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Research on market analysis and technology realization of intelligent water management system in China

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Abstract: This paper provides an in-depth analysis of the market status and technical implementation of intelligent water management systems in China. Firstly, the market advantages of smart water systems in improving water supply efficiency, reducing energy consumption, and reducing water waste are pointed out, and the role of policy support and new technologies such as Internet of Things and big data analytics in driving market growth is introduced. Secondly, through the data of the Bureau of Statistics and the chart of market size, this paper expounds the trend of continuous expansion of market size in China's water industry and the growth power of market demand behind it. In the industry analysis section, the main types of enterprises in the smart water industry and their product characteristics are listed, with special emphasis on the advantages of smart water management systems in improving the efficiency of water resource utilization and management. In the section of technology implementation cases, the successful cases of Quanzhijie Intelligent water management system in campus application are described in detail, including the use of Internet of Things technology to achieve the interconnection of facilities and equipment, real-time monitoring and analysis of water resources use dynamics, automatic control and intelligent scheduling and other functions. In summary, this paper comprehensively evaluates the development trend, technical implementation and future development potential of smart water management systems in the current market environment.

1. Introduction

With the acceleration of global urbanization and the increasingly severe challenges of water resources management, intelligent water management system is gradually becoming an important development direction of the water industry as a key tool to improve water supply efficiency, reduce energy consumption and reduce water waste. The purpose of this paper is to deeply explore the current situation and development trend of the smart water management system market in China. Firstly, the paper will present the background of the market size and demand to analyze the drivers of market growth. Secondly, the technical implementation of intelligent water management system will be analyzed in detail, including the application of Internet of Things, big data analysis, artificial

intelligence and other technologies in system optimization and management efficiency improvement. Finally, the effectiveness and potential of intelligent water management system in practical application are expounded through case analysis and technical realization flow chart display. This paper aims to provide in-depth understanding and practical guidance for related industries, and promote the further promotion and application of intelligent water management system.

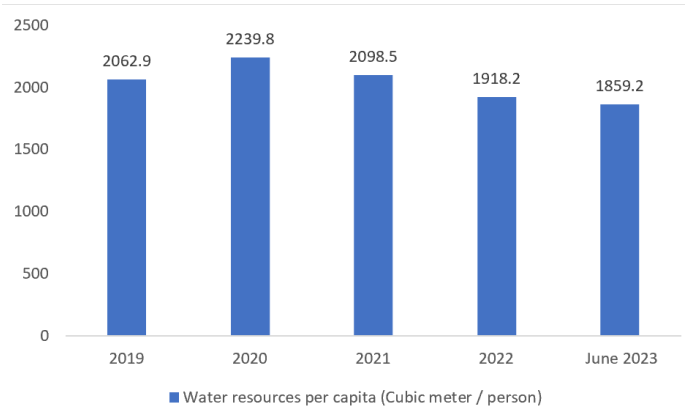
2. Industry background

The regional smart water management system market size is large, mainly due to the accelerating urbanization process and increasing demand for water resources management among the people. With the continuous improvement of consumers' requirements on water quality, quantity of water and safety of water supply, the advantages of smart water management system in improving water supply efficiency, reducing energy consumption and reducing waste of water resources have also been recognized by the market. In the future, national policies will continue to support the construction of intelligent water conservancy system, so that the competition in the intelligent water industry will intensify. And with the development of 5G, Internet of Things and other technologies [1], the series of intelligent water products will continue to explore how to achieve deep integration with emerging technologies, and the digitalization and intelligence degree of intelligent water products will also be further improved [2].

The development situation of intelligent water management system industry shows positive market demand and growth potential. The definition of market size includes hardware equipment, software platform, service and other aspects, covering all links in the water industry. In the past few years, the sales and transaction volume of the intelligent water management system market have shown an increasing trend, and the growth rate analysis shows that the market has a high growth rate and potential [3]. This growth is mainly driven by the development of new technologies such as iot, big data analytics, artificial intelligence, etc. Meanwhile, government policy support for water resources management and environmental protection is also an important factor for the growth of the market.

