Evaluating CO₂ Emission Performance of Public Transport Modes by Life Cycle Thinking

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INTRODUCTION

This paper proposes an evaluation method of environmental impacts of passenger transport systems based on the Life Cycle Assessment (LCA) framework and further applies it to evaluate medium capacity transport systems such as AGT (Automated Guideway Transit), LRT (Light Rail Transit), GWB (Guide Way Bus) and BRT (Bus Rapid Transit). The estimation is made in consideration of not only the emission volume of carbon dioxide (CO₂) but also the integration to different environment loads by using relevant parameters. This abstract shows only results with CO₂. The sensitivity analysis for the passenger demand enables the minimisation of environmental load by seeking for the best alternative travel mode for different level of demands.

METHODOLOGY

Each transport system consists of three main parts, i.e. track system, other infrastructural elements and rolling stock. The environmental effects through their whole life cycle are evaluated by SyLCEL (System Life Cycle Environment Load) concept as depicted in Fig.1. Each element is divided into three life stages including construction/production, operating/use (including maintenance and repair), and disposal. In order to estimate the total environmental load for the construction stage, the environmental load of each element is considered as a standardized emission factor of a typical structure and is multiplied by the quantity of each associated element. For the operating stage, the travel length is multiplied by the emission factor of consumption of fuel or electricity (See [1] for more details).

INVENTORY ANALYSIS

Infrastructure construction stage

The amount of embodied CO₂ emissions for the construction stage is 8,470[t·CO₂/km] for GWB, 9,940[t·CO₂/km] for AGT, 11,800[t·CO₂/km] for railway. For the railway system, embankments with less potential of environmental load compared to that of the bridges, covers 25% of the total infrastructure and elevated sections are dominated by concrete bridges which have less environmental impacts in comparison to steel structure.

SyLCEL evaluation

SyLCEL is calculated computed for each passenger transport system per passenger-kilometer again for each transport mode. The results of SyLC-CO₂ (System Life Cycle CO₂; value that appraises CO₂ by SyLCEL) are shown in Fig.2. Demand for each transport mode is set as 7,000 [person-trips/day].

GWB generates large environmental load not only during the operating stage, but also in the construction stage especially in consideration of the passenger volume. The environmental loads from constructions for LRT and BRT are rather little and their operating stage loads account for almost the total SyLC-CO₂ value.
SENSITIVITY ANALYSIS BY DEMAND VARIATIONS

Variations in SyLCEL by the passenger demand changes

SyL-CO$_2$ relies heavily on the presumed amount of passenger demand. Therefore a sensitivity analysis to measure the impacts of demand shifts on the environmental load is appropriate. SyL-CO$_2$ values are estimated for different levels of demands, which are described in Fig.3. For the daily passenger demand less than approximately 2,000 [person-trips/day], the smallest value of SyL-CO$_2$ is for BRT; for higher demand, the least SyL-CO$_2$ is for LRT, and subsequently when the demand exceeds 100,000 [person-trips/day], the railway takes the smaller value. For each of the five modes, SyL-CO$_2$ per passenger-kilometer reduces with the increasing demand, but converges to a steady value when the demand increases further to an extent. This means that environmental loads per passenger-kilometer, other than those arising from operating stage, approach to zero. In this case, the environmental load depends on the emission factor of vehicle operating, the average occupancy and its carrying capacity.

Evaluation by an eco-efficiency indicator

An eco-efficiency indicator is also defined as the effect or performance of services divided by the corresponding environmental load.

$$\text{Eco-efficiency} = \frac{[\text{Average number of person carried}] \times [\text{Life time travel distance}]}{[\text{Amount of time required}] \times [\text{Life time environmental load}]}$$

This indicator is useful for comparing alternative plans with different performances.

With the afore-explained approach, environmental load variations in relation to demand changes are analyzed, by taking the example of transport systems within the metropolitan area of Nagoya city in Japan. Eco-efficiency value by SyL-CO$_2$ is estimated for each alternative mode and the results are presented in Fig.4. Highest eco-efficiency values deriving from different ranges of demand are: BRT for the passenger demand less than 2,000 [person-trips/day], and LRT for high passenger demand. For every value of passenger demand, the eco-efficiency of GWB is below those of either AGT or railway.

The exchange point of the ranking between BRT and GWB is at 50,000 [person-trips/day] for SyL-CO$_2$ per passenger-kilometer and at 14,000 [person-trips/day] for eco-efficiency. This is the consequence of 1.67 times higher scheduled travel speed for GWB than BRT that is SyLCEL value per passenger-kilometer is 1.67 times more than the BRT at the turning point where the assumed passenger demand is 14,000 [person-trips/day].

CONCLUSION

On the purpose of exploring the environmental impacts of passenger transport systems, a systematic approach based on the LCA framework has been proposed for evaluation in planning phase. It can be concluded that the proposed evaluation approach is more suitable to estimate the environmental performance of passenger transport systems, with consideration of travel demand.

REFERENCE