Estimating the Change in Life Cycle Carbon Dioxide Emissions by Introduction of Light Rail Transit

Shingo MANO[1*], Hirokazu KATO[1], Naoki SHIBAHARA[1], Ryoko MORIMOTO[1] and Jun NISHIHARA[2]
[1]Nagoya University, C1-2(651) Furo-cho, Chikusa-ku, Nagoya, Aichi, 464-8603, Japan
[2]Shizuoka University, 3-5-1 Jyohoku, Naka-ku, Hamamatsu, Shizuoka, 432-8011, Japan
[*]smano@urban.env.nagoya-u.ac.jp

Abstract

This study aims to calculate the change in carbon dioxide (CO_2) emission with introduction of light rail transit (LRT) based on the life cycle assessment (LCA) approach. The LRT system boundary for evaluating CO_2 emissions includes infrastructure, vehicles and the operating phase. On-road exclusive LRT tracks generate traffic congestion with a reduction of road lanes. The framework provided by this study enables analysis of the influence of LRT on total transport systems, such as decline of traffic volume of other transport modes due to abolishment of bus operations and a shift from passenger cars to LRT. The estimation results show that introduction of LRT in Hamamatsu city in Japan would reduce CO_2 emissions if the shift ratio from passenger cars to LRT were higher than approximately 10%.

Keywords: light rail transit, system life cycle CO_2, low carbon transport, transport demand

1. Introduction

Environmental load reduction is often mentioned as an effect of introducing light rail transit (LRT) in a city area. However, proper judgment whether LRT introduction can reduce environmental impact, requires a quantitative evaluation that consider the specifications and use.

This study aims to calculate the change in carbon dioxide (CO_2) emission with introduction of LRT based on a life cycle assessment (LCA) approach. System boundary for evaluating CO_2 emissions of LRT includes infrastructure, vehicles and the operating phase.

On-road exclusive LRT tracks generate traffic congestion with a reduction of road lanes. This framework allows analysis of the influence of LRT on total transport systems, such as decline of traffic volume of other transport modes due to abolishment of bus operations and a shift of passengers from cars to LRT.

2. Environmental Load Estimation Method of LRT by LCA

2.1 A set up of the sysytem boundary

LRT system consists of infrastructure (incidental structures, and main structures, such as tracks and stops) and vehicles. The system life cycle environmental load (SyLCEL) was evaluated, and in addition it was assumed that the passenger car traffic driving on the parallel roads shifted to the LRT, and the reduction in environmental load as a result of this was also evaluated by extended life cycle environmental load (ELCEL).

This study evaluates only CO_2 in the environmental loads. However, this method can be extended to the estimation and integration of a number of different environmental load relevant parameters.

2.2 Inventory analysis

Inventory analysis of actual materials, energy consumption must be carried out using detailed data of controlled state, power consumption, etc.. However, in this study, we assume the conceptual phase of LRT that details about infrastructure or schedule are not decided. The method of "rough LCA", previously used by Watanabe and others[1] to find the emission factor by supposing a standard structure, is used. The emission factor is shown as in Table 1. A life stage is considered as (1) production of vehicle, (2) operating, (3) construction of infrastructure, and (4) maintenance of infrastructure. In the whole LRT system, the lifetime of a system set as 60 years and infrastructures set as 60 years and vehicles set as 30 years.

Table 1: CO_2 emissions applied to LRT development

Component	Stage	CO_2 emissions
Main body	(1) Production of vehicles [t-CO_2/car]	70
	(2) Operating [kg-CO_2/car- km]	0.846
Incidental structure	(3) Construction of tracks [t-CO_2/km]	1,510
	(3) Stops [t-CO_2/places]	14.9
	(4) Maintenance of infrastructure [t-CO_2/year]	4

Table 2: The outline of the LRT route

Item	Set value
Line length [km]	14.5
Number of tram stops [places]	36
Passenger transport volume [passenger/day]	27,000
Number of operations [servises/day]	320
Number of vehicles [vehicle]	20
Capacity [passengers/vehicle]	150
Travel speed [km/h]	16.8

3. Outline of Intended LRT Plan

Hamamatsu urban transport design study group suggests "Hamamatsu type new transport system"[2]. Among the lines consisting of this system, we evaluated the Mikatahara main line, which is expected to have highest feasibility as a primary arterious of north-south traffic (Table 2). With the concept we assume that the passengers carried 10 [million passengeres/year] and the number of train services are 320 [servises/day] (peak time

10 [servises/hour]). LRT tracks would prevent the cars from driving and the lane for cars would be reduced to one lane in each direction.

4. Estimation Result of Life Cycle CO_2

4.1 Estimation result of SyLCEL

The items according to the SyLC-CO_2 (SyLCEL evaluated using CO_2) estimation result in LRT introduction and its life stage are shown in Fig.1. SyLC-CO_2 is estimated at 1.9 [kt-CO_2/year]. The emission generated by operating for approximately 77% of the total SyLC-CO_2. Because LRT track can be constructed on the existing road, the CO_2 emission of infrastructure origin is small.

