ABSTRACT
Academics and practitioners in Europe and elsewhere have attempted to pinpoint the key urban freight transport problems and identify potential sustainable solutions. In this framework, the aim of this study is the evaluation of the environmental outcomes derived from the development of an alternative transport option for the management of Municipal Solid Waste (MSW), using a case study of a municipality in Athens, Greece. The proposed option is mostly based on rail transport, while current practice relies exclusively on road transport. For this purpose the CML 2 baseline 2000 tool was used and the results indicated that the proposed alternative scenario for MSW transport provides a sustainable solution. However, detailed feasibility study is required in order to evaluate the prerequisites, implications and benefits from such a practice that may be applicable in many cities worldwide which already have rail and tram infrastructure for the citizens’ transport movements.

Keywords: City Logistics, Municipal solid waste, Transport, Environmental impact

INTRODUCTION TO CITY LOGISTICS
During the last decades freight transport movements have increased enormously. The EU White Paper “European Transport Policy for 2010: time to decide” forecasted a 38% increase in the demand for goods transport by 2010, and predicted that heavy goods traffic alone will increase by nearly 50% over its 1998 levels (OECD, 2003). Currently, the number of vehicles used for freight deliveries in European urban areas represents 10% of all the vehicles circulating in the cities. The increasing trend of urban freight traffic has substantially affected the quality of life of the urban residents, who presently represent more than 75% of the European population (www.ue-portal.net), while they are projected to rise up to 83% by 2020 (OECD, 2001).

Urban freight transport has become a very important issue in urban planning. There are many challenges and problems relating to increasing levels of traffic congestion, environmental impacts and energy consumption. Historical city centers are
damaged by pollution, tourist industries are threatened, while the distribution of goods and services in the urban areas is getting more and more inefficient (Thompson and Taniguchi, 2001).

City Logistics (CL) refers to the techniques and projects that, through the involvement of a (usually) public agency, are aimed at reducing the total number of truck-trips in an urban area, and/or mitigating their negative impacts (Taniguchi et al., 2003). Until mid-1990s, researchers and policymakers paid relatively little attention to the increasingly severe freight CL problems facing urban areas. The basic constraints regarding the distribution of goods in urban areas are briefed as follows:

- The urban environment is characterized by high settlement and population densities, high consumption of goods and generation of huge amounts of waste. In such environments traffic infrastructure and the possibilities for its extension are both limited and unsustainable. This dichotomy between demand and limitations of the urban environment has resulted in significant problems associated with urban freight transport.
- Congestion in cities is continuously rising due to increasing levels of traffic demand. Most large cities are confronted with problems regarding air and noise pollution and congestion caused by motorized road traffic. The evolution of CL in the past decades even worsened the situation, due to an increasing use of heavier goods vehicles in city centers.
- Lack of a holistic approach based on a value creation process of integrated planning, attributing critical role in collective action, alliances, strategy to performing goals implementation, coordination, and information net. This leads to travel routes exaggerations, with consequent cost increase and negative impact on the environment, talking also into account the trend towards smaller orders with on a more frequent basis by the retailers.

From the above, it is evident the need for integrating transport into a sustainable development process. One of the big challenges at present is the creation of sustainable society with the least possible negative environmental impact. In response to this pressure, standard logistical imperatives for efficient, effective, and fast handling and movement of goods have to incorporate measures for protecting the earth's environment.

There is already growing interest in logistics planning and operations in town and city centers. Many projects in Europe have attempted to pinpoint the key urban freight transport problems and identify potential solutions. In this direction, this paper aims at enlightening the benefits derived from the use of tram and rail transport means for the MSW, by presenting the expected outcomes from the implementation of a new model of managing MSW in the
municipality of Nea Smirni, Athens, Greece. These are based on data concerning MSW generated in 2010, the current rail and tram infrastructure, as well as on the current landfill’s location.

