Walking School Bus Planning

Leena Ahmed
l.ahmed4@lancaster.ac.uk
Lancaster University
Lancaster, LA1 4YX, UK

Matthias Ehrgott
m.ehrgott@lancaster.ac.uk
Lancaster University
Lancaster, LA1 4YX, UK

Judith Y.T. Wang
j.y.t.wang@leeds.ac.uk
University of Leeds
Leeds, LS2 9JT, UK

Ahmed Kheiri
a.o.kheiri@gmail.com
University of Manchester
Manchester, M15 6PB, UK

Abstract

Walking School Bus (WSB) promotes Active School Travelling (AST) while reducing congestion and pollution around schools caused by parental chauffeuring. We introduce a framework to generate WSB walking networks from public data and perform multi-objective routing optimisation to support efficient route planning. Our approach ensures optimal routes that balance multiple criteria and meet the needs of both parents and children.

CCS Concepts

• **Computing methodologies → Planning and scheduling**; **Discrete space search**.

Keywords

Walking School Bus, Routing, Multi-objective Optimisation

ACM Reference Format:

Leena Ahmed, Matthias Ehrgott, Judith Y.T. Wang, and Ahmed Kheiri. 2025. Walking School Bus Planning. In *Genetic and Evolutionary Computation Conference (GECCO '25 Companion), July 14–18, 2025, Malaga, Spain.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3712255.3734269

1 Introduction

Despite extensive efforts in promoting walking as an active mode of transport for school trips, being driven to school remains a main mode of transport for school children in many countries around the world, including the United Kingdom and the US [2, 4]. The trend of walking to school being replaced by parents chauffeuring their children has created a vicious circle [3]. Walking School Bus (WSB) has been identified as a policy instrument to combat this vicious circle in an effective manner and even reverse the vicious circle to a virtuous one. The idea is that if parents switch from chauffeuring their children to school to joining a WSB, there will be less congestion around schools; creating a more walkable environment with less pollution from traffic where children can enjoy walking to school under the supervision of volunteers or hired WSB drivers; and naturally encourage more parents to switch their children to this enjoyable and healthy choice. One vital factor for the success of any WSB scheme is the planning of its coverage and routing such that parents will have convenient access to the WSBs and children are safe and enjoy their experience. There are only a handful of studies conducted on WSB routing problem, including studies in Canada [1], Italy [6] and Japan [5]. In terms of the optimisation objective, minimising the travel time for the journey time of door-to-school (with their home as the trip origin) has been the main focus. As safety is a very important factor, Tanaka et al. [5]'s study in Japan is the first that has looked at safety as a second objective, based on the assumption that children walking together is safer. More recently, Wang et al. [7] is the first study considering multiple objectives, including time, air pollution and walkability as their three objectives. Wang et al. [7] is also the first study that looked at WSB routing design *stop-to-stop* with the school as the common final destination of all WSB routes. That is, the parents can bring their children to the nearest WSB stop to their home, where their children will be joining the bus. This design of WSB with 'stop points' will enable extremely convenient drop-off for parents (one to two minute walk), bigger WSB service area and shorter total walking time for all children.

All these studies on WSB routing problem are conducted for a specific area in a city or a school. All the models have been developed based on specific data availability for each case. For instance, Wang et al. [7]'s model has very specific assessment of their walkability objective based on field work. In other words, these models have contributed to the science but their tools are not easily transferable. The aim of the present study is to cover some gaps in the previous WSB studies by designing a generalised multi-objective routing optimisation model, and testing it on walking networks and datasets from open-sources.

2 WSB Multi-objective Route Optimisation

2.1 Modelling concepts

A route set represents a set of connected routes that allows walking school buses to travel between any two points in the network. The WSB route optimisation problem is inherently complex due to the vast number of possible routes, the number of constraints on resources, and the number of conflicting objectives. These objectives include minimising pollutant dose, providing the best level of service to users of the system, and simultaneously respecting requirements of supervisors and volunteers. Automating route generation and route improvement on a computer is a challenging task as it must consider the road network's geography and the practicalities of travel – making up routes completely "at random" will not work, instead, routes must be structurally coherent while ensuring compliance with constraints such as coverage, connectivity, and supervisor allocation. The complexity further increases when incorporating bus stops into the model, where the number of nodes increases in the order of magnitude. The problem can be formulated using a graph, $G = (V, E, W)$, where V (the vertices / nodes in the graph) represents locations, E (the edges) represents connections between them, and W (the weights) represents the weight or cost needed to traverse the edge. Notably, W can be represented as a 3D

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
GECCO '25 Companion, Malaga, Spain
© 2025 Copyright held by the owner/author(s).
ACM ISBN 979-8-4007-1464-1/2025/07
https://doi.org/10.1145/3712255.3734269

list to account for time-dependent factors, such as different travel times across the week (for example, the travel time on Monday is different from that on Friday). In this context, a route is defined as a simple path in the graph, and a route network is a connected set of routes. A route network is considered feasible if it meets all the problem constraints, such as including all nodes, being connected, and containing a number of supervisors set by decision makers. The problem tackles several conflicting objectives, including time for traversing all the routes, walkability, and pollutant dose. Achieving a balanced solution that optimises these objectives poses a significant challenge.

