Songklanakarin J. Sci. Technol.
45 (3), 356–362, May – Jun. 2023

http://www.sjst.psu.ac.th

Original Article

A study on design and analysis of a school bus project for a municipality in southern Thailand

Nikorn Sirivongpaisal[1, 3], Walakkamol Kongyoung[1], Sakesun Suthummanon[1, 3], Pallapat Penjamras[2], and Sirirat Suwatcharachaitiwong[1, 3*]

[1] *Department of Industrial and Manufacturing Engineering, Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla, 90110 Thailand*

[2] *Department of Business Administration, Faculty of Management Science, Prince of Songkla University, Hat Yai, Songkhla, 90110 Thailand*

[3] *Smart Industry Research Center, Department of Industrial and Manufacturing Engineering Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla, 90110 Thailand*

Received: 17 May 2022; Revised: 30 January 2023; Accepted: 30 March 2023

Abstract

The key characteristic of a public transport project is its challenging requirements and the various stakeholders involved, like in the school bus project of this research. To substantiate the design of such a project and analysis of its performance, much information will be required to convince the stakeholders. Hence, acquiring the project information requires a solid framework for understanding and projecting the unseen problems that impact the stakeholders. This research studies the design and analyses a school bus system in Hat Yai City Municipality. The study process was formulated on the feasibility study framework, consisting of market, technical, and economic studies. The quantitative techniques were effectively applied, including behavioural customer study, city transportation design, simulation modelling, and economic analysis. The predicted system performances and analysis results were generated as information made available to the stakeholders, for them to make an insightful assessment. The proposed framework can provide incisive guidelines for the design and analysis of other projects.

Keywords: transportation designing, public project, school bus system, computer simulation, ProModel®

1. Introduction

Hat Yai City is the regional centre of education in lower Southern Thailand. At present, the total number of students is about 55,000. The projected number of students in the year 2027 is about 80,000. Ordinarily, most students use personal transport for travel to and from school, which spawns a large number of road trips and results in traffic congestion during school prime times at 6:30-8:00 am and at 3:30-6:30 pm. The traffic congestion in Thailand’s major cities, similar to other major cities, has recurring rush hours in the school area affecting its vicinity. However, the main distinction of Thailand from others is that students in Thailand do not necessarily attend a school in close vicinity to their homes; instead, they can commute across the zone to attend their school of choice. So, the voluminous student trips and serious traffic congestion contribute also to traffic accidents. In the past available data, the correlation between the number of students and the count of their accidents has a p-value of 0.093, so there is a strong relationship between the number of students and their accidents. This indication motivated the researchers to propose a school bus project to Hat Yai City Municipality, with the goal to provide safe, effective, and efficient transportation to students, as well as to reduce the rate of accidents in Hat Yai City. However, the design and analysis of such a project need interdisciplinary skills in

*Corresponding author
Email address: sirirat.su@psu.ac.th

marketing, computer modeling, and economics, to support the analysis and draw conclusions regarding whether the project is worth it or not. Consequently, this paper aims to offer a comprehensive design and decision analysis of the school bus project in Hat Yai City Municipality.

In the study, the researchers adopted research methodology from a project feasibility study, which consists of three main steps, namely market feasibility study, technical feasibility study, and economic feasibility study, while an administrating/organizing feasibility study and an environmental impact study were not regarded here. Contributions of this research include, firstly, design and decision analysis of the public transport project that can be attained with optimal selections under our proposed methods and set of techniques. Secondly, although the adopted techniques are plain, they still provide valuable insights to the project decision analysis. Thus, lastly, our methods generally can be adopted and applied to other public projects.

The remaining manuscript is structured as follows. A literature review is presented in the next section. After that, the research methods will be clearly explained, regarding our approach to the design and decision analysis of the project. Next, results are thoroughly examined and discussed for each stage of the research approach. Lastly, conclusions are provided.

