, the quantity of water per household must be increased to 400 liters. The water use is high on such days. If a certain household requires a substantial quantity of water for a personal event, it is necessary to provide the house with more water according to their needs. On the other hand, a sensor chip regulates the additional water supply through the same pipe. Since the firm receives all smart city house tank water, the water level does not change after three days. This ensures that the water level remains constant. The technique is reversible, which adds a little level of complexity.

6. Working method for proposed model

Sensor devices are utilised in order to quantify the water supply process that involves the proposed system. In a smart city, for instance, there will be a central station that supplies water to five sub-stations. This is typical of smart cities. Each of these sub-stations, in turn, gives water to five individual residences. Every dwelling is provided with a quantity of 500 gallons of water. The Corporation shall provide a daily supply of 12,500 litres of water. According to the proposed design, if there is already water present in the individual residences and this is identified by the sensors, the proposed system will update the sub-stations with these new values. Within the context of this scenario, the business supplies the remaining quantity of water to the various residential properties.

For instance, let's assume that a residence requires a supply of 500 liters of water on weekdays and 700 liters of water on weekends. In the proposed model, if there is already a certain quantity of water present in the tank, the firm will only supply the remaining amount of water. If the water tank contains 100 liters of water, the firm will only offer 400 liters of water for that day. By adhering to this procedure, Let's take into consideration a water tank that has a capacity of 1000 litres and is currently holding 520 litres of water so that we can better understand the circumstance. Due to the fact that the sensor device that is installed in the water tank regulates the water flow and causes it to stop once it reaches the authorised water level, the suggested model states that only 480 litres of water would be delivered through the water tank. However, in the model that is currently being used, the company fails to take into consideration the amount of water that is available and instead supplies 500 litres of water. This leads in an overflow of twenty litres of water given that the tank has a capacity of one thousand litres and the current water level is 520 litres. Likewise, it is possible for there to be a surplus of water in each household on a daily basis. In order to mitigate this issue, a proposed model has been devised. During weekdays, the firm provides a daily supply of 12,500 liters of water. The majority of water tanks in households already have a certain amount of water, and it is the responsibility of the corporation to supply only the remaining amount.

7. Conclusion

Water is a fundamental resource that is essential for all living beings. However, the user lacks knowledge on correct maintenance when utilizing water. If the user refrains from wasting any water, it can potentially contribute to the preservation of the environment. Water consumption can fluctuate due to factors such as climate change, the availability of water sources, insufficient water supply to meet the needs of users, sectors facing economic challenges and increased investment risks [60]. Therefore, the suggested system has a distinct advantage in the smart city setting by efficiently delivering water supply to every household.

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