This model may be applicable to a great number of cities that already have rail and tram infrastructure for serving citizens movements. Prerequisite of course is the analytical feasibility study per case, in order to identify the costs and derived benefits from the use of rail instead of road transport for the management of MSW, in a holistic framework, taking into account the three axes of sustainability: finance, environment and society.

MODERN CITY LOGISTICS SOLUTIONS

A number of projects have been implemented concerning the introduction of modern distribution models and solutions, some of which could be broadly applicable (Benjalloun et al., 2009), such as the Freight Transport Centers (FTC) that are already operating close to cities worldwide, as logistics facilities ‘from which consolidated deliveries are carried out within that area’ (Schäffeler and Wichser, 2003). The Freight Transport Centers have promoted the idea of intermodal transport (use of modes and vehicle types in cooperation), aiming at integrated supply chain schemes based on synergies, towards succeeding a value creating process and sustainability. Thus, Professor Kohler, presented a model, which was implemented in the city of Kassel, Germany (Figure 1).

![Figure 1: Kassel model (Kohler, 2003)](image)

The implementation of this concept produced significant results, such as reduction of truck deliveries per retailer (13%), truck-kms up to 60%, etc.

Geroliminis and Daganzo (2006), referred to 17 City Logistics projects that have been implemented in big cities all over the world, focusing mainly upon the use of environmentally friendly means of transport and introduction of traffic zones with specific requirements. One of them is CityCargo, a project that focuses on sustainable cargo distribution in urban centers, using the existing tram network. The process starts by receiving cargo in large
warehouses on the outskirts of the city, where the cargo of four trucks is transferred to one cargo tram. These trams depart to locations inside the city, where they are met by smaller electric vehicles that deliver cargo from the tram to the final destinations. CityCargo aimed to take out half the number of trucks that come into the city (in Amsterdam it would mean cutting the number of trucks from 5000 to 2500 a day). In addition, CityCargo intended to use zero emission electric vehicles (clean), to reduce the number of trucks (safer in the streets) and finally use the tram infrastructure (fast and efficient). It is a global market with over 240 cities, that have tram systems installed, in Europe alone (European Local Transport Information Service, 2007).

A similar approach has been applied for the transport of municipal solid waste (MSW) from cities to landfills or recycling centers. Thus, a project applied in Zurich made use of tram instead of trucks, loading waste from specific locations within the city and transporting them to the waste management center outside the city (Neuhold, 2005).

**CITY SOLID WASTE LOGISTICS AND ENVIRONMENT**

Modern cities generate daily huge amounts of MSW that have to be managed in a sustainable manner. An integrated approach, throughout the life cycle of solid waste, is the answer to the need for sustainability in the MSW management. This approach combines a range of collection and treatment methods to handle all materials in the waste stream in an environmentally effective, economically affordable and socially acceptable way (McDougall, 2001). Transportation is a key step in the management sequence of MSW. Transportation of MSW is defined as “the driving of the empty truck from the garage to the start of the collection route, driving of the full truck from the final stop on the collection route to the unloading point, and driving of the empty truck from that point either back to the garage or to a new collection area if more than one area is serviced on the same day” (Larsen et al., 2009). MSW transport is currently based mainly on road transport (Eisted et al., 2009). However, as mentioned before, there are reports that trains are being used for MSW transport in U.S. cities such as Seattle, New York, Beaumont, Texas and Annapolis, Maryland (Waste Age, 2004) as well as in Europe (Neuhold, 2005).

The management step between collection of MSW and transport is transfer. Transfer is “reloading of waste from one type of transport; transfer facilities make up the end of one line of transport and the beginning of another” (Eisted et al., 2009). The reasons for having the transfer facilities are: i) the rationalisation of transport in order to increase the efficiency and lower the costs, and ii) the demand for separate handling of waste fractions for recycling.
Some transfer facilities only provide reloading of MSW between means of transport, while others also provide some kind of compaction and/or segregation. The adverse environmental burdens related to waste transport and transfer, are related mainly to the use and combustion of non-renewable fuels in the vehicles engaged in those two MSW management steps. The use of fuels has a two-fold impact on the environment: at first it consumes non-renewable natural resources; it also generates emissions of various pollutants (greenhouse gases-GHG, particulate matter, oxides of nitrogen and sulphur, etc.). For example, Table 1 presents data on the emissions of GHG generated by different means of transport. However, in a life cycle perspective the consumption of resources for the manufacturing of the vehicles, the wear of tyres, breaks, engine oil, other lubricants, noise and odour should be also taken into account.