2. Literature Review

School Bus Routing Problem (SBRP) research is pertinent to the “Vehicle Routing Problem (VRP)”, which has been under research for a long time. SBRP is an NP-Hard problem, and it was studied and presented for the first time by Newton and Thomas (1969). That study aimed to design bus routing and scheduling for one school. The approach can be divided into two steps. One is determining the shortest route for infinite bus capacity. The other is partitioning the single route to individual bus routes and schedules, which satisfy bus capacity, bus loading policy, and passenger riding time constraints. Later on, Newton and Thomas (1974) developed their work further for bus routing in a multi-school system. Bowerman, Hall, and Calamai (1995) presented the urban school bus routing problem with a multi-objective function and described algorithms for generating the solution. The solution provided the optimum number of routes, total bus route length, load balancing, length balancing, and student walking distance. Braca, Bramel, Posner, and Simchi-Levi (1997) worked on routing and scheduling buses for multiple schools in urban areas in New York City with mixed loading allowance. GIS was applied to obtain actual travel time by student location and school location and to generate efficient bus routes and schedules considering also one-way streets. Schittekat, Sevaux, and Sörensen (2006) developed a model to select the bus stop where students will be assigned to from potential alternative stops, to minimize the total travel distance. In this model, the school was considered as a depot, and bus routings were obtained for single school problems and tested only for small-sized problems. Mix load algorithm was presented. Park and Kim (2010) provided a comprehensive review of the school bus routing problem. They summarized the various assumptions, constraints, and solution methods. They presented five sub-problems of SBRP, which are (1) data preparation, (2) bus stop selection, having location-allocation-routing (LAR) strategy and allocation-routing-location (ARL) strategy, (3) bus route generation, having “route-first, cluster second” approach and “cluster-first, route-second” approach, (4) school bell time adjustment, and (5) route scheduling. Last but not least, Park, Tae, and Kim (2012) developed a mixed load algorithm for the school bus routing problem (SBRP) and measured its effect on the number of required vehicles. Allowing mixed loads increases flexibility and gives cost savings. Bus starting points can be school, depot, or driver’s home. A constructive algorithm was developed and the number of vehicles could be reduced by 22 %.

Computer simulations are commonly used in studies on manufacturing systems, service systems, logistic systems, etc. Specifically, the use of computer simulations in transportation design has become common. Carotenuto, Serebriany, and Storchi (2011) studied a simulation model in a discrete event environment to help plan flexible services for people transportation, named the “Demand Responsive Transport System (DRTS)”. Routing and scheduling were planned for multiple vehicles with limited capacity and time window constraints. Service by DRTS can be both static and dynamic. If the customers’ requests are known in advance, this is the static case; otherwise, the case is dynamic. External factors such as congestion or failures of user arrival were coped with within the discrete event simulation by integrating real observation data with the algorithm. El-Gharably, El-Kilany, and El-Sayed (2013) studied discrete event simulation in tackling the VRP in a stochastic environment. A simulation model was developed in the ExtendSim^{TM} environment with three sections: router, customer, and total route distance calculator. The optimization was carried out by the Optimizer Block provided by the ExtendSim^{TM}. Finally, since the late 1980s, GIS has had a variety of applications in various fields such as public health, sustainable development, natural resources, regional and community planning, transportation, and logistics. Shah and Adhvaryu (2016) measured the Public Transport Accessibility Levels (PTAL) for Ahmedabad, India. A GIS mapping tool was applied for generating a visual illustration of PTAL taking into account average walk speed and time, distances to public transport stops, and peak-hour route frequencies of different public transport modes.

The above review regarded the nature and characteristics of a school bus routing problem. Effective technologies for addressing this type of problem in transportation planning include simulation and GIS, which are vastly helpful for our research. The main distinction of this research from other studies is that Thai students do not necessarily attend a school in close vicinity to their homes; instead, they can commute across the city to attend their schools of choice. The research methods are next described in detail.

3. Research Methods

The research methods, as shown in Figure 1, for the design and analysis of the school bus project, are described next. The study was initiated by obtaining data from the demand feasibility study, which will be used in the technical feasibility study. The sampling method in this step was stratified random sampling, which stratified the population into three groups: kindergarten, primary, and secondary

