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SELECTED ASPECTS OF ROAD CLEANSING IN THE CITY OF POZNAN

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ABSTRACT. This paper presents issues related to road cleansing in urban areas based on example of the city of Poznan. It describes typical operations in road cleansing and relations with city logistics and green logistics, as well. Road cleansing goals and its influence on transport systems' operations as well as legal framework for functioning of road cleansing in Poland are also presented. The paper includes literature review of decision problems and their solutions leading to improvements of these systems. The author analyses decision problems of similar areas such as road maintenance and transportation, which aims at indicating potential directions of further research.

Key words: road cleansing, decision problems, city logistics, green logistics.

INTRODUCTION

Road cleansing may be defined as a set of actions taken with the object of remove sand, mud, fallen leafs and other loose matter as well as other debris, such as branches, packaging and car accessories from surface [SIWZz 2008]. It is a part of routine road maintenance operations, that is one of three main components (beside development and rehabilitation) of road operations mentioned in OECD [1994] report, which contribute to providing improved service to road users and better environmental quality.

In following parts of the paper author presents respectively: legal framework for functioning of road cleansing systems in Poland, its goals and influence on transportation systems, basic operations included in road cleansing systems and a literature review of decision problems and their solutions, having an influence on increase of the efficiency of these systems. The paper ends with an example of functioning of road cleansing in the city of Poznan.

LEGAL FRAMEWORK FOR FUNCTIONING OF ROAD CLEANSING IN POLAND

Legal framework for functioning of road cleansing in Poland is regulated by two acts: act on public roads [Act 1, 1985] and act on preserving tidiness in municipalities [Act 2, 2005]. The first act defines road, as a bordered part of land with the space over and under its surface, in which the driving surface, buildings and technical devices related to conducting, securing and maintaining traffic flow are localized. Before the amendment in 2003, the act enumerated the following objects placed within road right-of-way: squares, lay-bys, sidewalks, bike lanes, side roads, trees and shrubs. According to the

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act, the responsibility for maintaining of roads is laid on the road administrator. Depending on the form of ownership, the road administrators may be a body of public administration in case of public roads or the possessor of ground in case of private roads. In the first case, the assignment of road to the specific administration body depends on the road category. Trunk roads are assigned to the State Treasury and the remaining roads to self-governing bodies. Public road administrator may carry out its obligations related to maintaining roads by itself or may create a special administrative unit in charge of these tasks.

Exceptions from road administrator's responsibilities are as follows [Act 1, 1985, Act 2, 2005]:

- maintaining of railway crossings, which is assigned to railway infrastructure administrators;
- maintaining of roadwork zones, which is assigned to contractors;
- sweeping, snow clearing and de-icing of sidewalks, which are located directly next to properties, which is assigned to their owners. The road administrator still has to dispose waste collected in these processes. This exception does not include payable parking places located on these sidewalks;
- sweeping, snow clearing and de-icing of public transport stops and track-ways, which is assigned to transit operators.

REASONS FOR ROAD CLEANSING AND ITS IMPACTS ON TRANSPORT SYSTEMS

Road cleansing is carried out for the following reasons: aesthetic and sanitary considerations, environment protection and traffic safety. The most important are aesthetic and sanitary aspects. Roads are one of waste generation sites. Street waste, that is street sweepings as well as contents of litterbins, is the most diversified group of municipal waste generated in urban areas [Szołtysek 2009a, Bendkowski, Wengierek 2004]. According to the Central Statistical Office [2009] there were 521 thousand of tons of street waste collected in Poland in the year 2008, which is 5,5% of total unsorted municipal waste. In the city of Poznan 10 thousand of tons of street waste, which is 4,9% of total waste share, were collected in the same period, which is equal to 17,83 kgs per citizen. This data also includes waste collection from cemeteries and garden areas. These issues are not considered in this paper due to insufficient space. Waste collection from roads is a part of cities' waste management systems, which is within the scope of research of city logistics [Szołtysek 2009b] as well as green logistics [Sbihi, Eglese 2010]. Street waste may be disposed of on landfills. However, there exist methods for its reuse and recycling. In these cases, the waste has to be screened first. Larger waste, e.g. packages, may be treated in the same manner as other municipal solid waste. Loose matter may be reused in such operations, as: waste covering on landfills or in road works and road maintenance, e.g. road gritting in winter season [Minnesota Pollution Control Agency 1997, Jang et al. 2009].