Table 1: GHG emissions derived from fuel for transport of 1 tonne of waste for 1 km

<table>
<thead>
<tr>
<th>Transport</th>
<th>GHG emissions (kg CO₂-eq. tonne⁻¹ km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck &lt; 16 tonne</td>
<td>0.221-0.557</td>
</tr>
<tr>
<td>Truck &gt; 16 tonne</td>
<td>0.091-0.190</td>
</tr>
<tr>
<td>Train (diesel)</td>
<td>0.002-0.058</td>
</tr>
<tr>
<td>Train (electric)</td>
<td>0.002-0.056</td>
</tr>
</tbody>
</table>


**METHODOLOGY**

The aim of this study is the development of an alternative option for the MSW management and comparison in terms of environmental impacts with the current practice, applied in the municipality of Nea Smirni, located in southern section of the greater Athens, Greece metropolitan area. The current practice it relies exclusively on road transport. The proposed scenario is mainly based on rail transport. The comparison of the current practice and future alternative scenario is based on the transport of the annual amount of MSW generated in the municipality of Nea Smirni for the year 2010.

Data for the implementation of the study were collected from the following sources:

- Actual MSW generation and transport data from the municipality of Nea Smirni,
- Data from peer-reviewed journals concerning emissions attributed to MSW transport,
- The use of ArcGis for the representation of the alternative routes (Figure 2),
- The use of SimaPro 5.1 for the environmental impact assessment.
**Current Practice**

The population of Nea Smirni in 2010 was estimated to be 78,000 people. Its MSW management infrastructure and facilities are very typical of the situation existing in the greater Athens metropolitan area. The MSW collection and transport operations are following the following pattern: collection trucks arriving at the transfer station are emptying their loads to containers. No compaction of MSW takes place in the containers.

![Map of alternative route (proposed scenario)](image)

Assuming an average daily generation of 1.4 kg per capita, a total of 40,000 tons per year has to be transported from Nea Smirni to the Fili landfill. Currently, the daily collected MSW are transported to the landfill in containers carried by trucks with tractors for a total distance of 35 km one way. There are 3 tractor trucks owned by the Municipality of Nea Smirni. Each truck is travelling to the landfill 3 times a day carrying containers full of non-compacted MSW. The truck returns empty from the landfill to Nea Smirni. This mode of transport adds up to a total of 630 km travelled daily or 230,000 km travelled annually by the municipality trucks. In addition, note that the daily transport is done via the roads of the greater metropolitan area which are heavily jammed, increasing thus the consumption of fuels.
Proposed scenario

The proposed alternative route is based on the following 4 sequential means of transport (Figure 3):

1. Containers full of MSW are transported by trucks from the municipality of Nea Smirni MSW transfer facility to the nearest tram station (named “Evangelist School”) in containers carried by trucks for a total distance of 1 km. Forklifts are placing the containers onto specially manufactured platforms that can be carried by tram engines.

2. From the “Evangelist School” tram station, containers are transported by tram to the Piraeus tram terminal, which is next to the “Proastiakos” terminal. Note that this is a rail line that its last 3.1 km (from Neo Faliro to Piraeus) are under construction. The distance from the “Evangelist School” station to the Neo Faliro tram station is 6.9 km. Therefore, the total distance from the “Evangelist School” tram station to the Piraeus tram terminal is 10 km (6.9 km + 3.1 km) At the Piraeus tram terminal, cranes and forklifts trucks are assisting the containers to move from the tram platform to the Proastiakos platform.

