PATTERNS IN THE REGIONAL CHARACTERISTICS OF CONCRETE SUSTAINABILITY AT THE PREFECTURAL LEVEL IN JAPAN

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1. Introduction

Differing practices to sustainability may arise from varied perspectives particularly by region. Moreover, approaches in a specific region under a given set of social, economic and environmental conditions may not be suitable in a different region under different conditions. Concrete materials are also often region-specific as concrete industries depend on a variety of factors such as availability of resources. It is therefore important to understand the regional context of concrete sustainability in making an appropriate sustainable concrete decision.

This paper aims to quantitatively identify patterns in the regional characteristics of concrete sustainability at a prefectural level in Japan. Japan is used as a case study because although it relatively appears as a homogeneous country, its prefectures possess distinct characteristics that may affect concrete sustainability. This analysis is carried out by establishing quantitative indicators that reflect regional differences in the sustainability of concrete materials and then utilizing a clustering method to group prefectures exhibiting similar patterns regarding these indicators.

2. Methodology

2.1. Regional Context Indicators and Data Collection

A set of 9 indicators was constructed in order to quantitatively analyze the regional context of concrete sustainability. These indicators encompass four categories including natural resource consumption (Res), waste generation (Wst), economic resources (Eco) and environmental impacts (Env) that cover various aspects of sustainability and are summarized in Table 1. The values of these indicators were normalized (per capita and usage rate) to adjust for different populations.

Data were collected from various available online resources such as the Ministry of Land, Infrastructure and Transportation (concrete construction waste and construction investment), Ministry of Economy, Trade and Industry (total cement and aggregate consumption in concrete), Ministry of Environment (total CO_2 and energy consumption), Japan Cement Association (usage rates of blast furnace slag and fly ash blended cements) and e-Stat for the official statistics in Japan (total water withdrawal and population).

Table 1. Regional Context Indicators

Label	Description (units)	Year
Res1	Total cement consumption in concrete per capita (100kg/person)	1996-2015
Res2	Total aggregate consumption in concrete per capita (100kg/person)	2007-2015
Res3	Total water withdrawal per capita (m^3/person)	2002-2013
Res4	Usage rate of blast furnace slag blended cements (% of total cement consumption)	1996-2015
Res5	Usage rate of fly ash blended cements (% of total cement consumption)	1996-2015
Wst1	Total concrete construction waste generated per capita (100kg/person)	2000, '02, '05, '08, '12
Eco1	Total construction investment per capita (¥1000/person)	1996-2015
Env1	Total CO_2 emissions per capita (tons/person)	2006-2015
Env2	Total energy consumption per capita (GJ/person)	1996-2015

The time variable of these indicators was integrated in the analysis to cover various periods particularly after Japan's economic bubble burst. As such, depending on the data availability of each indicator, numerous years were included in the analysis as indicated in Table 1. To carry out comparison of indicators with differing units and scales, the prefectural raw data were initially standardized to a mean of zero and standard deviation of one which converted the values to z-scores. After which, to reduce the dimensions of the analysis, the average z-score over the time period of each indicator per prefecture were calculated.

2.2. Agglomerative Hierarchical Clustering

Cluster analysis was performed in accordance with the guidelines provided by Kassambara (2017) using R, an open source statistical analysis software. Specifically, the agglomerative hierarchical clustering, a type of hierarchical clustering used to group objects in clusters based on their similarity, was found to be the most appropriate method for identifying regional context groups. The algorithm starts by treating each prefecture as a single cluster and are successively merged until all clusters have been combined into one big cluster containing all objects.

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3. Results and Discussion

The mean z-score over the time period of each indicator per prefecture were utilized as the base data for the clustering analysis. This analysis was conducted per indicator leading to nine iterations of the method corresponding to nine results. Each iteration has its discrete approach notably on the linkage function used and the number of clusters depending on the outcome of the estimation as suggested by Kassambara (2017) and are summarized in Table 2.