With the promotion of smart city construction and the improvement of urban development demand, the application scale of smart water gradually expands, bringing greater market demand for smart water enterprises [4]. In recent years, related technologies have developed rapidly, from the integration of intelligent management of traditional large water plants and water supply and drainage pipeline systems to the intelligent supervision of the whole process of smart cities, the system and safety performance have been significantly improved [5]. Emerging technologies, such as smart water quality monitoring and smart search, have greatly improved the existing assay and search technologies and water quality control capabilities, as well as the automated supervision capabilities.

According to the data released by the National Bureau of Statistics, the total amount of water resources in China in 2022 will be about 270881 billion cubic meters, and the per capita water resources will be about 1918.2 billion cubic meters, which is in a state of slow decline. It is estimated that the total amount of water resources in China in 2023 will be about 2625.37 billion cubic meters, and the per capita water resources will be 18092 billion cubic meters. It can be seen that the conversion rate of water supply is gradually improving, and the detailed statistics are as shown in Figure 1.



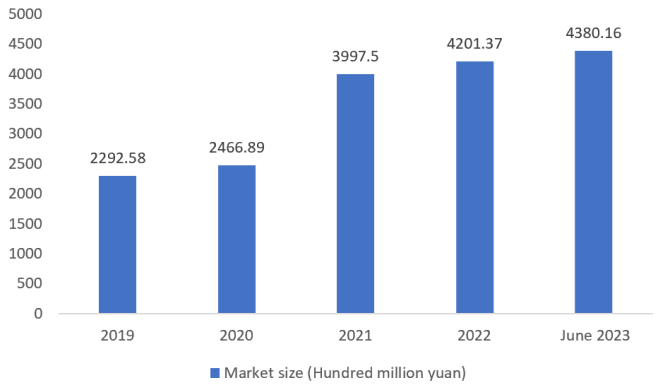
(Data source: National Bureau of Statistics, collated by Guanyan Tianxia Data Center)

Figure 1: Per capita water resources in China from 2019 to June 2023

According to the information revealed in Figure 1, although China's per capita water resources use efficiency shows a trend of steady improvement, it still faces the risk of continued decline. This situation warns us that while pursuing economic development, we must attach great importance to the conservation and protection of water resources. The decrease of per capita water resources is closely related to the continuous growth of China's population, the rapid development of economy and climate change. With the expansion of population scale and the intensification of economic activities, the demand for water resources is constantly rising, while the supply of water resources is restricted by both natural conditions and human activities, resulting in a downward trend of per capita water resources.

In the face of this grim situation, reducing the waste of water resources has become the primary task of the water industry. As the main body of water resources management [6], the water industry undertakes the important responsibility of ensuring the rational utilization and effective protection of water resources. Faced with the challenge of decreasing per capita water resources year by year, the water industry must take practical and effective measures to reduce the waste of water resources and improve the efficiency of water resources utilization [7]. This is not only the needs of the water industry's own development, but also an important contribution to the national water resources security and ecological environmental protection. Only through the joint efforts of the whole society can the sustainable use of water resources be realized and the sustainable and healthy development of economy and society be guaranteed.

According to the data released by the National Bureau of Statistics, in recent years, the operating revenue and total profit of enterprises above designated size in China's tap water production and supply industry have shown an upward trend. The market size of China's water utility industry was approximately 420.137¥ billion in 2022, as compared to the market size of approximately 438.016¥billion in June 2023. Due to the continuous expansion of stepped pricing in the past two years, the increase of some high-priced water consumption has accelerated the growth of the market scale of the water industry. As shown in Figure 2.