3. From the Piraeus terminal they are transported by the “Proastiakos” train to the Ano Liossia Station for a total distance of 20 km.

4. Finally, container trucks are transporting, via “Attiki odos”, the MSW containers to the Fili landfill (a total distance of 7.5 km).

Figure 3: Current practice and alternative scenario of MSW transport from Nea Smirni to the Fili landfill
IMPACT ASSESSMENT

Environmental impact assessment will be based on the comparison of the two scenarios. The scenarios are modelled using the academic version of the SimaPro 5.1 software. The major modelling data are presented in Table 2.

The most important factor in electricity consumption is the means and the fuels utilized to produce electricity. This mixture determines the environmental impacts of electricity generation in each country, especially in terms of greenhouse gas emissions. Based on the Public Power Corporation (PPC) data, the electricity mix in Greece is shown in Table 3. The imports were modelled as the average UMPTE from the SimaPro 5.1 database.

Table 2: Inventory of transport distances and means (one way)

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>by</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nea Smirni transfer station</td>
<td>Fili landfill</td>
<td>Truck</td>
<td>Diesel</td>
</tr>
<tr>
<td>Nea Smirni transfer station</td>
<td>Evang. school tram station</td>
<td>Truck</td>
<td>Diesel</td>
</tr>
<tr>
<td>Evang. school tram station</td>
<td>Pireaus tram station</td>
<td>Tram</td>
<td>Electricity</td>
</tr>
<tr>
<td>Pireaus proastiakos station</td>
<td>Ano Liossia proastiakos station</td>
<td>Train</td>
<td>Diesel</td>
</tr>
<tr>
<td>Ano Liossia proastiakos station</td>
<td>Fili landfill</td>
<td>Truck</td>
<td>Diesel</td>
</tr>
</tbody>
</table>

Table 3: The electricity generation mix in Greece

<table>
<thead>
<tr>
<th>Production source</th>
<th>% contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>51.52</td>
</tr>
<tr>
<td>Diesel oil</td>
<td>11.70</td>
</tr>
<tr>
<td>Natural gas</td>
<td>15.50</td>
</tr>
<tr>
<td>Hydro</td>
<td>7.70</td>
</tr>
<tr>
<td>Other renewable</td>
<td>5.81</td>
</tr>
<tr>
<td>Imports</td>
<td>7.77</td>
</tr>
</tbody>
</table>

Source: PPC, 2009

Current practice and alternative scenario are compared using the CML 2 baseline 2000 impact assessment method in terms of the following impact categories: global warming (100 years horizon), photochemical oxidation, acidification, and abiotic depletion. These impact categories are the most relevant to the transport sector. The results of the assessment are presented in Table 4, derived from the routes to and from landfill.
<table>
<thead>
<tr>
<th>Impact</th>
<th>Indicator</th>
<th>Current practice</th>
<th>Alternative scenario</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming</td>
<td>kg CO₂ eq.</td>
<td>6.31*10³</td>
<td>2.7*10³</td>
<td>57.1%</td>
</tr>
<tr>
<td>Photochemical</td>
<td>kg C₂H₂ eq.</td>
<td>146</td>
<td>68.7</td>
<td>53%</td>
</tr>
<tr>
<td>Acidification</td>
<td>kg SO₂ eq.</td>
<td>2.1*10³</td>
<td>1.31*10³</td>
<td>37.8%</td>
</tr>
<tr>
<td>Abiotic depletion</td>
<td>kg Sb eq.</td>
<td>3.57*10³</td>
<td>1.7*10³</td>
<td>53.3%</td>
</tr>
</tbody>
</table>

