Spatial analysis of life cycle stages of recycling: Locations of recycling activities

Xudong CHEN¹,², Tsuyoshi FUJITA¹,², Minoru FUJII²
1) Graduate School of Environmental Studies, Nagoya University; 2) National Institute for Environmental Studies;
3) Graduate School of Engineering, Toyo University
*chen.xudong@nies.go.jp

1. Introduction

Recently, regional recycling networks have received great attention in both research and practices in various countries. In order to better plan and manage regional recycling networks and simulate environmental and economic benefits, one needs to understand the characteristics of the spatial organization of the different life cycle stages of recycling, from waste generation, collection to recycling processing. The knowledge about these characteristics is not sufficient. Empirical studies existing recycling activities are needed to deepen our understanding.

There are some empirical studies on this topic in the literature¹. These studies focused on the pattern of recycling network and recycling boundaries of facilities. From the life cycle perspective, recycling typically includes several stages from waste generation, separation and collection to processing. Planning for recycling networks requires further understanding of how these stages are organized and on what conditions large regional recycling centers can be most likely viable. While the life cycle thinking has been applied widely on assessment and management, its application on analyzing spatial distribution of life cycle stages of recycling and waste management has not been widely practiced. This study takes waste plastics as an example and aims to analyze the spatial organization of waste generation, treatment (incineration), separation/collection, and recycling processing. It further reviews theories in industrial geography and tests four propositions that explain the formation of the current centers of waste plastics recycling.

2. Methodology

Generation, collection/packaging, recycling processing, and incineration of remaining plastics in the garbage stream are spatially separated and operated by different agents. In order to illustrate the spatial distribution of these activities, we borrow the concept of location quotient (LQ) from economics. In economics, LQ is determined as the ratio of employees in one industry in one city/region divided by the same ratio in the country. The higher the LQ of an industry in a city, the more agglomerated that industry in that city. Here, the location quotients of the four activities are defined as:

\[ LQ_{a} = \frac{WP_{a,i} / N_{i}}{WP_{a} / N} \]

where WP denotes the amount of waste plastics, N denotes population, and subscripts a, i, n denote activity a or population in prefecture i or in the whole nation indicated by n. Similarly to the economic LQ, LQa,i with a value greater than 1 indicate activity a is relatively agglomerated in prefecture i; the higher the LQa,i, the more agglomerated of activity a in prefecture i.

Based on classic industrial location theory⁴, new economic geography theory⁵, and knowledge based theory of spatial clustering⁶, we tested the following four propositions on plastic recycling: (1) Agglomerating in populous areas (close to the source and reduce transportation costs); (2) Agglomerated in industrial areas where manufacturing output is large; (3) Recycling firm’s scale being large in areas where recycling is agglomerated; and (4) Agglomerated in areas with high per capita recycling amount (effective recycling policy and high personal affectedness).

Data on waste generation, incineration, and total recycling are obtained from Ministry of Environment. Data on population and manufacture outputs are obtained from e-Stat, a public statistical database managed by the Japanese government. Data on waste plastics recycling (PET bottles excluded) are obtained from the Japan Containers and Packaging Recycling Association (JCPRA). All data except for manufacture outputs are in 2008, whereas the latest available data on manufacture outputs are in 2006. In 2008, the obligated amount of waste plastics to be recycled, as required by the waste packaging recycling law, was 771840 ton. The amount of waste plastic recycling contracted through the JCPRA system was 669102 ton, accounting for 87%. That is, the data from JCPRA basically represent the overall condition in Japan. In addition, the data from JCPRA are categorized by sources and the authors re-categorized them by the location of recycling firms so as to show the spatial distribution of recycling processing.

3. Results and Discussions

The LQ distributions of different life cycle stages of plastic recycling vary significantly. Along with the direction of waste flow from generation, separation/collection to recycling processing, the variation of LQs among prefecture increase. Such variation is much larger than the LQ of incineration (Figure 1). The distribution of incineration is fairly even across the country, mainly because each municipality is required to
properly manage their own wastes. On the contrary, plastic recycling is clustered in a few centers, not limited to the administrative boundaries of prefectures. Large centers include Hokkaido, Akita-Miyagi, Kanagawa-Chiba, Toyama-Niigata, Fukui-Shiga, Hiroshima-Yamaguchi, and Fukuoka-Oita areas. Another worth noting feature is that the LQs of waste generation, plastic separation/collection, and recycling are not correlated among one another. That is, on a per capita basis, the recycling process is not always clustered in prefectures with large waste generation and better waste plastic separation.

![Image](image.png)

Figure 1 The LQs of waste generation, incineration, plastic collection and packaging and recycling processing.

The amount of waste plastic recycling and different factors are illustrated in Figures 2 and 3. For testing the four propositions discussed in the previous section, we divide the factors (population, industrial output, facility scale, and amount of per capita waste recycling) by the national total or national average in order to make variables comparable with others. All of the four factors are statistically correlated with the amount of waste plastic recycling, but the patterns of distribution are slightly different. First, except for Toyama-Niigata and Akita, all clusters locate in areas with large population. This result confirms the first proposition that recycling clusters are close to populous areas from which large amounts of waste plastics could be collected. Second, except for Toyama-Niigata, Akita and Hokkaido, all clusters locate in areas with large shares of manufacturing outputs. This result supports the second proposition, indicating that similar to other industrial activities, most recycling clusters are close areas with sound industrial foundation and labor pool. Third, scale of recycling firms is highly correlated with the amount of waste plastic recycling. In the case of waste plastic recycling, the economies of scale is mostly gained from internal factors (e.g. cost saving as scale increases) rather than external factors (e.g. share of infrastructures and sources). In addition, path dependence is somewhat clear in this case. Except for Fukui-Shiga, all clusters have eco-town(s) located in respect area. As this "historical matter" was a government-driven project, it did emerge in a number of places almost in a short period of time. With favorable conditions, some firms in eco-towns operate in large scales, leading the cluster, while others in small scale do not attract additional businesses to form clusters. Finally, the per capita amount of waste recycling in the clusters is slightly greater than other areas. This result reflects that a local culture favoring recycling is present in the clusters. The development of recycling businesses, especially those in eco-towns, received support from local governments. Moreover, each eco-town plan contains outreach and public education programs. As a result reflected in residents' behavior, waste separation is performed better than non-cluster areas.

![Image](image.png)

Figure 2 Amount of waste plastics recycling, population ratio, and manufacturing outputs in prefecture

![Image](image.png)

Figure 3 Amount of waste plastics recycling, per capita waste recycling and scale of plastic recycling facilities in prefecture

4. Conclusions

Different from promoting advanced recycling technology at the firm level, planning and managing recycling activities in the regional level requires an understanding the spatial distribution of recycling activities. Findings in this paper can be useful for further planning and simulation studies to choose proper candidate areas to locate regional recycling centers and nodes of recycling networks.

5. References