International Journal of Knowledge and Systems Science
Volume 14 • Issue 1

Liquefied Natural Gas Logistics Management Through Optimal Road-Rail Intermodal Logistics Planning Considering Community Safety:
A Case Study in Thailand

Porntip Junsang, King Mongkut's University of Technology Thonburi, Thailand
Chorkaew Jaturanonda, King Mongkut's University of Technology Thonburi, Thailand*
Teeradej Wuttipornpun, King Mongkut's University of Technology North Bangkok, Thailand
Mayurachat Watcharejyothin, PTT Public Company Limited, Thailand

ABSTRACT

The demand for natural gas (NG) in Thailand has been continuously increasing, but part of NG volume has not been distributed to customers locating far from the pipeline network. Therefore, NG is transported by trucks in liquid form called liquefied natural gas (LNG) to meet the demand. However, road transportation by truck causes many problems such as high transportation cost, low capacity, poor environmental conditions, and low safety. To solve these problems, the road-rail intermodal transportation is an option to distribute a large volume of LNG in long-haul transportation more efficiently. This research proposes an optimal planning for LNG logistics management in a case study where the problem is modeled as a mixed-integer nonlinear program to minimize the total logistics cost. The optimal solution includes the LNG distribution center locations, transportation mode(s), train loading service type, and truck type. Community safety using the LNG damage radius criterion is considered in the model as a constraint. The solutions resulting from three planning scenarios are compared and discussed.

KEYWORDS

Damage Radius Constraint, Liquefied Natural Gas, Logistics Planning, Mixed-integer Nonlinear Programming, Road-Rail Intermodal Transportation

INTRODUCTION

Liquefied natural gas (LNG) is natural gas (NG) that is cooled down to the liquid state for easier and safer storage or transportation. LNG takes up only 1/600th the volume of NG in its gaseous state, which means the gas can be distributed more efficiently. LNG has to be converted from its liquid state to its gaseous state (to be NG) before it can be used, which is known as regasification process. NG can be used as a fuel in many sectors, including industrial, transportation, and power generation sectors. Although it can be used to substitute for fuel oil and liquefied petroleum gas (LPG) to reduce pollution problems, NG is not widely used in these sectors in Thailand. For this reason, the Thai

DOI: 10.4018/IJKSS.320486 *Corresponding Author

Ministry of Energy has continually promoted the use of NG as a substitute for fuel oil and LPG. In order to meet the domestic demand of NG, which is continuously increasing due to this government policy, LNG will become an essential part of the energy market in the very near future (Songbandid, 2016); then, LNG transportation in the country will also increase rapidly. For this reason, LNG transportation planning becomes an interesting issue.

Nowadays, Thailand imports LNG from abroad. Thus, LNG is stored in storage tanks at an LNG terminal before it is regasified, compressed, and distributed through pipelines. However, the NG pipeline network does not cover all areas in Thailand. As a result, LNG has only been distributed by tanker trucks to customers located far from the pipeline network. Because of the increasing trend of LNG demand derived from the government policy, various problems (e.g., accidents, traffic congestion, and air and noise pollution) caused by LNG transportation using trucks have increased as well. Rail freight transportation in the country is apparently a better alternative to the long-haul transportation for distributing a large volume of LNG and other goods. Indeed, it allows to reduce the abovementioned problems and to create economies of scale. Rail transportation clearly seems to be the best transportation mode for LNG, as it can also reduce the journey time and increase logistical efficiency. However, the railway is not able to access to all LNG customers' destination unlike the road, as its advantage is a direct transportation mode or so-call door-to-door (D2D) transportation. Hence, the road transportation mode using trucks integrated to rail transportation mode using trains, referred as road-rail intermodal transportation (RRIT), is considered to be a better option for serving all customers locating far from the pipeline network. Road-rail intermodal freight transportation is also beneficial to the environment, as Pinto et al. (2018) observed that its operation is a strategy to reduce atmospheric emissions and thereby help mitigate climate change worldwide.

Meanwhile, the Thai government has been developing a megaproject to change the existing railway from single-track to double-track, which will be finished in the next few years, to increase passenger and goods transportation potential (Rathanamanoonporn et al., 2020). Therefore, the objective of this research is to find an optimal LNG logistics planning via road and/or road/double-track-rail intermodal mode of a case study in Thailand mainly aiming at minimizing total logistics cost. The optimal solution of the case study includes locations of the distribution center (DC) and the transportation mode(s) suited for distributing LNG from the terminal to customers all over the country. Moreover, train loading service and tanker truck capacity are also matter to the cost. Therefore, the authors also considered both variables in the optimal solution. Notably, DC in this research means the railway station along the double-track railway where an LNG transshipment point exists between road and rail modes. There is an LNG storage area in it for the wait for changing transportation mode, not for reserving the fuel.

When DC is considered to set in an area, social issue should be carefully concerned. LNG is a hazardous material (HAZMAT) as it is highly flammable and explosive substance (Jianhua & Zhenghua, 2012); thus, community safety undeniably becomes one of the most important issues to be considered in DC location decision. A criterion used to measure a harmed area is the damage radius. In this research, the authors model a mixed-integer nonlinear program (MINLP) to minimize the total logistics cost under community safety constraint.

It can be noted that one of the aims of this research is to promote sustainability in LNG logistics, which is the proposed LNG logistics planning attends all of three pillars of sustainability including the environment, economy, and society (Chiadamrong & Suthamanondh, 2022; Fernando & Evan, 2015; Jarrah et al., 2019; Lee & Wong, 2018). RRIT utilized instead of road transportation by trucks not only reduces transportation cost and environmental problems, but also enhances the safety of the community of all DCs. Any LNG carriers (government or nongovernment sector) can consider this proposed plan for LNG sustainable logistics planning in the future, when double-track railway is prompt to service.

The remainder of this paper is organized as follows: The second section presents a literature review on the relevant topics; the third section contains the problem description and a mathematical formulation; the fourth section presents an application of the proposed model via a case study; the fifth section provides the authors' analysis and discussion of the results; the sixth and last section offers the conclusion and suggestions for further study.