The next purpose of road cleansing is minimizing the negative influence of transport activities on environment. These operations are aimed mainly at water protection, by eliminating pollution in its source, which is storm water [Jang et al. 2009]. However, road cleansing is also considered as a potential way of decreasing air-pollution in urban areas [Chang et al. 2005].

Road cleansing is also significant in promoting cycling policies in cities. Debris is more likely to accumulate close by the kerb [Riccio, Litke 1986] that is often where assigned for bike lanes are located. Bicycles are more likely to get damaged due to debris laid on road than other means of transport. Therefore, road cleansing is essential for maintaining proper condition of bike lanes. Poor conditions of roads are one of the reasons of resignation from using a bicycle as a mean of transport [Department of Public Works 2009].

Road cleansing may also affect on congestion both in positive and negative way. Positive aspects are related to improvement of traffic safety, which is threatened by debris as well as worse traction caused by loose matter. These factors are one of the causes of road incidents [Komenda Główna

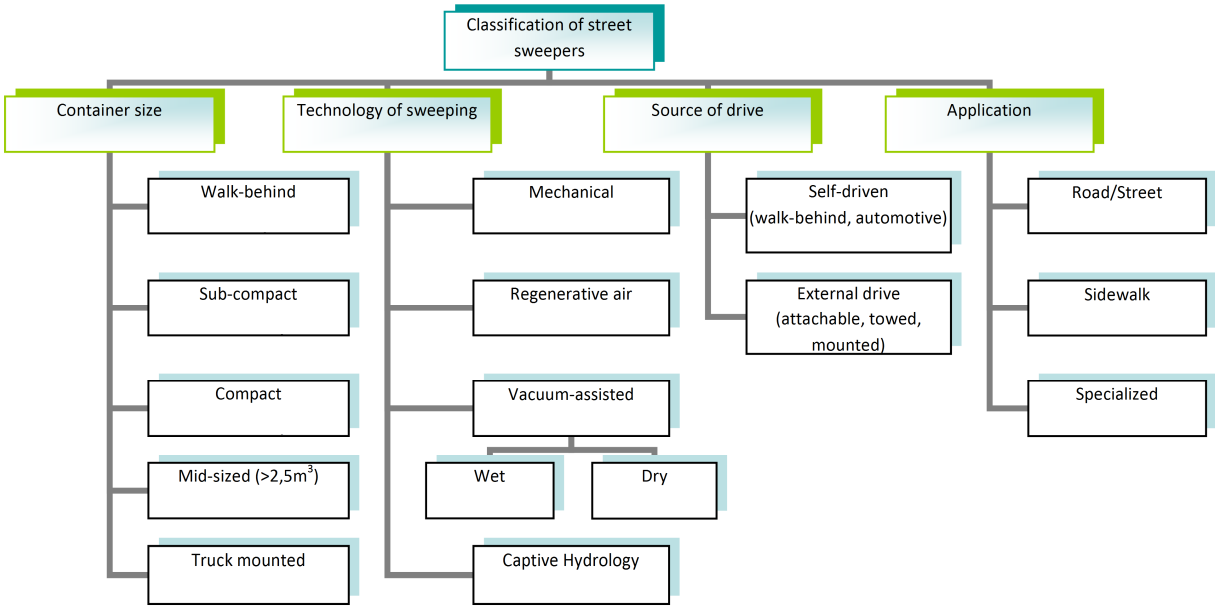
Policji 2009, Retting et al. 2000], which is one of factor of congestion [Szołtysek 2009b, www0]. Negative influence on congestion is related to relatively small speed of road cleansing operations.