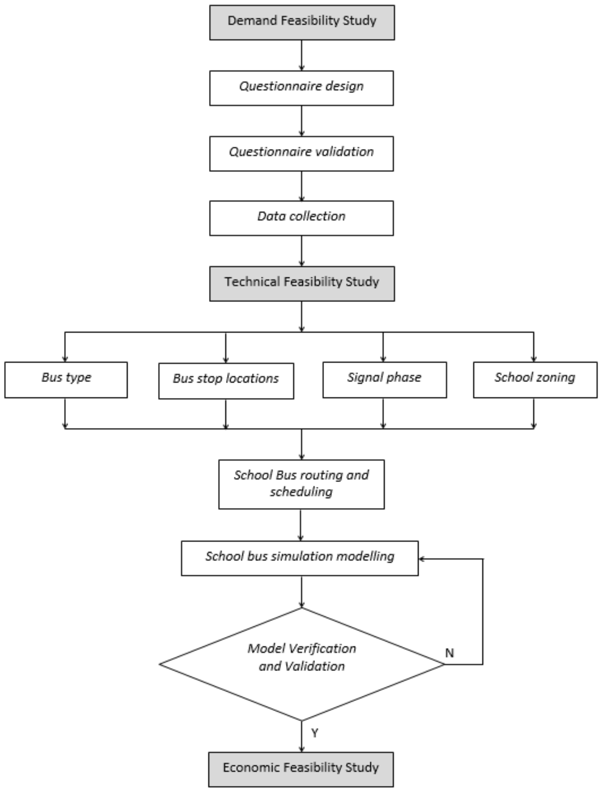


Figure 1. Research method

students. The necessary sample size was calculated by Taro Yamane's equation with a 5% error rate, which yielded 400, 420, and 420 samples of kindergarten, primary, and secondary students, respectively.

In the technical feasibility step, a simulation model was built and used as an experimental tool to provide insights into project performance. Practically, the simulation model was a discrete event simulation that performed a significant role in the decision analysis. School bus routing and scheduling were considered under time window constraints and with multiple vehicles of limited capacity. The simulation results were then finally used in an economic analysis.

Due to the complexities and numerous factors involved in the model, an analytical solution that can deal with all complexities and factors is not practical. Thus, the ArcGIS software was applied using its powerful data visualization, query, and analysis capabilities. The simulation technology allowed tackling the complexities and stochastic nature of the problem efficiently.

The following is a general description of our simulation model. The bus stop locations were fixed first. Students were assigned to the nearest bus stops from their houses. Routes were generated for the selected bus stops to minimize the daily total travelled distance. In the morning, a student or a group of students would be picked up at a bus stop and delivered to a school. Vice versa, a student or a group of students would be picked up at the school and delivered to a bus stop in the afternoon.

In order to design bus routing, students' addresses and school locations were needed within the layout of Hat Yai City Municipality. While the development of bus routing is an NP-hard problem, it can be fragmented into smaller sub-problems by school zoning, which was done before addressing bus routing. A number of conditions were taken into consideration in the routing, namely (1) bus stops are commonly used by students of every school, (2) a specific school in each zone will be located as a hub of transportation (start-stop location for buses), (3) each route is set with a radius of 500 meters, (4) but for the first 500 meters there will be no school bus service because the demand survey found that parents who are within 500 meters between home and school are more likely to pick up and send students by themselves, (6) the bus will travel only on roads more than 6 meters wide, and (7) the morning time-window is from 6:30 am through 7:50 am, but the bus must arrive at the last school at least 5 minutes before school starts; and the afternoon time window is during 3:30 pm through 7:00 pm. The bus routing network was then built, and the shortest path analysis used Dijkstra's algorithm.

The computer simulation model for school bus system was built using the ProModel® software package. Main elements in ProModel® such as Locations, Entities, Path Networks, Resources, Processing, and Arrivals represented the school bus system. Various declared input variables, such as traffic lights, bus stops, school buses, schools, and bus seats were managed in Microsoft Excel and imported to ProModel®. Flow of the simulation program is shown in Figure 2

