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Where to dispose of urban green waste? Transportation planning for the maintenance of public green spaces

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ABSTRACT

Urban green spaces provide various social and environmental benefits that strongly improve the quality of life in a city. Municipalities are responsible for maintaining their green spaces in order to preserve these potentials. This paper supports municipalities in planning the transportation and disposal logistics of the green waste that is produced by the maintenance activities. The approach combines ecological issues like the seasonality of green waste generation and different types of biomass with economically driven decision making. We show how to determine cost efficient transportation plans for the disposal logistics and how to capture the seasonality of green waste generation when booking capacities at disposal facilities. It is also shown how a municipality can select the disposal facilities to cooperate with in a competitive environment where facilities offer capacities at differing conditions, as is the case for disposal sites that dump the green waste and for conversion plants that use the biomass for producing renewable energy. We illustrate the approach using case data of a major city in Germany.

1. Introduction

Urban green spaces are local ecosystems that contribute substantially to the quality of urban life. They provide a valuable opportunity for recreational and cultural activities that improve the physical and psychological well-being of citizens. They also positively effect ecological factors like air quality and noise levels (Bolund and Hunhammar, 1999). Therefore, urban planners strive for greening of cities by establishing networks of diverse forms of green spaces that cover the urban area and, in the best case, enable that all residents can reach a green space within walking distance (Jim, 2004). According to Heynen et al. (2006), this even becomes a political issue if an unequal distribution of green space and urban vegetation impacts on the value of private property and the social equity of an urban area.

In order to provide the mentioned benefits, the urban green spaces must be managed by the municipality, which involves a variety of tasks in the fields of finance, policy, development, and maintenance, see Lindholst (2009). These activities incur cost that must be met by a city's government. Especially the maintenance of the green spaces is a recurring item that strains the annual budget. For this reason, green space maintenance is in competition with further spending of a city's government like those for infrastructure investments, social spending, eduction, housing, and administration, which makes efficient maintenance activities relevant also for political reasons. Maintenance activities produce green waste (also referred to as

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green material or biomass in this paper) that needs to be transported to appropriate facilities for disposal. In this regard, municipalities are interested in cost efficient solutions for managing the related transportation logistics. There is also a growing interest in further utilizing the obtained biomass instead of considering it just as waste that is dumped and composted (Bratkovich et al., 2008). The material can serve, for example, as a source of renewable energy for generating heat, power, or biofuel. Clearly, the volumes are small compared with an industrial production of biomass. Nevertheless, urban green waste has the advantage that it is produced without demanding agricultural space that is better used for growing food (with the exception of urban space that is used for food gardening projects (Guitart et al., 2012)).

The goal of this paper is to support a municipality in making relevant decisions regarding the maintenance of its urban green spaces. We combine environmental and economic aspects of green space maintenance for generating transportation plans and for booking capacity at disposal sites. The goal is that the municipality can minimize the cost related to the transportation and disposal of the green waste. The organization of urban green space maintenance is briefly described as follows. The maintenance of public green spaces is the responsibility of the municipality. On behalf of the municipality, worker teams mow lawn, clean flower beds, and prune trees, hedges and bushes. The workers also collect the green waste and transport it to disposal sites for further utilization. These sites can be landfills, conversion plants for producing renewable energy, or any other type of facility interested in receiving such material. In this paper, for reasons of simplicity, we will refer to all kinds of such facilities as disposal sites. Planning the transportation and disposal logistics for urban green space maintenance involves several challenges:

- Green spaces are typically scattered all over the city area, which involves a substantial transportation effort for disposing of the green waste. They are also very heterogeneous with respect to their size and vegetation, which impacts on the amount and type of derived biomass. Also, green spaces require continuous maintenance in the course of the year, but the amount of biomass retrieved in a month follows strong seasonal fluctuations.
- Worker teams are equipped with flexible but small trucks that can access the green spaces. The small capacity of the trucks necessitates multiple round trips between a green space and a disposal site if a large amount of green waste must be transported. Furthermore, the low truck capacity does not allow to set up collection routes that could efficiently gather the waste of several green spaces within one truck trip.
- Working hour regulations can cause that the maintenance of a green space spans several days. The resulting traveling of maintenance workers between their depots and the green spaces reduces the working time that can be used effectively for the actual maintenance.
- The green waste that is produced at a green space by the monthly maintenance must be removed promptly for aesthetic reasons. Also, the municipality cannot store it which means that all green waste must be brought to disposal sites directly.
- There may exist multiple facilities that accept green waste for further utilization. These sites can differ with respect to the disposal fees they charge and with respect to the available disposal capacities.

This paper takes the mentioned issues into consideration and helps municipalities to develop a logistics solution for the green waste management. It also supports a municipality in selecting the disposal sites to cooperate with and in deciding on the disposal capacities that should be booked there. Such issues of green space maintenance have not been studied before as is shown in the literature review in Section 2. Our study then provides the following four contributions. In Section 3, we describe how to quantify the green waste that is generated at a green space and how to derive the number of truck loads that are needed to retrieve this material in each month of a year. The determination of corresponding transportation cost rates is explained in Section 4. In Section 5, we present the resulting logistics planning problems. First, on a monthly basis, a transportation plan is sought that allows the municipality to clean its green spaces at lowest cost. Second, the approach is extended to jointly consider all months of a year, which allows the municipality to book capacities at disposal sites with respect to the seasonality of green waste formation. We demonstrate our planning approach at a comprehensive case study for the German city of Halle in Section 6. Section 7 concludes the paper.

2. Literature

There exist several streams of research where environmental issues are combined with the planning of logistics operations. One issue is to cope with the fuel consumption and the greenhouse gas emissions caused by transport operations. With this regard, companies in the road transport sector may invest in fuel efficient vehicles and switch to using biofuel (Lieb and Lieb, 2010) or they may shift their operations to the night in order to mitigate congestion and environmental impacts (Sathaye et al., 2010). Also municipalities that run public transport or waste collection systems may consider switching to biofuel for the mentioned reasons (Silvestrini et al., 2010). Another issue is managing the supply chain for the production of biofuel. Papers in this field investigate the coordination of the various supply chain stages, starting with the agricultural process of harvesting the biomass and ending with the distribution of biofuel to gas stations or power plants, see e.g., Allen et al. (1998). In such supply chains, biomass is typically produced purposeful through farming and foresting. There are also several studies that consider the green waste of urban areas as a source of biomass. These papers typically address green waste that is part of household garbage. For example, Jahre (1995) and Caplan et al. (2002) compare different collection options for household garbage with respect to the collection and separation effort and the incurred cost. They compare