Road cleansing management is also related to availability of parking space. It may be necessary to impose some parking limitations, i.e. alternate-side parking regulations, in order to ensure sufficient level of tidiness [Riccio, Litke 1986].

OPERATIONS UNDERTAKEN WITHIN ROAD CLEANSING

Road cleansing consists of three main operations [SIWZl 2008]: spraying, pressurised washing and sweeping. Spraying operations are carried out during hot, rainless days in order to decrease the temperature and wash out dust from road surface. Pressurised washing is conducted on porous pavements in order to preserve their characteristics, by removing matter deposited in pores. Sweeping may be carried out manually with brooms or mechanically by using street sweepers. Manual sweeping occurs especially when it is impossible to use heavy equipment due to its transporting and using in certain places difficulties, as well as in other situations, such as administrative limitations, e.g. heritage conservator's ban or insufficient quantity of street sweepers. According to rough estimations, there are a few thousands of street sweepers working in Poland [Hondo 2009]. Street sweepers may be classified in a few manners (see Fig. 1) [Ramsey 2005, Hondo 2009]:

- by technology of sweeping applied - mechanical sweepers, regenerative air sweepers, vacuum-assisted sweepers with further division to wet and dry technology and captive hydrology sweepers;
- by container size - walk-behind sweepers (<1m^3), sub-compact sweepers (0,5-1,5m^3), compact sweepers (1,5-2,5m^3), mid-sized (>2,5m^3) and truck-mounted sweepers (usually ranging from 5m^3 up to 12m^3);
- by the source of drive - self-driven sweepers (walk-behind, automotive) and sweepers which need external source of drive (attachable, towed as well as mounted sweepers which may be de-mountable or non-de-mountable);
- by application- street sweepers or road sweepers designed for general sweeping, sidewalk sweepers and specialized sweepers designed for sweeping in special conditions, such as runway sweeping, industrial zones sweeping, tunnel washing or tram track cleaning.



Source: own work based upon manufacturers' information and Ramsey [2005]

Fig. 1. Classification of street sweepers
Rys. 1. Klasyfikacja zamiatarek

Street sweepers may carry out duties individually or in tandems. In latter case fine sweeping is preceded with rough sweeping [Ramsey 2005].

DECISION ANALYSIS AS A METHOD FOR IMPROVING FUNCTIONALITY OF ROAD CLEANSING SYSTEMS

A decision problem may be defined as a complex issue which needs to be solved or judged. A decision problem arises in situations when a decision making entity (decision maker) seeks for the most appropriate solution among a set of feasible variants [Żak 2005]. Decision problems occur on strategic, tactical, operational as well as real-time level of management [Perrier et al. 2006a]. Beside the decision maker, in decision process may be also participating other parties - interveners, which are interested in effects of decision solving [Żak 2005]. In case of road cleansing systems in Poland, one may specify the following participants of decision processes: road administrator, municipal service companies as well as road users, some of which are city dwellers. In every decision problem of road cleansing systems one can distinguish a decision maker, who can be a road administrator or municipal service company. Road users are interveners in such decision processes.