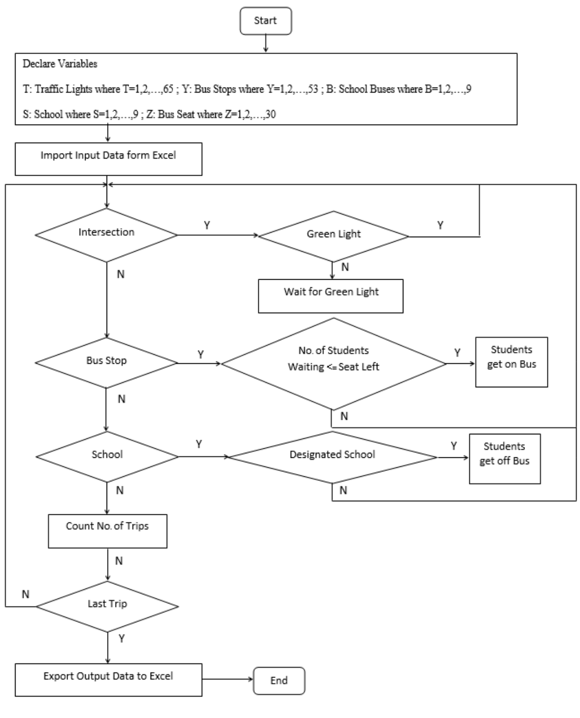


Figure 2. Simulation program flow chart (Kongyoung *et al.*, 2017)

3. Results and Discussion

3.1 Demand feasibility study

There were 35 schools in Hat Yai City Municipality. The planned sample sizes, which are target groups, were 400, 420, and 420 of kindergarten, primary, and secondary students, respectively; and 1,480 sets of questionnaires were distributed inducing 1,400 responses (94.60% response rate).

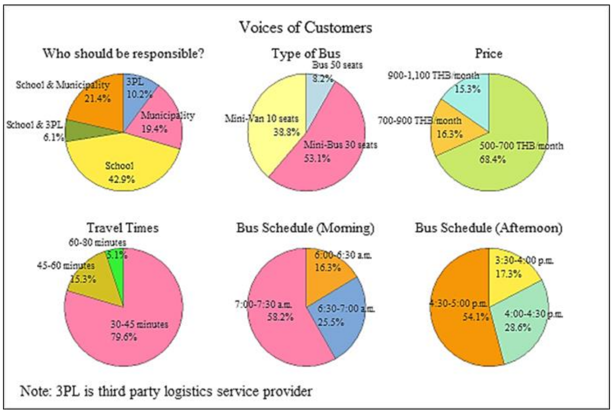
Statistical analysis of the demand survey is summarized as follows. The survey of the demand feasibility study found that more than 50 % of samples are interested and intend to employ the bus service, and the highest demand for school bus service was 42.3% among the primary school students. The kindergarten level has moderate demand, about 36.8% because parents demand close supervision and high security for their children. Consequently, they may deliberate that a school bus is not suitable for them. The primary level students are more mature in taking care of themselves, so their parents are more interested in school bus service. The secondary level students had the lowest demand for school bus service at 42.3%. Their parents are more likely interested in bus services with economic benefits to them, and the lowest cost option may not be a school bus.

In addition, the survey data disclosed ranking of the decision factors to the priority order safety, travel time, convenience, and price, concerning how the potential customers determine and decide about using the service. Also, Figure 3 exhibits their requirements for the service. Also, such information was deployed in the service design parameters in the next phase.

3.2 Technical feasibility study

Initially, the preferred bus type in this project, due to the survey, was a minibus that provides more seats than a van, at a lower cost. A minibus with 30 seats and a diesel engine (175 horsepower at 2,600 rpm) was selected. Because mini-buses were chosen for the service, it was necessary to limit the routing to primary and secondary roads only. Consequently, the bus stops were designated to the main roads, with a total of 53 bus stops covering the Hat Yai City Municipality, and 64 traffic lights in the model, based on the density of students and the road network for each school. Next, school zoning and school bus routing were designed following the previously stated requirements in the Research Methods section.

The 53 bus stops located in Hat Yai City Municipality and the 2 school zones for providing the school bus service were initially planned in the project. The bus routings of zones 1 and 2 had 5 and 4 routes, respectively. A summary of the routes in each zone is given in Table 1. The proposed solutions with minimum length routes were obtained with Dijkstra’s algorithm in ArcGis Network Analyst, which integrates information on the road network accounting for one-way streets, U-turn points, speeds, etc. Such detailed information cannot be dealt with in analytical models found in prior literature.



