Impact of end uses knowledge in demand strategic planning for Madrid

F. Cubillo
Deputy Director of Research, Development and Innovation Canal De Isabel II, Madrid, Spain

Abstract In recent years, there have been substantial changes in the factors that affect a growth in water demand and in the framework and constraints for providing the solutions that will meet these demands. Requirements are growing at the speed of light, whereas solutions are being established at a snail’s pace.

In the past, there was considerable headroom where guaranteeing the supply were concerned, but unfortunately the leeway that once existed is being rapidly eroded away. The procedures for facing up to these challenges and new frameworks and problems require new ways of analysis and approach to the solutions. This paper explains the factors that are determinants for the requirements and their solutions, provides figures of reference for the Autonomous Region of Madrid supply system in Spain (5.5 million inhabitants) and the lines that are being followed to reduce the uncertainties involved in demand prediction, so that planning investment in infrastructures can be adapted and water can be managed in a way that is consistent with a set of factors that determine the eventual water consumption as a result of a profound interaction between territorial, social, environmental and economic factors.

Keywords End uses analysis; demand management; urban water supply; demand forecasting

Introduction
It has been common practise to approach the planning of urban water supplies under the assumption of direct relationships between the expectations and their respective structural solutions. The relationships were based upon predicting the way in which consumption would develop using population growth rates whose trends were both linear and stable, and by referring to a series of uniform and steady patterns of demand and their respective flow rates.

The panorama has changed considerably in recent years as a result of major changes in the main factors that constitute the context in which water supply occurs, and the determinants and factors that explain the way the situation will evolve in the future. This, in turn, has brought about changes in the procedures that have to be used to forecast and guarantee a suitable balance between the demand that is to be expected from the population and the resources and infrastructures that are available to meet these demands.

Therefore, the task of guaranteeing this balance must now be based upon a more exact understanding of the factors that really affect the way demand evolves, together with a knowledge and a prediction of how the context variables and the potential for acting upon these factors develop.

The situation has gone from dealing with simple considerations whose basis was mainly hydraulic, to others that have to take into account social, environmental and economic factors.

Urban development and the territorial model that has to be considered for the different future horizons, together with the cultural parameters of lifestyle, consumption habits and water use, will be the variables that are used to make the evaluations for the different horizons and scenarios.

The way in which the feasibility of incorporating infrastructures and of increasing resource availability is assessed has also changed with respect to former practise, because
of the greater constraints imposed and an increase in the number of determinants. Therefore, it is essential to modify existing practises of planning.

The aforementioned situation brought about by the sudden changes that have recently modified the main factors that affect the water supply process, has lead to scenarios with a risk level that is much higher than desired in many parts of the planet. Above all, there is the prospect of the situation worsening in the future if no modifications are made to the procedures used to ensure the service guarantee, or if there is no modification to the principles of risk taken on by society in the continuity of supply and the willingness to temporarily modify the consumption patterns.

### Main characteristics of the Canal de Isabel II supply system

Canal de Isabel II supply system for the Madrid Region is one of the most complex systems in the world.

It provides water services to 170 municipalities with more than 5.5 million inhabitants. Transmission infrastructures are constituted by 2,533 km of mains, 49 pumping stations, 16 service reservoirs for Treatment Plants regulation, 31 service reservoirs for transport regulation and 152 service reservoirs for distribution and consumption regulation.

The distribution network adds up to 12,000 km of pipes.

### Demand evolution indicators

The most useful indicators for establishing and explaining the ways in which demand has evolved are associated with the explanatory factors referred to in the preceding section and their usefulness will depend on the degree of uncertainty involved in predicting how they will evolve in the different future horizons.

Table 1 contains the values for the most significant parameters that play a role in the Canal de Isabel II Supply System in the Madrid Region, separating those values for two periods in the recent past and in the medium term.

As from 1996, there has been a change in the development trends that has affected most of the explanatory factors. The following stand out when analysing the values contained in the table:

- The way in which the total bulk consumption of resources has evolved has gone from an annual growth rate of 2.03% to 2.95% (Figure 1).
- There has been a threefold increase in the annual growth rate of the population being supplied, and the percentage of foreign inhabitants registered has risen from 2.7% in 1999 to 11.0% in 2003.
- The annual growth rate of properties being supplied has increased from 2.39% to 3.11%. The percentage of detached or semi-detached houses has risen from 3.8% to 12.3%, when compared to the total number of dwellings, and the unitary consumption in such types of homes is 40% higher than in blocks of flats.
- There has also been a redistribution affecting the relative importance of the different types of water consumption, which is also variable, with an increase in commercial and municipal use compared to a slight decrease in the industrial use of water.
- A peaking of the maximum consumption values that is shown with greater intensity than the average values.
- The greatest stability revolves around the percentage of unaccounted-for water, with a drop in the actual losses in the supply and distribution systems.

### Predicting how demand will evolve

In the context outlined in the preceding section, it is necessary to evaluate how demand will evolve in the future, because this is the main point of reference for the challenges
that will have to be faced and which will have to be balanced with the resources that are available in each particular case.

