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Building a Performance Indicator to Investigate the Robustness of Water Supply Businesses in Japan

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1. Introduction

One of the main purposes of the government is securing a universal and economical water supply. A strong water supply system (WSS) is needed for all countries to develop human health by increasing water infrastructure. Japan practically achieved the SDG goal: ensure availability and sustainable management of water for all, achieving almost 100% water supply coverage. The water supply can be severely disrupted due to natural disasters. Therefore, it is important to develop the Performance Indicators (PI) to measure the robustness of Water Supply Business quantitatively. It provides future strategic planning to avoid the lacking areas and strengthen the disaster mitigation policy in Japan. This paper focuses on building PIs under the themes of management, facility/equipment, and utility operation.

2. Methodology

We define variables as set of categories I, set of evaluation items J, and set of Target items K as I= {1, 2, n_i}, J= {1, 2, n_j}, and K= {1, 2, n_k}, respectively. Calculate mean μ_ij and standard deviation σ_ij

$$\mu_{ij} = \frac{1}{n_k}\sum_{k=1}^{n_k} x_{ijk} \qquad i \in I,\ j \in K$$

$$\sigma_{ij} = \sqrt{\frac{\sum_{k=1}^{n_k}(x_{ijk}-\mu_{ij})^2}{n_k-1}} \qquad i \in I,\ j \in K$$

Using index value x_{ijk}, mean μ_{ij} and standard deviation σ_{ij}, we normalize the data for each category

$$z_{ijk} = \frac{x_{ijk}-\mu_{ij}}{\sigma_{ij}},\ i \in I, j \in J, k \in K$$

Based upon the above definition, we define the folloing variables such as TWSP: total water supply population, TPLL: total pipeline length, TRVN: total revenue, AWSP: average water supply population, APLL: average pipeline length, ARVN: average revenue, RDIF: ratio of TWSP and total population, RRVC: ratio of TRVN and TCST, TSTF: total number of staff, ASTF: average number of staff, RTST: ratio of total technical staff and TSTF, TEPL: total earthquake-proof pipeline length, REPL: ratio of TEPL and TPLL, AWPR: ratio of within duration purification plants to the total, AWPL: ratio of within duration purification pipeline length to the total, ASLR: average salary of staff.

Then apply cluster analysis (CA) and principal component analysis (PCA).

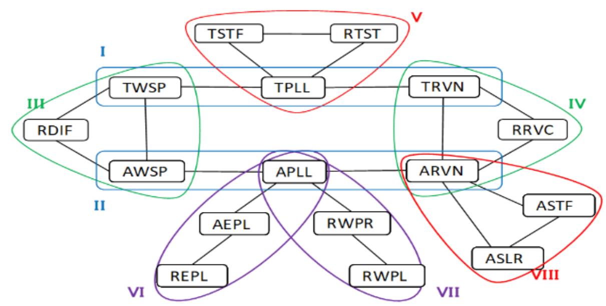


Figure 1 Cases for the CA

3. Numerical Results & Analysis

Letting the total number of clusters be 4 for all cases and using the data for the years 2006, 2011, and 2016, we obtain the following results.

(i)Cluster 1, indicating the largest center of gravity (CGV) in each case of 2006, 2011, and 2016, contains only one prefecture, TKY, in all cases. Exceptions show that all those prefectures in addition to TKY contain large designated capital cities, such as Osaka, Nagoya, Yokohama, and Sapporo.

(ii)Cluster 2 has the second-largest coordinate of the CGV after cluster 1 for most variables in almost all cases. The elements included in cluster 2 in most cases consist of urbanised prefectures with large designated cities in Japan's metropolitan areas, such as Sapporo, Saitama, Chiba, Yokohama, Nagoya, Osaka, Kobe, and Fukuoka. Cluster 2 has one to six prefectures, except for cases V and VII, which include twelve and twenty-six elements, respectively.

(iii)Cluster 3 has the third-largest CGV coordinates after clusters 1 and 2 in most variables and cases. The elements included in cluster 3 consist of prefectures mostly neighbouring those included in clusters 1 and 2. We observe a smaller number of prefectures in cases II and VII for all years as they contain only five or six prefectures fewer than other cases.

(iv)Cluster 4 has the smallest CGV among the four clusters in most variables and most cases. We observe that most prefectures included in Cluster 4 are remote areas in Japan. For cluster 4, we observe that the number of prefectures contained in case VII is exceptionally small as three in 2006 and 2011.

From the above numerical results we can summarise the clustering result as the reference clustering provided in Table 9, in which we consider the fundamental and common clustering results for all years 2006, 2011, and 2016.

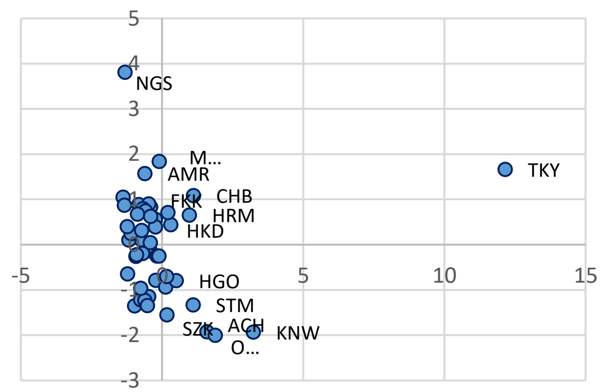
Table 2: Reference clustering result.

Cluster	Prefecture
1	TKY
2	HKD, STM, CHB, KNW, ACH, OSK, HGO, FKK
3	MYG, FKM, IBK, TCG, GNM, SZK, MIE, NGT, NGN, GFU, SHG, KYT, OKM, HRM, YMG, KGM
4	AMR, AKT, IWT, YGT, YMN, TYM, IKW, FKI, SHG, NRA, WKM, SMN, TTR, KGW, EHM, TKM, KCH, OIT, SGA, NGS, KMT, OKW

Based on the centre of the gravity of the cluster analysis, we identify the highest performance prefectures and the lowest performance prefectures. These results explain some important results in the cluster analysis based on the center of gravity.

Also, PCA is used and we clarified the characteristic factors driving the operation of the water supply business in Japan. Investigating four PC factors, we observed that the PCs represent the scale of water supply business operations (PC1), enable the sound development of the management of water supply businesses by introducing the technology of water supply operation by adding technical staff (PC2), represent the improvement of operational efficiency by the technology of water supply business operation (PC3), and represent the quality of technology associated with water business operations (PC4), respectively. The correlation coefficients among the variables TRVN, TSTF, and TPLL are significantly high at 0.98 or higher. For the variables, RRVC, RTST, and SPPR, the correlation coefficients between these variables and others are all approximately 0.0 and are very low. In general, when the raw data represent ratios or rates, if no large disparity exists between them, the normalization of the data will probably expand the disparity.

Figure 4: Distribution of PC scores 1 and 2.



4. Summary & Conclusion

We construct a WPI for the water supply business and quantitatively analyse regional characteristics and regional disparities by applying cluster analysis techniques. We provide our concluding clustering results as a reference clustering with four clusters to explain the regional characteristics of Japanese water supply businesses depending on the degree of urbanization. By defining eight cases containing three variables separately for each, on the various sizes of the water supply businesses, we observe that most variables correspond to the reference clustering from clusters 1 to 4 on the degree of urbanization from the highest to the lowest in general.

References

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