4.2 Estimation result of ELCEL

Traffic congestion reduces fuel economy. This study estimates the environmental load by whole traffic on the target section in account of relationships between traffic congestion and decrease in fuel efficiency.

Q = kv curve is made in relation to speed v [km/h] and traffic density k [vehicles/km].This curve is identified by the data with traffic volume (on a weekday and a holiday) and speed of the target section obtained from road traffic census in 2005. The CO_2 emission factor is obtained by applying car fuel efficiency function[3] to this curve.

Fig.2 shows the estimated amount of ELC-CO_2. This result shows that ELC-CO_2 emission would be decreased if the shift ratio from passenger cars to LRT were higher than approximately 10%.

4.3 Cumulative CO_2 emissions and CO_2 pay back time

Fig.3 shows the variation with time of cumulative CO_2 emission and CO_2 pay back time for the alternative proposals of implementing the LRT project (with) and not implementing it (without). Pay back time indicates the number of years over which the investment amount can recovered by the results of the project.

In the case study, it can be seen that the period over which the CO_2 for construction of the LRT infrastructure and manufacture of the vehicles and operation until the end of the pay back time is recovered from the reduction in CO_2 due to passenger car use is 5-6 years, when 30% traffic volume of the passenger cars running on the same road convert to LRT.

5. Conclusion

This research estimates life cycle CO_2 of LRT system and the increase in CO_2 emissions accompanying new introduction.

The analysis considered the influence of traffic congestion accompanying use reduction of other traffic systems, such as cars, produced by LRT introduction, and the lane reduction by the exclusive track.

Analysis showed that CO_2 reduction was seen when the conversion ratio from passenger cars to LRT was 10% or more in the case study.

Moreover, regarding CO_2 emissions occuring by LRT introduction, it was shown that pay back in 5-6 years is possible in case of the conversion ratio to LRT is 30%.

The effect of CO_2 reduction by introducing LRT with exclusive tracks could be appeared over a short period, depending on the conversion ratio in the setting in this study.

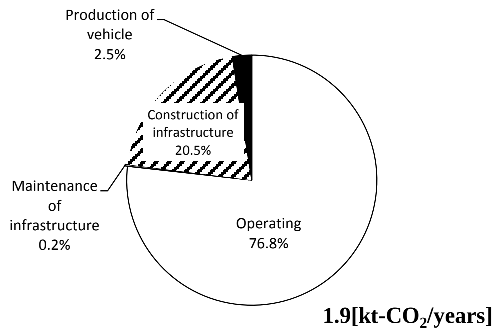

Fig. 1: SyLC-CO_2 and details of life stage

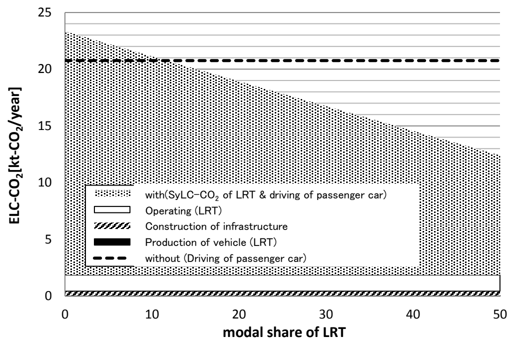

Fig. 2: ELC-CO_2 by LRT system

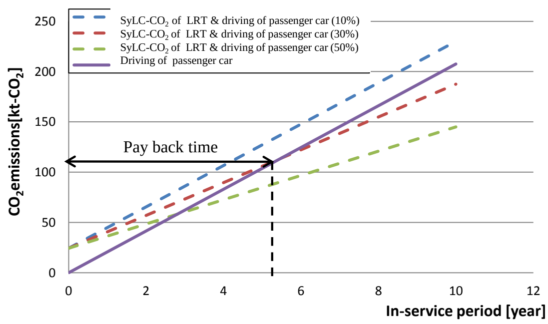

Fig. 3: Cumulative CO_2 emissions and the pay back time

6. References

[1] Y.WATANABE, M.OSADA, H.KATO, Environmental assessment of introducing LRT (Light Rail Transit) system -- Comparison with alternative modes and an application of eco-efficiency, *Journal of Life Cycle Assessment*, Japan, Vol.2 No.3, 2006, pp. 246-254 [*in Japanese*]

[2] Hamamatsu city -- Urban transport design study group, The proposal of the Hamamatsu type next generation traffic system, Japan, 2010, pp.60-63 [*in Japanese*]

[3] N.Oshiro, M.Matsushita, Y.Namikawa and H.Ohnishi *Civil engineering journal*, Vol.43, No.11, 2001 pp. 50-55, [*in Japanese*]