(Source: National Bureau of Statistics, collated by Guanyan Tianxia Data Center)

Figure 2: Market size of China's water industry from 2019 to June 2023

As shown in Figure 2, the scale of China's water market shows a steady growth trend, especially during the period from 2020 to 2021, when the growth rate of market size reached a new peak. This change reflects that China's water industry is facing unprecedented development opportunities. With the continuous economic growth and the acceleration of urbanization, the demand of the water market continues to expand, providing a broad space for the development of the water industry.

With the continuous expansion of China's water market scale, water industry will usher in a broader prospect for development. Enterprises need to keep up with the pace of the market and constantly improve their own strength to cope with the challenges of the market and seize the opportunities of development [8].

At present, China's smart water industry related enterprises are mainly divided into the following three types:

The first category: equipment manufacturers with water information hardware products such as instruments and automatic water supply equipment as the core products and the main source of income, and provide water information services for water enterprise customers through the integration of equipment and information technology. Such enterprises are represented by listed companies Xintian Technology and Weipaiger.

The second category: professional software enterprises with self-developed water information system software as the core product, that is, through self-developed software system, embedded software intelligent terminal integration of external sensors, instruments and automation equipment to provide water information services for water enterprises. This kind of enterprises are represented by Heda Technology, three high shares, easy maintenance information;

The third category: large IT companies, such as Huawei, Tencent, Ali, etc., which have the advantages of cloud platform and big data analysis and other basic technologies, accelerate the layout of smart water business in recent years.

Combined with various advanced technologies and ideas, the Quanzhijie developed by us can automatically plan the best route arrangement through code and algorithm, and realize the adjustment of water pressure by using intelligent water management system to automatically control the valve, saving manpower and time costs; On the other hand, Quanzhijie can automatically manage the water system through the data returned by the PLC controller, and the system automatically adjusts the water supply and water pressure of each area. Compared with the existing management technologies on the market, Quanzhijie is supported by cloud computing, big data and other technologies, and has significant competitiveness in intelligent information services.

3. Technical implementation

This product is called Quanzhijie, which is a regional intelligent water management system. The established system will use the Internet of Things technology to realize the interconnection of water facilities and equipment, and has powerful real-time monitoring and analysis functions to accurately grasp the use dynamics of water resources, independently adjust the water use scheme, and realize the efficient regulation of water supply and drainage facilities and improve the utilization rate of water resources. Through the application of this system, the efficiency and quality of water management can be improved at the same time, and the sustainable utilization and optimal allocation of water resources can be realized.

In the data analysis, we first conducted descriptive statistics on the collected data to obtain missing values, abnormal values, and the overall characteristics of campus water use. Then, according to the relationship between water meters, we established a relationship model between water meters at different levels. The first level of water meters adopts electromagnetic meters with higher accuracy, and the second to fourth level adopts mechanical speed meters that have been widely used. In the leakage analysis of water network, we should be clear about the leakage situation and leakage position, and make smooth prediction of the value of time series t by spline interpolation, so as to estimate the leakage. At the same time, according to the deviation statistics, the risk level is divided, and the possible location and probability of leakage in the water supply network are given. In the cost analysis, this article need to refer to the relevant national water data, labor data and material cost data, so as to determine the range of water price and the range of single maintenance price. We take the minimum amount of total loss as the objective function of the rule, and take whether to maintain every day as the decision variable to establish a 0-1 planning model [9], so as to obtain the optimal maintenance decision scheme.

In this paper, the intelligent water management system designed by this method has been successfully applied in a school in Hainan province, and accurate data have been obtained. Through the in-depth study of the campus water supply problem, the model is continuously optimized from the actual situation, and the remarkable application effect is achieved. Ensure the quality of campus water supply and provide a better living environment for the audience. In addition to the application of the system, we have also accumulated enough experience to further improve the smart water management system in the future to achieve more intelligent and efficient water resource management, and actively promote it to other campuses to provide quality water supply services for more campuses and even larger areas. The system solves the problems of water supply and pipeline leakage, improve the ability of timely maintenance.