Note: 3PL is third party logistics service provider

Figure 3. Survey of customer preferences for a school bus service

Once the simulation model was built, it was verified and validated. The simulation was used to investigate the expected performance of the tentative school bus system. The simulation runs in this research were terminating simulations. They delivered a comparison for the SBRP between “mixed load plan” and “single load plan”. Key performance indicators of the system are travel times, the number of trips in the specified time window, bus waiting time at the red light, the total number of served students, and CO2 emissions.

3.2.1 Travel times

On top of that, the preferred travel times of the customers from the survey designated as 30-45 minutes was set as service target. A summary of the travel times from all routes is presented in Table 2. The minimum travel time was 21.03 minutes in the morning for the single load plan, while the maximum was 42.19 for the afternoon in the mixed load plan, which does not violate the customer requirements.

Table 1. Route information

Zone	Route	Number of bus stops	Number of traffic lights	Distance (km.)		Number of trips			
						Time window (6:30-7:50 am)		Time window (3:30-7:00 pm)	
				One way	Round trip	Mixed-load	Single- load	Mixed- load	Single- load
1	1	10	11	14.987	29.974	2	2	5	6
	2	9	13	15.305	30.610	2	3	5	7
	3	11	17	15.199	30.398	2	2	5	6
	4	11	23	10.280	20.560	2	3	5	6
	5	10	15	13.034	26.068	2	3	5	5
2	1	12	8	16.717	33.434	2	2	5	5
	2	12	12	12.449	24.898	2	2	5	6
	3	12	18	12.510	25.020	2	2	5	5
	4	10	11	15.926	31.852	2	2	5	6

Table 2. Travel time summary

Plan	Time window	Average (minutes)	S.D. (minutes)	COV	Sum (minutes)	Min (minutes)	Max (minutes)
Mixed load	Morning	31.05	3.58	11.52	279.47	25.97	36.92
	Afternoon	35.56	3.82	10.75	320.07	30.08	42.19
Single load	Morning	27.91	5.52	19.77	251.18	21.03	35.57
	Afternoon	33.38	2.83	8.48	300.44	28.62	37.34

In addition, the travel times can be comparatively distinguished by zone, by type of plan, or by time window, in the following Figure 4. Examining the confidence intervals of the travel times, they do not significantly differ between the school zones, types of plan, or time window, except for the travel time in the morning with single load plan in zone 1. Details of travel time confidence intervals are also illustrated and again there was no violation of the customer requirements from our design.

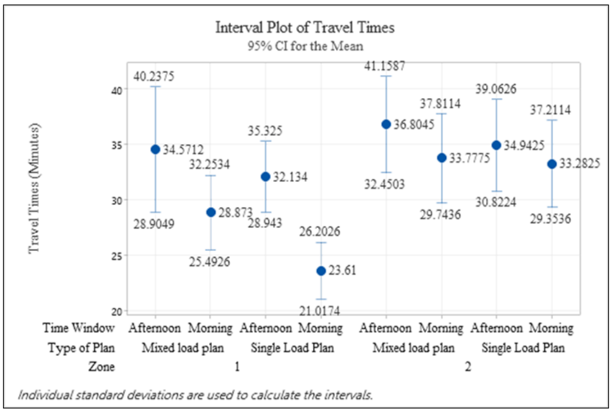


Figure 4. Bus travel times

3.2.2 Number of trips in the specified time window

The initial design was based on each route to be served by one bus, so there will be 9 buses in the system. Table 1 will clarify how many trips will be operated for both zones during each time window. Overall, a single load plan can generate more trips, as well.

3.2.3 Bus waiting time at red lights

Likewise, the bus waiting times at traffic lights are predicted for the system performance, based on real traffic data. This is an advantage of using simulations to assess the designs. Figure 5 exemplifies a situation of the bus waiting time in the afternoon trip, in which the longest expected bus waiting time is in zone 2 (bus 1) with a time between 611.63 and 921.97 seconds. Also, the rest of the results can be realized from below figure.