**EVALUATION OF RESULTS AND DISCUSSION**

Based on the results presented in Table 4, the proposed alternative scenario for MSW transport is preferable to current practice in all 4 impact categories. Based on the results of Table 4, we can calculate the impact per tkm of transported waste. For example, we calculate the global warming potential per tkm of transported waste: for current practice which is based on truck transport via the congested traffic conditions of the greater Athens metropolitan area, the calculated value is 0.225 kg CO₂-eq. tonne⁻¹ km⁻¹, while for the proposed scenario that involves the use of train this respective value is 0.088 kg CO₂-eq. tonne⁻¹ km⁻¹. Both of these results are comparable to those of Eisted et al. (2009) presented in Table 1. Despite the fact that Greece relies heavily on lignite for electricity generation (therefore it sets a heavy burden in terms of the CO₂ emissions per kWh), the substitution of trucks by trains for the transport of MSW proved to be very effective in terms of improving the environmental performance of the transport. A similar result has been reported by Neuhold (2005) for the city of Zurich in Switzerland.

This study is based on the following key assumptions which set certain limitations to the implementation of the project:

- The proposed alternative transportation route requires the involvement of people from various organisations. For example, the Municipality of Nea Smirni will be required to cooperate with Tram S.A. (which operates the tram), the National Railway Organisation of Greece (which operates the Proastiakos trains) in addition to the ESDKNA that operates the Fili landfill, who will be responsible for the final part of the transportation. The proper management of those people, coming from different organisation cultures, may prove to be a very difficult task.
• Then, there must be a minimum level of consensus among the various municipalities that the MSW will go through, since it is very possible that the residents along the train routes will complain for the train activity during the night.
• The required infrastructure (railways, loading decks, auxiliary vehicles, etc.) must be available before the implementation of the proposed scenario.

Despite the practical difficulties that may arise, the proposed alternative scenario for the transportation of MSW from the Nea Smirni facility to the Fili landfill has the following environmental advantages (Table 4):
• It reduces the emissions of GHG by 57.1%,
• It reduces the emissions of gases that cause photochemical oxidation by 53%,
• It reduces the emissions of gases that cause acidification by 37.8%,
• It reduces the abiotic depletion of resources by 52.3%.

In addition to the environmental advantages, the proposed scenario for the engagement of the tram and proastiakos infrastructure offers more utilisation for both of these means of transportation. It also, possibly, results in more revenues for both of these organisations and a lower cost per ton of managed MSW for the municipality of Nea Smirni. However, a detailed technical and sustainability assessment is required to include financial, social and environmental aspects of this proposed city solid waste logistics option.

**CONCLUSION**

The combined effects of CL are both economic and societal, in that they not only improve the efficiency and effectiveness of urban freight transport and logistics operations but also impact on the well-being of a nation and the quality of life of citizens, through detrimental effects on health. Despite the fact that freight transport sector has been characterized by EU as ‘key to sustainable mobility’, relatively little attention has been paid by researchers and policy-makers until recently (European Community, 2008). Indeed, especially in the first half of the 1990s, in the documents that the Commission has published in support of a common European transport policy, issues of CL have in fact been only rarely mentioned. European policy documents focusing specifically on urban freight transport and logistics are increasing. The EU Urban Development Network Programme 2007-2013 (URBACT) aims to support innovation and creativity by networks and foundation of an urban ‘knowledge house’, for competitive, socially integrated and sustainable cities.
In addition, the sustainable management of MSW is also a necessity for modern cities. As part of this research, an alternative scenario for the transportation of MSW from Nea Smirni to the Fili landfill has been proposed. The alternative scenario offers certain environmental advantages. However, it is not yet applicable due to the lack of the available railway infrastructure. Once this infrastructure is in place, the proposed scenario has to be tested in real-life conditions, and if practicable it can be extended to facilitate the transportation of MSW generated from other municipalities, in the southern part of the greater Athens metropolitan area, along the tram line.

The adoption of best practice methods offers the most promising opportunities for urban logistics operations to become both more efficient and more environmentally sustainable. Such best practice methods have to be approached within the supply chain framework in order to gain all the expected value adding benefits derived from effective collective action, innovative coordination and control, throughout the supply chain.

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