The varying linkage functions and different number of clusters of the indicators imply that the indicators themselves have wide-ranging behavior which cannot be captured by using a single method all throughout. This behavior may be attributed to the internal features of the indicators as well as their trend over the analyzed periods. Incorporating a certain period of time in this analysis helps acknowledge that considering only one time point may not be a representative of the indicator's attributes. However, the differences of the indicators' time periods may have an effect on the clustering results and thus, it can be said that these results are not entirely comparable from one indicator to another.

Table 2. Clustering Characteristics per Indicator

Label	Linkage Function	No. of Clusters
Res1	average	8
Res2	average	7
Res3	single	4
Res4	average	5
Res5	average	4
Wst1	complete	5
Eco1	single	3
Env1	single	7
Env2	average	4

For most of the indicators, it can be deduced that only a few prefectures demonstrated extreme behaviors; approximately 30% of the prefectures have at least one indicator with values of 1.5 standard deviations above or below the mean. Shimane, Okayama, Yamaguchi, Oita and Okinawa which are all located in the southwestern part of the country are the most "unique" prefectures overall having three indicators with in-cluster mean values of 1.5 standard deviation above or below the mean. A high correlation between Env1 (total CO_2 emissions per capita) and Env2 (total energy consumption per capita) can also be observed based on their in-cluster mean values. The in-cluster mean values present an important implication on the regionality of concrete sustainability especially that these factors may positively or negatively affect the sustainability of concrete.

