Proceedings of the 2022 Winter Simulation Conference
B. Feng, G. Pedrielli, Y. Peng, S. Shashaani, E. Song, C.G. Corlu, L.H. Lee, E.P. Chew, T. Roeder, and P. Lendermann, eds.

CHARGING SCHEDULE PROBLEM OF ELECTRIC BUSES USING DISCRETE EVENT SIMULATION WITH DIFFERENT CHARGING RULES

Chun-Chih Chiu

Industrial Engineering and Management
National Chin-Yi University of Technology
Taichung, 411, TAIWAN

I-Ching Lin
Ching-Fu Chen

Transportation Communication & Management
National Cheng Kung University
Tainan, 701, TAIWAN

ABSTRACT

Urban air quality is a global problem because of emissions from vehicles. Thus, many bus operators are switching to electric buses in order to improve the air quality on their bus network. Electric buses have more complicated scheduling aspects than traditional internal combustion engine buses, including battery recharging. Although most studies use a mathematical model, the model usually considers simplified operating rules in the deterministic environment to achieve a single objective. The long waiting time in a recharging process affects the resting time and satisfaction of drivers. An essential operational concern in the charging schedule problem is how to reduce the waiting time. We propose a hybrid algorithm, which is a simplified swarm optimization with a dynamic rule in a discrete event simulation model for improving the solution quality. The proposed method for improving the waiting time of electric buses is demonstrated through a case study of a bus company.

1 INTRODUCTION

Electric buses (EBs) are replacing traditional internal combustion engine buses (ICEBs) in urban public transportation services owing to their emission-free and low-noise operation (Basma et al. 2020; Zhou et al. 2022). Since EBs have a limited battery capacity, they can only travel approximately 25%–65% of the distance of ICEBs can travel (Ibarra-Rojas et al. 2015); therefore, they must be recharged multiple times daily. Usually, the recharge process occurs between two routes, which is when the drivers typically rest. However, if a charging pile is in use, drivers must wait until it is idle before beginning the charging process. Thus, the challenge of a bus operator is to provide a proper charging schedule to decrease waiting time and increase the satisfaction of drivers. In this study, we addressed a charging schedule problem by minimizing waiting time. In this study, we propose a hybrid algorithm, which is a simplified swarm optimization (SSO) with a dynamic charge rule for improving the solution quality. A comprehensive analysis indicated that the proposed algorithm is highly competitive and performs well in terms of the solution quality of the case study.

2 METHODOLOGIES

Figure 1 depicts the flowchart of the EB charging process. The battery capacity for the next route is calculated while the EB is completing each route. The three dispatching rules are as follows: (1) Full charge (FUC): If the battery of an EB cannot complete the next route, it would be charged to its maximum capacity. (2) Flexible charge (FLC): If the battery of an EB cannot complete the next route, it would be charged to a capacity sufficient for the next route. (3) Dynamic charge (DC): If the battery of an EB cannot complete the next route, it has two charging alternatives. If charging piles are occupied, the battery of the EB would be charged to a sufficient capacity for the next route. Otherwise, it would be charged to its maximum capacity. The DC is an integration of FUC and FLC depending on the state of charging piles. Although DC can be successfully executed, it can still be improved by employing a hybrid approach. Thus, we propose a hybrid algorithm called SSO with DC (SSO_{DC} for short). The newest SSO version can be found in the work by Lai and Tseng (2022). The SSO can be used to explore how many additional battery capacities of each trip should be charged and DC can determine whether EB should charge or not after finishing the trip. Thus, the SSO_{DC} can be employed to further reduce the waiting time.

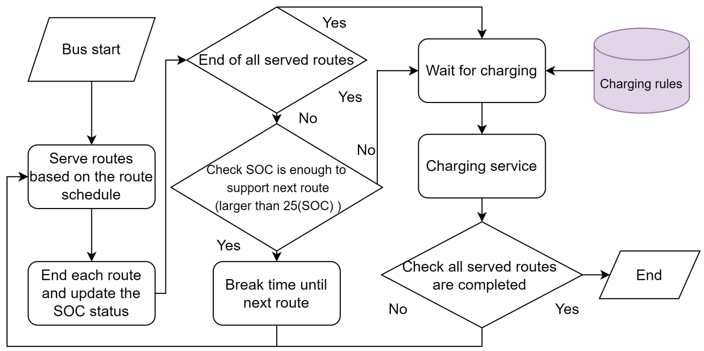

Figure 1: Flowchart of the charging schedule for EBs

3 EXPERIMENTAL RESULTS AND DISCUSSIONS

A case study was used to verify the effectiveness of the proposed method. In this case study, we analyzed a leading bus operator in Taiwan. Table 1 presents the related attributes. Four methods were implemented in the plant simulation software. Table 2 presents the total waiting time and the improved gap between the proposed algorithm and the three dispatching rules. DC was found to reduce the waiting time more significantly than FUC and FLC. Furthermore, the SSO_{DC} can significantly reduce the waiting time when compared to the three charging rules. The proposed approach can be further implemented in reality to support decision-making.

Table 1: The related EB attributes in this case study.

Battery capacity	72 C	Charging efficiency	72 C/15 min	Number of EBs	37
Energy consuming	1.3 km/C	Number of piles	1		
Number of routes	145	Safety state of charge (SOC)	25		

Table 2: Comparison of the three charging rules and SSO_{DC}.

	FUC	FLC	DC	SSO_{DC}
Total waiting time	26,744 s	42,482 s	11,799 s	9,698 s
Improved gap (%) compared with DC	126.66%	277.84 %	-	-
Improved gap (%) compared with SSO_{DC}	175.76%	338 %	21.66%	-

REFERENCES

Basma, H., C. Mansour, M. Haddad, M. Nemer, and P. Stabat. 2022. "Comprehensive Energy Modeling Methodology for Battery Electric Buses". *Energy* 207:1–14.

Ibarra-Rojas, O. J., F. Delgado, R. Giesen, and J. C. Muñoz. 2015. "Planning, Operation, and Control of Bus Transport Systems: A Literature Review". *Transportation Research Part B: Methodological* 77:38–75.

Lai, C.-M., and M.-L. Tseng. 2022. "Designing a Reliable Hierarchical Military Logistic Network Using an Improved Simplified Swarm Optimization". *Computers & Industrial Engineering* 169:108153.

Zhou, Y., Q. Meng, and G. P. Ong. 2022. "Electric Bus Charging Scheduling for a Single Public Transport Route Considering Nonlinear Charging Profile and Battery Degradation Effect". *Transportation Research Part B: Methodological* 159:49–75.