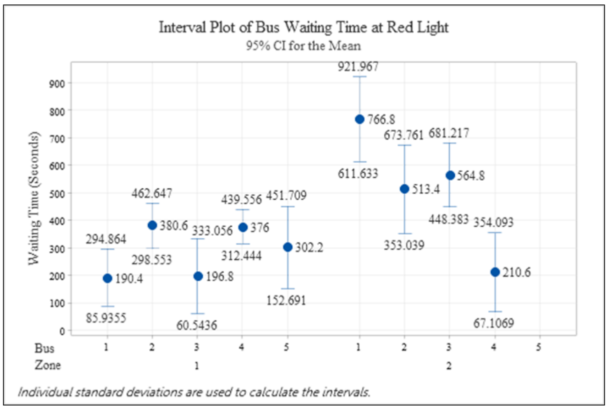


Figure 5. Bus waiting times in afternoon runs

3.2.4 Total number of served students

The total number of served students can be seen in Figure 6, presented as the total of students served per day. It can be observed that the mixed load had more students served than the single load, this appearing only at School 6 (Zone 2, Route 1) and School 4 (Zone 1, Route 4). Nevertheless, the single load plans mostly provide greater service than the mixed load. It is not clear cut that the single load plan would guarantee better service than the mixed load plan. Also, such outputs might be concerned with the uncertainties in the simulation model. However, Park and Kim (2010) concluded that a mixed load plan has advantages in high flexibility and cost savings, whilst a single load plan could require an excessive number of buses.

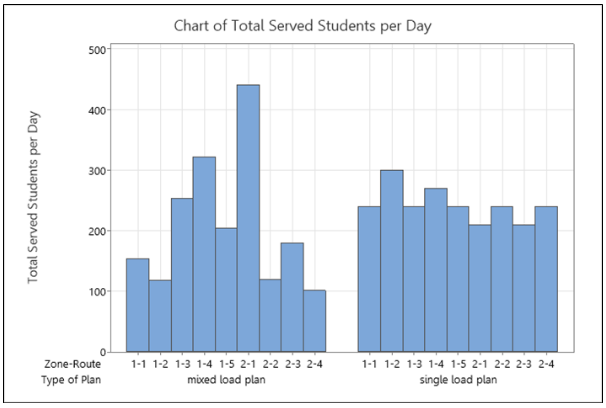


Figure 6. Total number of served students per day

3.2.5 CO_2 Emission assessment

Last of all, the assessment of CO2 emissions was performed to finalize the study and involve the city sustainability issues, which are of concern in a modern transport project. Figures 7 and 8 present the results of the assessment in this project. Figure 7 illustrates the relation map

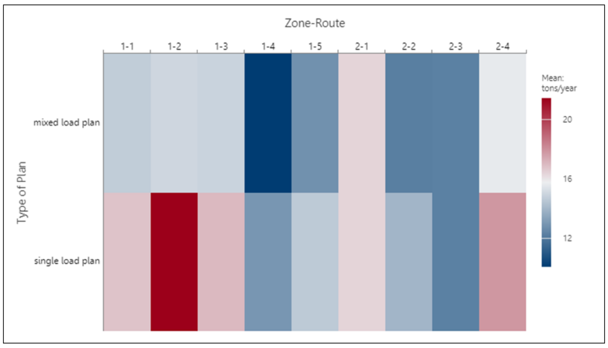


Figure 7. Tons of CO_2 emissions per year

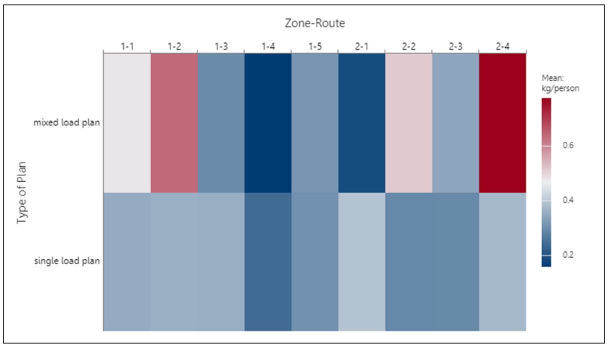


Figure 8. Kilograms of CO_2 emissions per passenger

between "zone-route" and "CO2 Emissions (tons/year)", while Figure 8 similarly presents the relationship between "zone-route" and "CO2 Emissions per Passenger (kg/person)". The shades in each figure are relative to the degree of CO2 Emissions in either "ton/year" or "kg/person". It seems like there is a higher degree of yearly emissions for a "single load plan". However, the emissions per passenger had a milder degree than in the "mixed load plan", due to the larger number of students served.