First of all, the terminal equipment of the intelligent water supply system can automatically analyze the user's water consumption and water consumption time, and formulate the optimal water supply scheme according to the current water resources status and equipment operation status. The system realizes the rational allocation and scheduling of water resources through intelligent control equipment, such as pumps and valves. The system can monitor the water pressure, flow and other parameters in real time to ensure the safety and stable operation of the water supply system. If there is any abnormal situation in the water supply process, the system will issue an alarm in time and take corresponding measures to adjust to ensure the normal operation of the whole system. According to the user's water consumption, the system can automatically charge and notify the user. All data in the system will be connected to the system control center through PLC for analysis, so as to facilitate the decision-making of managers and optimize the water supply system [10].

Ter consumption of each functional area mainly has the following characteristics:

1) The overall data show periodic fluctuations, and the weekly water consumption has peak and valley changes according to working days and non-working days;

2) From January to March, the water consumption of each functional area is relatively low. This period is during the winter vacation.

3) The data of teaching buildings and canteens increased significantly from September to October, which was the time for freshmen to register, thus causing changes in water consumption;

4) The water consumption data of office buildings and dormitories do not change significantly in the periods other than winter holidays.

Analyze pipeline leakage and preprocess data. As shown in Figure 3.

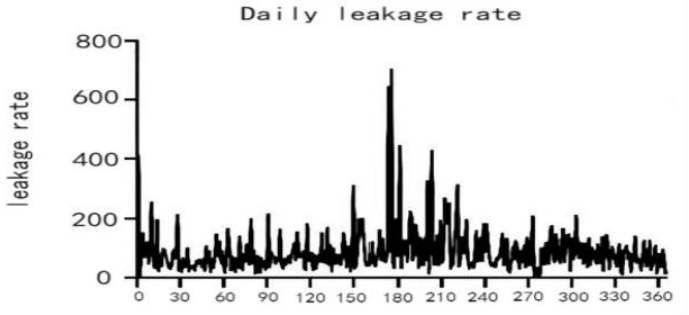


Figure 3: Time series diagram of the overall leakage amount and leakage rate of the whole year

As can be seen from the figure above, the annual leakage water and leakage frequency are stable fluctuations, the average daily leakage water is 88, and the average daily leakage rate is 8.8%. In July and August of the year, the leakage water and leakage rate have large fluctuations, which need to focus on prevention and maintenance. The basic principle of spline interpolation is as follows:

Let a partition of a given interval [a,b] be:

$$\triangle: a = xo < x_0 < \cdots < xo = b \tag{1}$$

If the function s(x) satisfies the condition:

In each individual interval segment $[xi - 1, x;], (i = 1,2, \ldots, n)$, is a polynomial of degree k; s(x) and the derivatives up to k-1 are continuous on a given interval [a,b]. Then the function s(x) is called a polynomial spline function of degree k with respect to partition $\triangle$, $xo, x_1, \ldots, xn$ called a spline node, and the spline function is denoted Sp(△,k). The general form of the polynomial spline function of degree k is:

$$s_k(x) = \sum_{i=0}^{k} \frac{a_i x^i}{i!} + \sum_{i=1}^{n-1} \frac{\beta_j}{k!}(x - x_j)^k \tag{2}$$

Where $\alpha_1(i = 0,1, \ldots, k)$ and $\beta_1(i = 1,2, \ldots, n - 1)$ are arbitrary constants. Here we use cubic spline interpolation to forecast each time series data of the first level water meter. In data xi; There are 10 data selected from the left and right respectively. That is $[xij - s \ldots X_1 j - 1Xij + 1 \ldots X$, the regional intelligent water management system can more accurately grasp the water situation, improve management efficiency and reduce management costs. The predicted data is obtained by interpolating the prediction（ $i; j + 5]$) of x through these ten data.Analyze the leakage situation: The calculation method of leakage data x leakage at time points of each level water meter is as follows:

$$X\,\text{leakage} = X\,\text{Primitive} - X\,\text{forecast}$$

Leakage rate p Leakage is:

$$\text{leakage} = \frac{x_{\text{leakage}}}{x_{\text{forecast}}} \tag{3}$$

By means of Python data processing, the specific data of each level of water meter is obtained, and the water leakage rate in our country is generally more than 15%, and even reaches 40% in the northern region, on this basis, the number of water leakage and water leakage of each water meter are calculated, as shown in Figure 4.