It is a complex exercise and it will necessarily have to be based upon a prediction of each one of the main factors that account for the total consumption in each zone that has to be supplied. The exercise has to be carried out not only under the hypotheses of not taking action where those factors are concerned for reasons associated with water availability, but also by taking all the action that are considered feasible on those determinant factors.

It is thus necessary to predict the 'natural' evolution of the explanatory factors and how each of those factors can be influenced on each horizon.

The medium-term and long-term reference base can only be the official frameworks for urban development, which brings together the expectations of territory use and the

<table>
<thead>
<tr>
<th>Table 1 Parameters of Canal de Isabel II system</th>
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<tbody>
<tr>
<td>Medium-term past</td>
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<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Supplied people</td>
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<tr>
<td>Registered immigrants</td>
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<tr>
<td>Type of dwellings</td>
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<tr>
<td>Size of homes</td>
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<tr>
<td>Unitary consumption</td>
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<td>Daily peak consumption</td>
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<tr>
<td>Municipal uses</td>
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<tr>
<td>Industrial uses</td>
</tr>
<tr>
<td>Commercial uses</td>
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<tr>
<td>Unaccounted for water</td>
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<tr>
<td>Real losses</td>
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Figure 1 Canal de Isabel water supply
type of activity to be performed. The same base has to serve for the short-term predictions but, in this case, the certainty is greater, in view of the fact that they will be drawn up from the initiatives already under way for urban planning, construction work that is either planned or in progress and contracts that have been signed and are pending for active and normalized consumption.

Planning solutions
Where forecasting solutions is concerned, certain parallels can be drawn between the approach and the needs. A clear distinction can be made between three time scales for the solutions of a permanent nature, owing to the differences between the financial, environmental and institutional requirements. A service for a new contract in an established zone is provided within less than a month. However, it will take between two and five years to implement and put into service strategic constructions or installations, depending on their size, nature and the environmental sensitivity of the location concerned. Finally, the timescale for the solutions that are adopted to guarantee the balance resources/demands is considerably longer, taking approximately ten years.

It is necessary to include temporary reduction in demands within the framework of the solutions and as part of the risk management policies. These reductions, which require a very swift response, can only be based upon the temporary changes in habits and use behaviour, which could conceivably be obtained on a certain amount, in about two months.

Risk as a basic management factor
In the aforementioned context, the problems develop at dizzy rates with changes in trend whose knowledge requires considerable time intervals. A wide range of constraints increasingly slows down the solutions. Due to these circumstances, most of the water supply systems are being affected by an increase in the risk of not fulfilling their supply and service continuity reliability, and these risks are exceeding reasonable levels.

Furthermore, if one adds to this situation the variation in external agents such as climatic change or a greater social demand for standard of service in the face of contingencies, the future outlook is worrying and requires a major change in the principles of supply planning and management, which must begin not only by redefining the risk level objectives, but also by involving the citizens and clients who will ultimately have to cope with them.

This change cannot be brought about without an increased awareness of the factors that determine water consumption and use and the agents that condition them.

Lines of research
Canal de Isabel II has established the lines for acquiring the knowledge that is essential for deciding actions to take and investments guarantee the supply for the different future horizons.

These lines can be summarized around the following:
- Procedures for an updated monitoring of urban planned development and the parameters for territory utilization.
- Improving an awareness of the relationship between final consumption and its explanatory factors.
- Studying the end uses to which the water is put, in domestic activities, and describing and defining the commercial and industrial activities.
- A detailed study of water use in institutional and municipal activities.
Evaluating the potential for reducing consumption that is feasible within different future horizons, under different circumstances and with different types of policies. Canal de Isabel II has tackled these lines with the following results:

**Analysis of main demand patterns based on historical billing data.** Based on the fact that all customers are metered every 1–3 months, main consumption explanation factors were determined. Results were more significant in factors like geographic area, average income of the neighbourhood, type of activity, type of house, age of house or business (showing a very different pattern for the new properties), monthly climate influence (up to 12% global variation due to climate in one month) and, which is very important for defining drought management policies, reductions obtained in past drought scenarios through different measures, jointly with the time required to obtain them.

**Survey on 5000 domestic and commercial customers.** According to information acquired on the previous analysis of billing records, 5000 properties were selected to get a representative sample. A survey was carried out on them to know their specific characteristics related to water consumption, making special emphasis in parameters like number of inhabitants or users, incomes, age of users, type and age of plumbing and appliances, saving taps, etc.

**Study of the needs and water consumption for outdoor uses.** Results obtained from the analysis of billing data reveal an increasing weight of outdoor use of water in the total consumption, showed by the trend in unitary and total consumptions associated to detached houses. So, it was decided to carry out a more detailed evaluation of that type of water use. An inventory of all urban areas with watered vegetation, and swimming pools was developed, using updated cartography at 1:5000 scale, and with the help of aerial photographs, which cover the whole region (8000 km²). Different types of vegetable coverage were identified, and their water requirements calculated. Cadastre and GIS information was used to distinguish public and private properties and to assign them to service connections of the distribution network.

