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A STUDY ON THE METRO LOGISTICS FOR REDUCTION OF GREENHOUSE GAS AND SOCIAL LOGISTICS COST USING THE MODAL SHIFT

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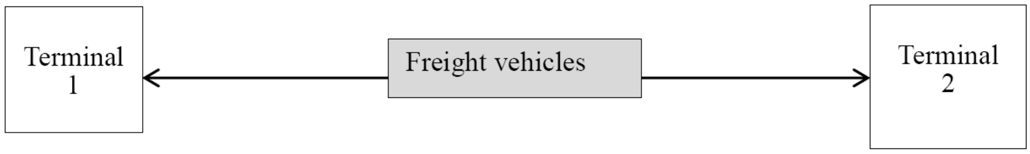
Abstract. *After the Kyoto protocol was negotiated, reducing greenhouse gases emissions has become a global issue and challenge to most of countries in the world. Korea belongs to non-Annex B parties without binding targets, but has been devoting a lot of effort into low-carbon policies and reduction of greenhouse gases emissions to coping with predictable future demand. Based on the concept of modal shift, this paper proposes a logistics system using underground (railway) trains and the route network as part of eco-friendly green logistics to reduce greenhouse gases emissions in the transportation sector. The proposed system also is to reduce logistics and road transport-induced social costs. Computational results show that greenhouse gases emissions as well as logistics and social costs are reduced significantly.*
Keywords: Kyoto protocol, Greenhouse gases emission, Eco-friendly green logistics, Transport-induced social costs

1. **Introduction.** Recently, diversifying consumer needs in the urban area requires more frequent, small-sized, just-in-time shipments in the distribution system. This structural change is causing several problems such as air pollution from vehicle exhaust gases and increasing traffic jam by freight vehicles' on-street parking for cargo handling [1].

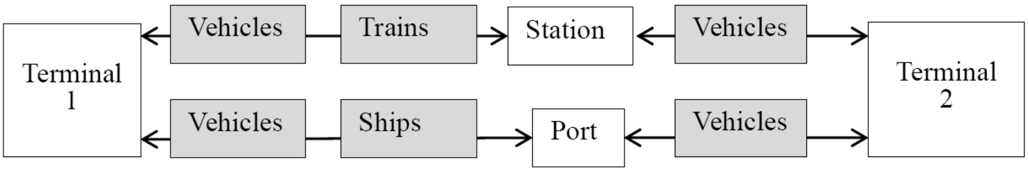
As part of a wider package of integrated transport measures, rail transport has a role to play in reducing transport pollution. Policies encouraging modal shift from road to rail can result in quantifiable environmental and human health benefits [2].

In this paper, a metro logistics system based on the modal shift in Seoul metropolitan area is proposed to reduce greenhouse gases (GHGs) emission as well as logistics and social costs in the transportation sector. In the next section, the concept of modal shift is defined and its main motivation is explained. In Section 3, the new metro modal shift system is proposed to reduce freight transport cost and socio-logistics cost. In Section 4, the total logistics cost of the proposed system is compared to that of road transport logistics system to show the performance of the proposed system. Finally, summary and conclusions are provided in Section 5.

2. **Modal Shift.** Modal shift generally is the principle of shifting freight (or people) from road based transport to other transport modes such as maritime transport, railways or inland waterways [3-6] as shown in Figure 1. The main motivations are an expected reduction of congestion as well as expected environmental and social benefits. The term of modal shift is used interchangeably with mode of transport, means of transport, transport mode, transport modality, form of transport, etc. [7,8].



(a) Road-based transport



(b) Modal shift

FIGURE 1. Concept of modal shift

3. **Metro Modal Shift System.** Logistics costs are composed of freight transport cost and socio-logistics cost (including GHGs emission). Unit socio-logistics cost is calculated as sum of the following unit social costs of air pollution compositions: carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), exhaust gas, sulfur dioxide (SO_2), GHGs (carbon dioxide, methane, hydrofluorocarbons, perfluorocarbon, sulfur hexafluoride), noise, collision, traffic congestion. Unit social costs of air pollution compositions for road transport and railroad transport are shown in Table 1 [9]. Total socio-logistics cost depends on the total distance shipped by the transports.