Water meter number	412X	40336T	40403T	40105T	40502T	40334T	4010401T	03350202T	40126T	40118T
Water leakage rate	34.8%	25.8%	25.2%	20.2%	20.0%	19.2%	18.9%	18.6%	17.9%	17.7%
Water leakage	6.33	76.22	163.9	10.53	228.9	0.97	292.14	10.87	0.92	4543
Water meter number	40124T	417T	40316T	4013403T	40333T	40318T	4013407X	40121T	40331T	40120T
Water leakage rate	17.2%	16.6%	16.6%	16.0%	15.5%	15.5%	15.2%	14.9%	14.6%	12.8%
Water leakage	14.15	335.4	89.36	474.39	26.09	10.32	347.28	27.74	13.54	17.26
Water meter number	40119T	4160101T	40136T	40214T	40115T	40321T	40135X	40509T	4013404T	413T
Water leakage rate	12.6%	12.2%	11.9%	11.8%	11.7%	10.4%	10.3%	9.9%	9.7%	9.5%
Water leakage	90.18%	51.17	25.28	1115.73	89.82	440.32	106.94	33.17	91.73	26.69
Water meter number	4013501T	4051101T	4013307T	40511X	4013401T	40106T	401330BT	40508T	40133K	40405T
Water leakage rate	9.4%	9.2%	9.2%	9.1%	9.1%	8.8%	8.5%	8.3%	8.2%	8.2%
Water leakage	39.86%	148.22	285.15	140.48	99.98	6.98	441.09	161.01	1308.17	733.24
Water meter number	4013305T	406T	4013406T	41601X	40313T	418T	40116T	40402T	40401T	40123T
Water leakage rate	7.9%	7.8%	7.6%	7.5%	7.4%	7.4%	6.9%	6.8%	6.7%	6.7%
Water leakage	88.29	75.24	43.03	150. 84	233, 82	52.82	398.88	123.85	65.72	39.73
Water meter number	4013303T	40122T	40134X	4033725T	40338T	40504T	401X	4033506T	4040501T	419T
Water leakage rate	6.6%	6.5%	6.4%	6.3%	6.1%	6.1%	5.7%	5.6%	5.3%	5.0%
Water leakage	684.46	9.51	1032.6	645.72	184. 70	154.5	2872. 94	106.29	89.74	47.77
Water meter number	40218T	40507T	40315T	4013502T	4033725T	03350301T	03350101T	416X	40117T	4033723T
Water leakage rate	5.0%	4.8%	4.7%	4.3%	4.1%	4.1%	4.0%	3.8%	3.7%	3.7%
Water leakage	95.09	113.88	203.48	10.19	115.34	235.91	115. 72	907.76	191.78	74.13
Water meter number	40404T	03350201T	40219T	40501T	4013402T	40337X	4033720T	40217T	40325T	11T
Water leakage rate	3.7%	3.7%	3.7%	3.5%	3.4%	3.4%	3.0%	3.0%	2.9%	2.9%
Water leakage	273.55	212 11	87.4	429.83	7. 90	3006 97	463.68	184.87	544.23	490.07
Water meter number	4033602T	40503T	405X	40325X	40215T	403X	4033501T	40213T	4033503T	4013304T
Water leakage rate	2.8%	2.7%	2.7%	2.7%	2.6%	2.6%	2.5%	2.3%	1.9%	1.2%
Water leakage	524.61	539. 53	1227.3	1525.04	343.88	4724.68	282.11	153.52	353.49	0.33

Figure 4: Leakage amount and leakage rate of each water meter

The above figure.4 shows that the leakage of the first level water meter is estimated to be 10766, the leakage of the second level water meter and above is estimated to be 21488, and the total leakage rate is estimated to be 9.8%. Meanwhile, the data show that in the first level water meter, the leakage rate at 403X is the highest, and the leakage rate at 412X is the highest, and the average leakage loss is 978. Among the water meters above level 2, 40337X has the most leakage, and 40336T has the highest leakage rate, with an average leakage of 268.