The literature devoted to road cleansing decision problems is rather scanty. Author of this study found only one decision problem connected with this issue during the literature review that is a routing and scheduling problem for street sweepers. A routing problem is defined as optimal planning of routes and it is related to operational level of management. The decision maker is the party directly involved into street sweeping. Routing of street sweepers problem is classified as arc routing class problems. Arc routing problems are common with routing of various groups of vehicles used for road maintenance, such as street sweepers, garbage trucks [Eiselt et al. 1995, Wøhlk 2008, Lacomme et al. 2006], snow ploughs [Perrier et al. 2007b], vehicles used to mark the roads [Amaya et al. 2007] and vehicles used for road monitoring [Marzolf et al. 2006]. The most developed versions of arc routing problems are Capacitated Arc Routing Problem (CARP) and its variants. CARP was introduced by Golden and Wong in 1981 and originates from such problems, as Chinese Postman Problem or Rural Postman Problem. In this problem, streets are represented as a graph and the demand is assigned to the arcs [Wøhlk 2008]. In the basic version of CARP, it is assumed that a certain quantity of homogenous vehicles start their tasks from one depot and go back to this depot after finishing work. However, such problems are continuously developed. Modifications of CARP may include such features, as time windows - CARP-TW or planning in a longer time horizon - Periodic CARP [Wøhlk 2008]. CARP is classified as an NP-hard problem. Usually there is only one optimization criterion - minimization of total cost or total time needed to serve whole demand in road network. However such problems may be also considered as multi-criteria problems. In this case, the additional criterion may be work balancing of every vehicle [Lacomme et al. 2006]. Marzolf et al. [2006] argues that in certain situations in road maintenance i.e. routing and scheduling of crew monitors roads condition, other group of criteria shall be used. They propose the following criteria: maximization the number of passages on the highest category of road as well as minimization of the assignment costs or maximization of the covering of priority class roads. The other approach to solve arc routing problems is their transformation into node routing problems where the demand is placed in nodes of a graph [Sbihi, Eglese 2010]. Node routing is widely used in routing of goods in supply and distribution systems (Vehicle Routing Problems) or in refuse collecting problems, which may be considered both as arc routing problems or stringed vehicle routing problems [Wøhlk 2008]. Considering node routing problems, the same set of criteria may be used as in arc routing problems. However, Sbihi and Eglese [2010] argue that environmental criteria such as exhaust emission minimization should be also taken into account in order to comply with green logistics goals. In real-life applications arc routing problems, due to their complexity, are usually solved by approximate methods [Laporte 2008]. Algorithms for solving street sweeper routing problem are implemented into commercially available decision support software, such as GeoRoute [www4, Lapalme et al. 1992, Perrier et al. 2007b] or RouteSmart [www5, García-Ortiz 1995]. Apart from routing, these computer programmes are also used for supporting user the in scheduling of street sweepers. Different aspects should be implemented

in street sweeper scheduling, such as various sweeping strategies, e.g. tandem operations, compliance with parking regulations as well as negative influence on road traffic.

Interesting information of different decision problems in road cleansing may also be given by the existence of such problems in similar operations related to road maintenance and rehabilitation as well as in transport systems. Literature review of these areas shows a great amount of decision problems. In case of road rehabilitation and maintenance, one may distinguish such problems as: scheduling of works in the road network with priorities given to these works and with consideration of their potential influence on congestion [Álvarez et al. 2007, Dekker, Scarf 1998, Lamptey et al. 2008, Qian, Jing 2008]; determining the service-level for various road classes [Perrier et al. 2006a]; contractor selection [Perrier et al. 2006b] as well as garbage truck assignment into the route with determination of the proper size of compartments for selective waste collection [Reimer et al. 2006]. The issues related to decision problems in winter road maintenance are also often a subject of research. Perrier, Langevin and Cambell [2006a, 2006b, 2007a, 2007b] extensively describe various problems related to this topic, such as: districting or sectoring road network, localization of depots and snow disposal sites and assignment of sectors to these sites, fleet replacing as well as fleet sizing problems. Żak [2005] presents major decision problems in road transport companies, which are as follows: determining services portfolio; order selection with resources assignment; crew sizing and scheduling as well as vehicle selection problems. In addition, the literature review gives some examples of decision problems related to designing waste transport and disposal systems, e.g. landfill localization problem [Chang, Wang 1997]. However author of this work does not know of any literature related this topic including road cleansing issues.

In the author's opinion, some of the above mentioned above decision problems are also related to road cleansing systems and may be successfully applied into this area.