Table 3. In-cluster Mean Values of Regional Context Indicators per Prefecture

Prefecture	Res1	Res2	Res3	Res4	Res5	Wst1	Eco1	Env1	Env2
Hokkaido	0.00	-0.34	-0.21	-0.11	0.94	1.72	1.10	-0.39	-0.41
Aomori	0.00	0.21	-0.21	-0.92	2.50	0.00	1.10	-0.39	-0.41
Iwate	0.45	1.62	-0.21	-0.92	0.94	0.65	1.10	-0.39	-0.41
Miyagi	-0.47	-0.34	-0.21	-0.92	0.24	0.00	1.10	-0.39	-0.41
Akita	-0.47	-0.34	-0.21	-0.92	0.24	0.65	-0.29	-0.39	-0.41
Yamagata	-0.47	-0.34	-0.21	-0.92	0.24	0.65	-0.29	-0.39	-0.41
Fukushima	0.00	0.21	-0.21	-0.92	0.94	0.00	-0.29	-0.39	-0.41
Ibaraki	0.45	-1.13	-0.21	-0.92	-0.33	-0.54	-0.29	1.06	1.16
Tochigi	0.00	-1.13	-0.21	-0.92	-0.33	-0.54	-0.29	-0.39	-0.41
Gunma	-0.47	-0.34	-0.21	-0.92	-0.33	-0.54	-0.29	-0.39	-0.41
Saitama	-0.97	-0.34	-0.21	-0.92	-0.33	-1.22	-0.29	-0.39	-0.41
Chiba	-1.35	-1.13	-0.21	-0.92	-0.33	-1.22	-0.29	0.67	1.16
Tokyo	-1.35	-1.13	-0.21	-0.92	-0.33	-1.22	-0.29	-0.39	-0.41
Kanagawa	-0.97	-0.34	-0.21	-0.92	-0.33	-1.22	-0.29	-0.39	-0.41
Niigata	0.00	0.21	-0.21	-0.11	0.24	0.65	1.10	-0.39	-0.41
Toyama	0.45	0.90	-0.21	-0.11	0.24	1.72	1.10	-0.39	-0.41
Ishikawa	-0.47	0.90	-0.21	-0.11	0.94	0.00	-0.29	-0.39	-0.41
Fukui	0.97	1.62	-0.21	-0.92	0.24	0.00	1.10	-0.39	-0.41
Yamanashi	0.97	1.62	-0.21	-0.11	-0.33	0.00	1.10	-0.39	-0.41
Nagano	-0.47	0.21	-0.21	-0.11	-0.33	0.00	-0.29	-0.39	-0.41
Gifu	0.97	0.21	-0.21	-0.11	0.24	0.00	-0.29	-0.39	-0.41
Shizuoka	-0.47	0.21	-0.21	-0.11	-0.33	0.00	-0.29	-0.39	-0.41
Aichi	-0.97	-1.13	-0.21	-0.92	-0.33	-0.54	-0.29	-0.39	-0.41
Mie	0.45	-0.34	-0.21	-0.11	-0.33	0.65	-0.29	0.67	1.16
Shiga	0.97	-0.34	-0.21	-0.92	-0.33	-0.54	-0.29	-0.39	-0.41
Kyoto	-1.35	-1.13	-0.21	-0.11	-0.33	-0.54	-0.29	-0.39	-0.41
Osaka	-1.35	-1.72	-0.21	-0.11	-0.33	-1.22	-0.29	-0.39	-0.41
Hyogo	-0.97	-1.13	-0.21	-0.11	-0.33	-0.54	-0.29	-0.39	-0.41
Nara	-1.96	-1.72	-0.21	0.71	0.24	-0.54	-0.29	-0.39	-0.41
Wakayama	0.45	0.21	-0.21	1.40	-0.33	-0.54	-0.29	1.06	1.16
Tottori	0.00	0.21	-0.21	1.40	-0.33	0.65	-0.29	-0.39	-0.41
Shimane	1.51	0.90	-0.21	1.40	0.94	1.72	2.30	-0.39	-0.41
Okayama	-0.47	-0.34	3.32	0.71	-0.33	-0.54	-0.29	2.38	3.11
Hiroshima	-0.47	-0.34	-0.21	0.71	0.24	-0.54	-0.29	1.44	0.56
Yamaguchi	0.45	0.21	4.00	0.71	-0.33	0.65	-0.29	3.66	3.11
Tokushima	1.51	1.62	-0.21	1.40	0.24	0.65	-0.29	-0.39	-0.41
Kagawa	0.45	0.21	-0.21	-0.11	-0.33	-0.54	-0.29	-0.39	-0.41
Ehime	0.45	0.90	-0.21	1.40	-0.33	0.00	-0.29	0.67	1.16
Kochi	1.51	1.62	-0.21	1.40	-0.33	0.65	-0.29	-0.39	-0.41
Fukuoka	-0.47	-0.34	-0.21	-0.11	-0.33	-0.54	-0.29	-0.39	-0.41
Saga	0.00	0.21	-0.21	0.71	0.24	0.65	-0.29	-0.39	-0.41
Nagasaki	0.00	-0.34	-0.21	1.40	-0.33	0.00	-0.29	-0.39	-0.41
Kumamoto	0.00	-0.34	-0.21	0.71	-0.33	-0.54	-0.29	-0.39	-0.41
Oita	0.97	-0.34	2.02	1.40	-0.33	0.65	-0.29	3.29	3.11
Miyazaki	0.45	-0.34	-0.21	1.40	-0.33	0.65	-0.29	-0.39	-0.41
Kagoshima	0.97	0.21	-0.21	1.40	-0.33	0.65	-0.29	-0.39	-0.41
Okinawa	1.51	2.27	-0.21	-1.93	-0.33	0.00	-0.29	-0.39	-0.41

4. Conclusions

In this paper, the patterns in the regional characteristics of concrete sustainability at the prefectural level in Japan were examined. Though most of the prefectures' behavior can be considered "average", there are still a few prefectures manifesting excessive behaviors in each indicator. These unique characteristics will argue that a generalized decision in choosing a sustainable concrete material will not be applicable to all prefectures. Thus, these results emphasize the vital role that regional context play in describing the sustainability of concrete.

References

[1] Kassambara, A. (2017). "Multivariate Analysis I, Practical Guide to Cluster Analysis in R: Unsupervised Machine Learning Edition 1". STHDA.