**Continuous end uses monitoring in 300 domestic properties.** Those properties were selected within the 5000 surveyed ones and from those that provided a representative sample and showed willingness to be monitored in their consumption every second along one year. The monitoring period finished in September 2003. The results provide valuable information on volume of water used in each type of activity, frequency in the use of taps, showers, washing machines, etc., correlation of these values with the main consumption explanation factors, internal losses, minimum night flows, undermetering, simultaneity flow factors for condominiums, daily weather impact in consumption, consumption patterns with new standard plumbing, or with efficient plumbing, and potential water savings with different initiatives.

Preliminary results obtained from these studies present very interesting information for the knowledge of water uses as a basis for updating forecast, planning and operational procedures in the Madrid area. These figures differ significantly from those reported from studies developed in other regions of the world, but there are also some very useful similarities that would be applicable for many other water supply and distribution systems.

**Results**
The main results obtained from this research work have led to a redefinition to a certain extent of the parameters used in strategic infrastructure planning. Figure 2 summarizes
the main parameters considered for infrastructure planning tasks, and Figure 3 shows the changes in forecast after end uses analysis. Significant differences have been found relating patterns of consumption in different geographic areas of the region (residential, industrial and peripheral areas).

Climate impact on water demand has been assessed and different climatic scenarios defined for planning. This knowledge allows an accurate calculation of demand for these scenarios. Design peak demands could be calculated on the basis of hard climatic conditions (Figure 4).

On the other hand, information obtained from end uses monitoring has lead to more realistic expectations on potential water demand reduction based on substitution of inefficient plumbing. Initial estimates of 20% residential demand reduction achievable for a 10
year term, have turned into just 6.9% considering actual distribution of residential use of water through different devices and its potential of water saving, by substituting them with standard efficient appliances available in the Spanish market, and estimating that 30% could be replaced in this time, as detailed in the following table. This figure represents water saving to be achieved only by the use of efficient plumbing, and without modifying habits of consumers (see also Table 2).

Also potential demand reductions to be achieved temporally in situations of scarcity are calculated for different degrees of severity of drought, and taking into account current utilization of water for different uses, geographical areas and climatic conditions, the savings obtained in historical events of shortages and elasticity of demand (prior levels of consumption previous to the last drought event are not entirely recovered). Results are summarized in Table 3.

**Actions**

The actions taken, according to the results obtained, follow:

- Modifying the planning criteria for balancing resources/demands and implementing strategic infrastructures.
- Well defined procedures for preventing and coping with water shortage and discontinuity risks.
- New procedures for reducing the volumes of water that flow to unknown destinations, to the extent that this is technically and economically achievable.

**Table 2 Reduction of residential demand by improving efficiency of infrastructure (plumbing)**

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<tr>
<th>Horizon: long term (10 year)</th>
<th>Maximum potential reduction</th>
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<tr>
<td>Option</td>
<td>Expected demand (l/p/day)</td>
</tr>
<tr>
<td>Taps</td>
<td>66.54</td>
</tr>
<tr>
<td>Showers</td>
<td>46.64</td>
</tr>
<tr>
<td>Toilets</td>
<td>37.91</td>
</tr>
<tr>
<td>Outdoor</td>
<td>42.79</td>
</tr>
<tr>
<td>Other</td>
<td>4.51</td>
</tr>
<tr>
<td>Total</td>
<td>198.40</td>
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![Figure 4 Daily peak demand](chart.png)
All of this is supplemented by intensifying the actions taken to increase operational efficiency, thanks to ‘adaptive operational planning’ so that they reach optimum levels that can cope with the new circumstances.

**Conclusions**

The traditional procedures used to plan and guarantee the urban water supply have to be thoroughly reformed, so that the calculation plans for investing in infrastructures can be transformed, from a simplistic assessment of flow rates associated with the population growth rates in a particular region, to an accurate forecasting of the main demand exploratory factors and their relation with significant parameter for decision making.

The delicate scenario of regulatory, financial, environmental and institutional limitations makes it necessary to alter the principles of water management and planning, so that they attach greater importance to all the agents and factors that affect the way in which requirements develop and condition the implementation of solutions.

This highly complicated scenario involves (or will involve) a large number of water supply systems where there are risks of failing to fulfil the objectives of service and supply continuity. This problem can be solved by modifying these principles of risk taken on by public participation and by the supply companies introducing protocols for preventing and managing risk situations.

Canal de Isabel II is tackling these challenges by carrying out research work and innovative activities, with a view to obtaining a greater awareness of the factors that account for and determine demand, as well as by incorporating into its planning and management systems, new methods for analysing and taking actions that are capable of ensuring that the guarantee levels established for each future horizon are fulfilled.

End uses analysis constituted a basic knowledge to forecast and manage properly reliability for the whole Madrid water supply system.