FUNCTIONING OF ROAD CLEANSING SYSTEMS IN THE CITY OF POZNAN

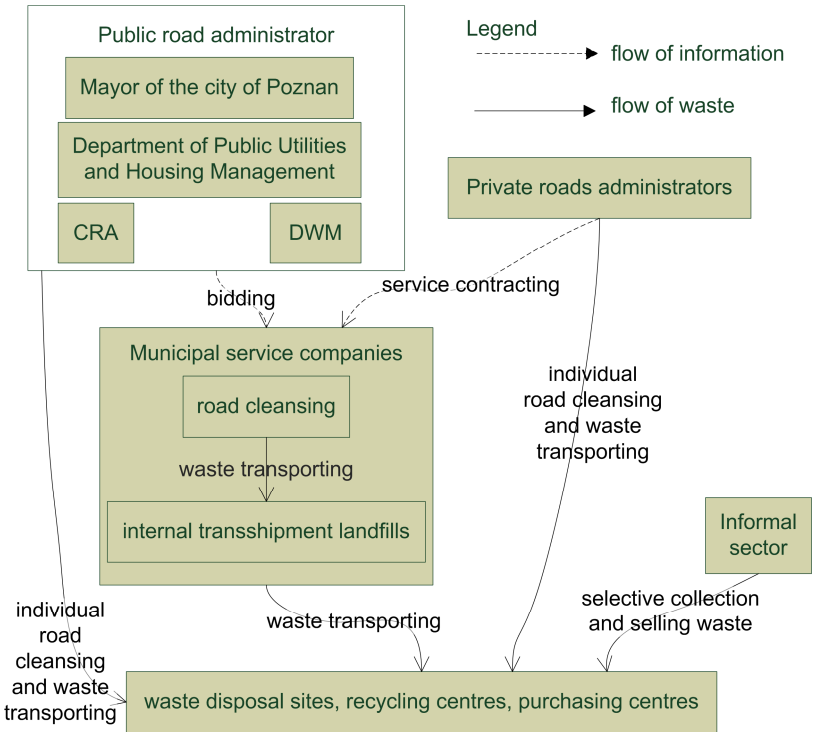
The city of Poznan has a territorial self-government status. Therefore, the responsibility for administrating roads within the city borders, with the exception of freeways and highways, lies on the city mayor [Act 1, 1985]. The tasks covered by the act on public roads are committed to local City Roads Administration unit (pl. Zarząd Dróg Miejskich) - CRA [www1]. CRA is supervised by Department of Public Utilities and Housing Management which is subordinated to the second vice-president of the city [www2]. Another city's body which is involved into road cleansing in Poznan is Division of Waste Management - DWM (pl. Zakład Zagospodarowania Odpadów) [www3]. Similarly to CRA, DWM is also supervised by Department of Public Utilities and Housing Management. The scope of responsibility of DWM includes interventional removal of dead animals and hazardous waste from public places as well as removal of consequences of road accidents. DWM is also responsible for management of local municipal waste disposal site. Tasks committed to these administrative bodies may be conducted by themselves individually or may be outsourced to municipal service companies by bidding procedures. There are several dozen companies on the Poznan market which offer their municipal services for city administration as well as for private roads owners. About ten of these companies provide road cleansing services. In case of Poznan, municipal service companies usually use two-phase method for transporting collected street sweepings to disposal sites. In phase one, collected street sweepings are transported to companies' internal transshipment landfills, where they may be sorted and consolidated. Then in phase two, waste is transported to final disposal sites.

Execution of basic tasks related to road cleansing is ordered by CRA through two open auctions on closed bids - on winter [SIWZz 2008] and summer [SIWZl 2009] road maintenance and cleansing. Both tenders ensure continuity in road maintenance the whole year round, including over 1100 km of streets and 630 thousand m2 of sidewalks in the city and sidewalks, which are located next to city's or State Treasure's properties [SIWZl 2009], as well. The tenders include also collecting waste from litterbins. There are more than 3000 litterbins in the city with the capacity of several dozen litres each. Maximal mass of vehicles used for litter collection from these bins is limited to 4 tones [SIWZl 2009]. This limit has been imposed to prevent fast deterioration of city's sidewalks. The tenders divide also

streets into categories with determining minimum maintenance service level for each category, e.g. minimum frequency of street sweeping as well as frequency of litterbins empting [SIWZl 2009, SIWZz 2008].