TABLE 1. Unit social costs of air pollution compositions (unit: won per ton per km)

Composition	Road transport	Subway transport
CO	15.70	1.96
HC	2.19	0.93
NOx	17.00	5.76
Exhaust gas	10.81	1.21
SO_2	0.39	0.17
GHGs	22.00	1.80
Noise	3.36	1.57
Collision	1.64	0.024
Traffic congestion	37.50	0

The freight transport cost is the sum of load-related cost and distance-related cost. Suppose that the modal shift system uses two transports such as road transport and railroad transport. Let $TC(Road)$, $TC(Railroad)$ and $TC(Modal)$ be the total cost of road transport, that of railroad, and that of modal shift, respectively. Let $TC(Transit)$ be the total transit cost between road transport and railroad transport. Let t and d be the load and the distance per shipment, respectively. For each shipment, let $f_R(t)$, $f_R(d)$, and $f_T(t)$ be the load-related road transport cost function of t, the distance-related road transport cost function of d, and the distance-related railroad transport cost function of d, respectively. Since the cost of railroad transport does not depend on the load, the load-related railroad transport cost can be regarded as constant. Let n be the number of shipments. Then $TC(Road)$, $TC(Railroad)$ and $TC(Modal)$ can be defined as follows

$$TC(Road) = [f_R(t) + f_R(d)]n \tag{1}$$

$$TC(Railroad) = f_T(d)n \tag{2}$$

$$TC(Modal) = TC(Road) + TC(Transit) + TC(Railroad) \tag{3}$$

4. **Computational Experiments.** In this paper, the proposed modal shift system has been applied to the YJ Publication Company located in Seoul. The company is a 3PL (third party logistics) company to distribute books to 3PL and wholesale destinations belonging to 14 distribution areas. The number of destinations in each area, the total distance and the load for the current road transport are shown in Table 2 (Numbers are the daily average between February 26, 2013 to March 25, 2013).

Table 2. Distributions, distances, and loads

Area	Destination		Distance (unit: km)	Load (unit: ton)
	3PL	Wholesale		
1	19	27	61.8	9.02
2	11	46	19.4	0.14
3	11	45	54.0	0.03
4	5	36	74.2	0.03
5	35	29	52.3	0.2
6	14	23	48.5	0.24
7	46	66	51.5	0.32
8	17	32	46.7	0.29
9	19	17	58.9	0.21
10	26	48	99.3	0.14
11	9	53	76.9	0.89
12	7	24	63.9	0.08
13	9	49	58.9	0.02
14	10	28	44.3	0.04
total	238	523		

Let d_R and d_T be the distance of shipment for road transport and that for railroad transport, respectively. Using the data with regard to load-related and distance-related road transport and railroad transport [10], $TC(Road)$ and $TC(Modal)$ can be calculated as follows:

$$TC(Road) = 28.5234 + 13.5882t - 0.1971t^2 + 0.456d_R \tag{4}$$

$$TC(Modal) = 28.5234 + 2,271.2782t - 0.1971t^2 + 0.456d_R + 46.75d_T \tag{5}$$

where $TC(Transit) = 2,261.69t$, $f_R(t) = 28.5234 + 13.5882t - 0.1971t^2$, $f_R(d) = 0.456d$, and $f_T(d) = 46.75d$.

The proposed logistics system is shipping books from distribution centers (sources) to the nearest subway stations using road transport and then shipping the books to destinations using railroad transport. Using Equations (4) and (5), the logistics costs for road transport and for the modal shift system have been obtained as 1,280,085 won and 469,890 won, respectively. Using the new system, the logistics cost has been reduced by 63.3% on the average. The proposed system has reduced GHGs emission by 82% as shown in Table 3.

Table 3. Comparison between transport systems (CO_2 kgeq)

System	Road	Road-subway
GHGs emission	226.519	39.466

5. **Conclusions.** This research proposes the new logistics system based on modal shift from road transport to subway transport in Seoul metropolitan area. The system utilizes the current subway network and is shipping books by road transport to the nearest subway stations from distribution centers and then shipping the books to destination centers by subway transport. Computational experiment shows that the proposed modal shift system reduces greenhouse gases emission and total logistics significantly.

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