Imperial College London

Short-term Demand Forecasting for the Operational Control of Water Supply and Distribution Systems

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1. INTRODUCTION

Near real-time operational control of water distribution networks allows utilities to optimise the performance of their networks and respond to failures. This proactive system management depends upon the accurate short-term demand forecasting. In this study, regression and time series based methods were used to develop and evaluate techniques for short-term demand forecasting integrating the significance of climatic variables (rainfall, air temperature) and past water demand. Analysis was carried on operational data from three District Metering Areas (DMAs): DMA 9060, DMA 1061, and DMA 7063.

2. PRELIMINARY DATA ANALYSIS

An interpolation procedure was conducted to replace missing values with interpolated values for more stable flow data. This would ensure more accurate forecasting. Data was separated into 6 groups: spring & autumn weekday, spring & autumn weekend, summer weekday, summer weekend, winter weekday, and winter weekend due to the distinct water demand pattern of the type of day of the week and the season. Spring and autumn seasons were aggregated into one dataset due to similar demand pattern.

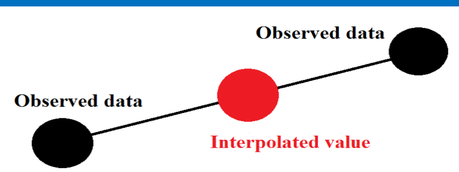

Figure 1: Interpolation procedure

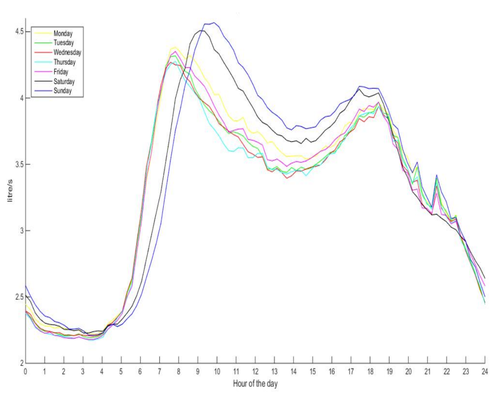

Figure 2: Daily mean flow evolution of DMA 1061

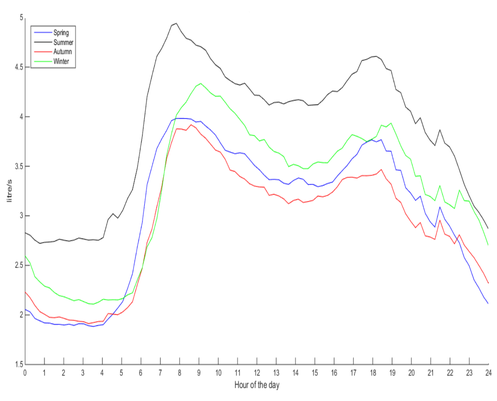

Figure 3: Seasonal mean flow evolution of DMA 1061

3. NARROWING DOWN OF CLIMATIC VARIABLES

26 climatic variables such as maximum temperature, total rainfall amount, number of days since last rainfall, and maximum temperature of 7 days ago were identified then narrowed down by multiple regression analysis to ascertain the impact of the climate in each season. The multiple regression analysis returned the p-value of each weather variable and variables which exhibit p-value less than 0.1 were integrated into the forecasting model to express the stochastic component of water demand.

Table 1: Regression analysis hypotheses

Hypothesis	Interpretation
Null hypothesis	No correlation between specific weather variable and water demand.
Alternative hypothesis	There exists a correlation between weather variable and water demand.

4. RESULTS AND DISCUSSION

A SARIMAX forecasting model of order $(0,1,0) \times (2,1,2)_{96}$ was implemented on each seasonal dataset. The root mean square error (RMSE) and normalised root mean square error (NRMSE) of each forecasting model were calculated to assess forecasting performance and better understand the degree of prediction problems between DMAs.

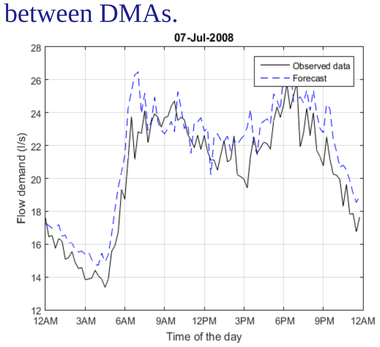

Figure 4: Typical summer weekday forecast of DMA 9060

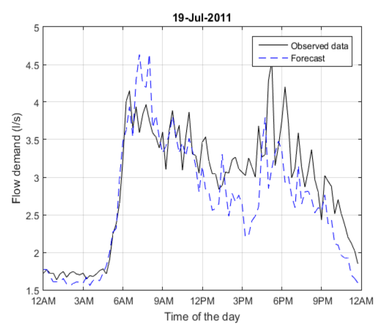

Figure 5: Typical summer weekday forecast of DMA 1061

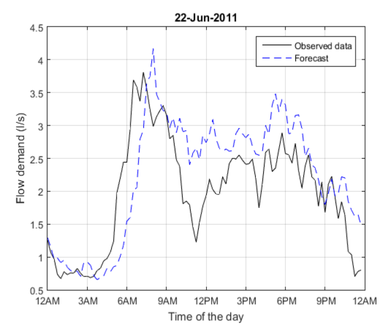

Figure 6: Typical summer weekday forecast of DMA 7063

Table 2: Normalised RMSEs and RMSEs of the summer season

Type of day	Average NRMSE			Average RMSE		
	DMA 9060	DMA 1061	DMA 7063	DMA 9060	DMA 1061	DMA 7063
Weekday	0.0709	0.1280	0.2190	1.6036	0.4668	0.5064
Weekend	0.0874	0.1257	0.2108	1.9776	0.4533	0.4806

DMA 9060 produced smaller average NRMSEs than DMA 1061 and DMA 7063. The average RMSEs show that DMA 9060 exhibit larger errors than other DMAs due to the DMA's larger demand. The relatively larger average NRMSEs of DMA 1061 and DMA 7063 are due to the lower number of consumers in the DMAs while the relatively larger average RMSEs of DMA 9060 is due to the segregation of days into weekdays and weekends.

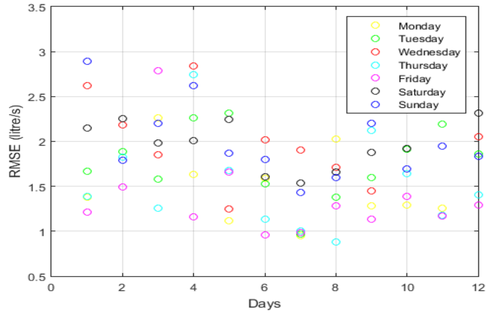

Figure 7: RMSE of each day in summer (DMA 9060)

Table 3: Average RMSE of each day in summer and their ranks (DMA 9060)

Rank	Day	Average RMSE
1	Friday	1.3773
2	Monday	1.5100
3	Thursday	1.5221
4	Tuesday	1.7621
5	Sunday	1.9883
6	Saturday	2.0633
7	Wednesday	2.0753

The forecasting ability of each day in DMA 9060 was assessed. There is reasonable level of evidence, based on the average RMSE of each day, to suggest that short-term demand forecasting accuracy is strongly dependent on the day of the week.

5. ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr Ivan Stoianov, for his assistance throughout the project.