To determine the optimal maintenance plan, a 0-1 programming model is established.

According to the data of the National Water price Network, the average price of water use in public institutions is 5.5-6.5 yuan/ton. In addition, according to the data, the price of underground hidden pipes for water supply is 300 yuan /m. The number of people for a single maintenance is 3, the labor cost is 200 yuan/person, and the total cost of a single maintenance is b maintenance = 500-1500 yuan. It can be seen from the third and fourth questions that the annual leakage water is not fixed, so the 0-1 planning model is established with the minimum amount of total loss:

$$\min \sum^{365} \left(b_{repair} w_{repairi} + b_{repairi} \left(1 - w_{repairi} \right) \right) \tag{4}$$

This algorithm proposes and solves new problems on the basis of existing problems through scientific calculation and modeling knowledge.

1) Firstly, with the help of pandas library in Python, the advantages of large-scale and coexistence of multiple data types of data processing are operated and processed, and the water consumption characteristics of dormitory, teaching building, office building and canteen are described and analyzed.

2) On this basis, the data relationship topology diagram of all levels of water meters is established by using the hierarchical relationship attachment of water meters. According to the analysis of the actual situation, the error rates of the data at 401X, 403X and 405X in the first-level water meter are

11%, 11% and 4% respectively compared with the second-level water meter; Other grade 1 water meters according to the quality water meter ±0.5%-±3%; The error of water meters above grade II shall be marked according to the ordinary meter -5%-3%.

3) In view of the pipeline leakage situation, we use 5 points around the time point to carry out spline interpolation smooth prediction for itself, and estimate the leakage amount by using the difference between the predicted value and the original value. The total leakage amount is 32215, and the total leakage rate is 9.8%. If the leakage rate exceeds the threshold, a leakage accident will be marked. Combined with the leakage water situation at each water meter, the leakage rating of the water meter is evaluated according to the leakage times, and the possibility of water leakage at the water meter points such as 40118T/40121T/40331T is high.

4) By checking relevant literature, the average water price range is obtained from 5.5 yuan/ton to 6.5 yuan/ton, and the single maintenance cost is 500 yuan/time to 1500 yuan/time. The 0-1 planning model of whether to maintain every day is established. The average water price is 6 yuan/ton and the average single maintenance cost is 1000 yuan/time to analyze the relationship between the number of maintenance and loss amount and the water price and maintenance cost. The final water leakage repair is 33 times, and the total loss amount is 174,630 yuan.

Based on the above, our model can not only be extended to other water supply network data analysis, but also can be further applied to heat supply data analysis, network flow data analysis, and highway network data analysis, which has good promotion value.

4. Conclusion

The important role and potential of high water use efficiency, optimized water supply management, and reduced operating costs. In terms of market demand, with the advancement of urbanization and economic development, the market scale of intelligent water management system continues to expand, which has brought broad space and opportunities for the development of the industry. In terms of technology implementation, the application of advanced technologies such as Internet of things, big data analysis and artificial intelligence in the intelligent water management system is introduced in detail, which not only improves the intelligence and automation level of the system, but also improves the management efficiency and response ability, and effectively deals with the increasingly severe challenges of water resources management.

Through the case analysis of this paper (taking a campus in Hainan as an example), the successful experience and application effect of smart water management system in practical application are displayed. These cases fully prove the significant effect of intelligent water management system in improving water supply quality, reducing water leakage rate, and optimizing maintenance costs, which provides strong support for future system promotion and market expansion.

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