3.3 Economic feasibility study

In the technical feasibility section, we were unable to make a definite choice between "mixed load plan" and "single load plan", yet we decided to propose the mixed load plan to the school bus project because of its advantages in flexibility and the cost-savings of the project.

An economic feasibility analysis of the "mixed load plan" will be presented in this section. Three scenarios of the business model were considered under the economic feasibility study. The first scenario had passengers pay 16 THB per trip or 32 Baht per day (round trip). This ticket rate was set based on the demand survey. The second scenario had mark-up for profit by 50% from the total service cost, including investment cost and operating cost. And last scenario was providing a public service without charge to those who use the bus service. Results of the economic feasibility are summarized in Table 3.

The feasibility analysis can provide economic insights regarding the project, and in those aspects this project is not so interesting. The outputs shown in Table 3 indicate that the project is infeasible under scenario 1 since all NPV and IRR results are negative, except for the case with electric buses having IRR 1.56, but this is still lower than of MARR.

In contrast, with scenario 2 it was found that NPV of diesel bus and NGV bus are negative while an electric bus had positive NPV, since the service costs of diesel and NGV buses are higher than of electric buses. On considering scenario 2 under IRR criteria, it can be seen that all bus types have IRR lower than MARR (20.75%), which means the project is still not feasible. About scenario 3, which proposed a public service, no economic indicators were calculated. Simply, the total accumulated expenses of servicing school buses for 10 years are reported as 71,754,201 THB, 61,101,888 THB, and 54,518,275 THB for diesel buses, NGV buses, and electric buses, respectively.

Even though the school bus project is not worth the investment, a school bus service could assist parents to reduce their travel expenses. Based on the survey of demand feasibility, transportation to school takes about 58 minutes on average, per student per day. The average distance per student per day is 24.56 kilometres, which translates to fuel consumption of a car worth 12,157 THB per student per year, or for motorcycle 2,820 THB per student per year. Thus, this project could be considered as public service, such as scenario 3, that benefits and impacts many individuals. It can help reduce family expenses, fuel consumption, traffic problems, as well as accident rates. It also promotes health and quality of

Table 3. Economic feasibility study under each scenario

Scenario	Indicator	Fuel Type		
		Diesel	NGV	Electricity
1	Fare	16 THB/Trip	16 THB/Trip	16 THB/Trip
	NPV	-15,796,559 THB	-12,805,939 THB	-7,777,855 THB
	IRR	-6.36	-1.50	1.56
	Payback Period	N/A	N/A	N/A
2	Fare	26 THB/Trip	23 THB/Trip	20 THB/Trip
	NPV	-4,361,278 THB	-1,538,781 THB	3,489,303 THB
	IRR	5.95	8.73	13.51
	Payback Period	9 years 11 months	8 years 3 months	5 years 9 months
3	Fare	0 THB/Trip	0 THB/Trip	0 THB/Trip
	NPV	N/A	N/A	N/A
	IRR	N/A	N/A	N/A
	Payback Period	N/A	N/A	N/A

Note: MARR Rate is 20.75 percentages

life for Hat Yai people as in previous studies. The increased traffic congestion has a negative impact on air pollution, due to vehicle emissions, which can harmful the urban inhabitants' health. There are several studies such as by Levy, Buonocore, and von Stackelberge (2010), Zhang and Batterman (2013), and Requia *et al.* (2018), which evaluated health impacts or assessed health risks due to traffic congestion. Levy, Buonocore, and von Stackelberge (2010) estimated the economic impact of $PM_{2.5}$-related mortality attributable to congestion, and Requia *et al.* (2018) also performed a health risk assessment of $PM_{2.5}$. The results of both studies pointed to a significant impact on human health and the economy, because of $PM_{2.5}$ emissions from traffic congestion. Zhang and Batterman (2013) studied the characteristic of traffic risk for on- and near-road populations, focusing on NO_2 concentrations. The study disclosed health risks from traffic congestion as potentially large. So, public transport such as with school buses can mitigate the health risks. Hence this project remains worth consideration for the stakeholders in Hat Yai City. Consequently, in further study, such stated benefits may be assessed in an economic feasibility study for the sake of ensuring an accurate analysis.