The city of Poznan has been divided into seven sectors for purposes of bidding process. This division is similar to the city's quarter division with two exceptions. "Old Town" (pl. Stare Miasto) quarter has been divided into two parts, one of which includes only the central area. The "New Town" (pl. Nowe Miasto) quarter has been also divided in two parts - Northern and Southern. Tender for every district may be contracted to different municipal service company. Winner companies may hire subcontractors or carry out contracted works by themselves.

Sometimes an additional party is also included in waste management systems - the so called "informal sector". The informal sector consists of individuals who selectively collect and sell waste, e.g. aluminium cans, without conducting any formal business activities related to waste management. The significance of the informal sector is noticed especially in low income regions of the world, such as India, Senegal or China [Ali et al. 1999, Berthier 2003]. In case of Poland, the informal sector sells collected waste through waste purchasing centres. Fig. 2 presents participants of road cleansing system in Poznan as well as links between them.



Source: own work

Fig. 2. Participants of road cleansing system in Poznan
Rys. 2. Uczestnicy systemu oczyszczania pasów drogowych

CONCLUSIONS

Author of this study described the specifics of city's road cleansing systems. Participants of these systems were shown as well as typical decision problems related to the subject of this study. Author's considerations described in this paper indicate a need for further research aimed at improvement of functioning of road cleansing systems due to lack of literature devoted to this area.

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www2:http://bip.city.poznan.pl/bip/public/bip/attachments.html?co=show&instance=1001&parent=578&lang=pl&id=25091

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WYBRANE ASPEKTY OCZYSZCZANIA PASÓW DROGOWYCH NA PRZYKŁADZIE MIASTA POZNAŃ

STRESZCZENIE. W niniejszej pracy poruszono problematykę oczyszczania pasów drogowych w obszarach zurbanizowanych na przykładzie miasta Poznań. Opisano podstawowe działania wykonywane w ramach oczyszczania, wskazano jego cele, powiązania z logistyką miejską i ekologistyką, wpływ na funkcjonowanie systemów drogowych, jak również ramy prawne funkcjonowania tych systemów w Polsce. Dokonano również literaturowego przeglądu problemów decyzyjnych rozwiązywanych w celu poprawy funkcjonowania tych systemów, jak również problemów decyzyjnych występujących w zbliżonych obszarach utrzymania pasów drogowych i transportu w celu wskazania potencjalnych kierunków dalszych badań.

Słowa kluczowe: oczyszczanie pasów drogowych, problemy decyzyjne, logistyka miejska, ekologistyka.

WEGREINIGSUNGPROBLEME - CASE STUDY AUS POZNAŃ

ZUSAMMENFASSUNG. Ziel der vorliegenden Arbeit war die Auseinandersetzung mit dem Problem der Reinigung von Fahrstreifen auf den urbanisierten Gebieten am Beispiel der Stadt Poznan. Es wurden die Haupthandlungen beschrieben, die mit der Reinigung zusammenhängen. Es wurden sowohl Ziele der Reinigung, als auch ihr Einfluss auf Betrieb des Verkehrssystems in Polen dargestellt. Es wurden auch die gesetzlichen Bestimmungen dargestellt, die in Polen für die Verkehrssysteme gelten. Es wurde auch eine literarische Überprüfung von den Entscheidungsproblemen vorgenommen, deren Lösung zum fehlerhaften Betrieb von den Systemen beitragen soll. Es wurde auch auf weitere potenzielle Forschungen hingewiesen.

Codewörter: Wegreinigung, Entscheidungsprobleme, Stadt Logistik, Grüne Logistik.

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