4. Conclusions

This research study was intended to plan, design, and analyze a school bus project in Hat Yai City Municipality to inform related decisions. The project feasibility framework was adopted in the approach, including demand analysis, technical analysis, and economic analysis, which were integrated with simulation modelling to enable the focus on the decision effects. In technical terms, this research problem is comparable to the SBRP. The integration of GIS technology and computer simulation technology facilitated a straightforward feasibility study supporting assessments by the stakeholders. The benefits of a simulation model supplementing basic SBRP include accounting for complexities and stochastic fluctuations in the problem. The forecasts based on simulations were produced for the school bus system performance indicators and applied in the assessment process. Last but not least, not only does this research provide valuable insights for decision-makers regarding the school bus project for safe, effective, and efficient transportation of students, but also the proposed method can be adopted in some other public projects.

Acknowledgements

The authors thank the Southern Regional Center of Geo-Informatics and Space Technology, Prince of Songkla University, for providing instruments.

References

Bowerman, R., Hall, B., & Calamai, P. (1995). A multi-objective optimization approach to urban school routing: Formulation and solution method. *Transportation Research, 29*(*2*), 107-123. doi:10.1016/0965-8564(94)E0006-U

Braca, J., Bramel, J., Posner, B., & Simchi-Levi, D. (1997). A computerized approach to the New York city school bus routing problem. *IIE Transactions, 29*(*8*), 693-702. doi:10.1080/07408179708966379

Carotenuto, P., Serebriany, A., & Storchi, G. (2011). Flexible services for people transportation: A simulation model in a discrete events environment. *Procedia Social and Behavioral Sciences, 20,* 846-855. doi:10.1016/j.sbspro.2011.08.093

El-Gharably, N. E., El-Kilany, K. S., & El-Sayed, A. E. (2013). Optimization using simulation of the vehicle routing problem. *World Academy of Science, Engineering and Technology, International Journal of Industrial and Manufacturing Engineering, 7*, 1588-1593.

Kongyoung, W., Suthummanon, S., Penjamras, P., & Sirivongpaisal, N. (2017). A simulation study of school bus system project in Hatyai City municipality. *Proceedings of SIMMOD 2017 International Conference on Simulation and Modeling, 2017*, 93-101.

Levy, J. I., Buonocore, J. J. & von Stackelberg, K. (2010). Evaluation of the public health impacts of traffic congestion: A health risk assessment. *Environmental Health, 9*(65). doi:10.1186/1476-069X-9-65

Newton, R. M., & Thomas, W. H. (1969). Design of school bus route by computer. *Socio-Economic Planning Sciences, 3*(*1*), 75-85. doi:10.1016/0038-0121(69)90051-2

Newton, R. M., & Thomas, W. H. (1974). Bus routing in a multi-school system. *Computer and Operational Research, 1*(*2*), 213-222. doi:10.1016/0305-0548(74)90047-1

Park, J., & Kim, B. (2010). The school bus routing problem: A review. *European Journal of Operational Research, 202*(*2*), 311-319. doi:10.1016/j.ejor.2009.05.017

Park, J., Tae, H., & Kim, B. (2012). A post-improvement procedure for the mixed load school bus routing problem. *European Journal of Operational Research, 217*(*1*), 204-213. doi:10.1016/j.ejor.2011.08.022

Requia, W. J., Higgins, C. D., Adams, M. D., Mohamed, M., & Koutrakis, P. (2018). The health impacts of weekday traffic: A health risk assessment of PM2. 5 emissions during congested periods. *Environment International, 111*, 164-176. doi:10.1016/j.envint.2017.11.025

Schittekat, P., Sevaux, M., & Sörensen, K. (2006). A mathematical formulation for a school bus routing problem. *Proceedings of the IEEE 2006 International Conference on Service Systems and Service Management, 2006*, 1552-1557. doi:10.1016/j.eswa.2014.03.028

Shah, J. S., & Adhvaryu, B. (2016). Public transport accessibility levels for Ahmedabad, India. *Journal of Public Transportation, 19*(3), 19-35. doi:10.5038/2375-0901.19.3.2

Zhang, K., & Batterman, S. (2013). Air pollution and health risks due to vehicle traffic. *Science of the total Environment, 450*, 307-316. doi:10.1016/j.scitotenv.2013.01.074