The WSB route optimisation problem involves conflicting goals that inversely impact each other. Utilising a single-objective method makes it difficult to effectively trade-off each goal and find a solution that provides quality and compromise. In contrast, the multi-objective modelling framework treats each objective separately, meaning trade-offs are more natural and, with the right methods, can be done effectively. Our proposed solutions produce efficient routes, yet workable and fair schedules. In the context of WSB route optimisation, this is a valuable achievement as different stakeholders, such as school managers, supervisors, and parents, have differing opinions on what makes a good solution. Our model stands out by managing scarce resources while simultaneously respecting safety and managing the level of emissions exposed. Some of these factors have been considered individually in existing approaches, but their joint impact has not been thoroughly explored.

2.2 Open data-source for walking network

We developed a multi-objective routing optimisation model for a stop-to-stop Walking School Bus (WSB), considering three key criteria: travel time (as a proxy for distance), walkability, and pollution dose. This work builds upon the study by [7], which explored the stop-to-stop WSB for Shipley C.E. School in Bradford, UK. However, their approach relied on manually selecting WSB stops along the routes, applying a multi-objective shortest path algorithm between each pair of stops. In contrast, our model is the first fully automated optimisation model for stop-to-stop WSB routing, integrating open-source data to derive the necessary datasets. Our primary dataset source is OpenStreetMap (OSM), which provides detailed and regularly updated pedestrian infrastructure data, including sidewalks, crossings, road types, and safety features. To extract the walking network for a given catchment area, we developed a software tool that processes OSM data within a defined radius. Travel time is estimated based on edge lengths from OSM, assuming a constant walking speed, following the approach in [7]. Walkability is scored based on factors such as road type, pedestrian infrastructure, and traffic conditions. Pollution dose is estimated using publicly available APIs that provide hourly pollution concentration forecasts, though additional processing steps were required to overcome the low resolution of these datasets.

2.3 Route optimisation formulation

In this study, we propose a solution model based on a multi-objective optimisation to generate walking routes based on user-defined inputs such as the number of routes, number of WSB stops, and maximum walking distance per route. The model optimises three objectives: travel time, walkability, and pollution dose. The quality of solutions is evaluated using a weighted sum of individual objectives: $\sum_{\substack{i,j \in \mathcal{N}, i \neq j \\ k \in K}} x_{ijr_k} \left\{ \alpha d_{ij} + \beta w_{ij} + \gamma p_{ij} \right\}$, where K is the set of routes, N is the set of WSB stops, and α, β, γ are the objective weights. The decision variable x_{ijr_k} equals 1 if edge (i, j) belongs to route r_k, and 0 otherwise. The model dynamically adjusts route selection based on the chosen weights, allowing prioritisation of a single objective or balancing trade-offs among them. The output is a set of routes that adhere to constraints such as maximum walking distance, required WSB stops, and a school endpoint. This approach represents a major improvement over existing WSB planning tools, as it fully automates the route design process while allowing user-defined input and preferences.

3 WSB Optimisation Suite

The route optimisation model is only one component of a broader WSB planning system. The WSB service has the potential to greatly benefit schools, children, and communities, however, its adoption has been hindered by logistical challenges. We believe that optimisation can play a crucial role in addressing these barriers. Our model is generic and adaptable, making it applicable to any school and catchment area scenario. This flexibility enables schools and planners to easily identify safe and healthy walking routes. Additionally, the walkability model can be refined further by incorporating future data on parental and child preferences regarding safety and enjoyment, allowing for a more tailored approach to route planning. Beyond routing, the scarcity of personnel for operating WSBs presents another major challenge. Future optimisation models could address this issue by focusing on rostering and scheduling of both paid and volunteer supervisors. We are developing a prototype that will integrate our optimisation suite to provide real-time route updates and improve overall service efficiency. We aim to deliver a holistic and intelligent WSB system by linking a mobile front-end with a robust optimisation back-end, ultimately making walking to school a safer, healthier, and more sustainable choice.

Acknowledgments

This work was supported by EPSRC grant EP/W010232/1.

References

[1] Negin Bolkhanian and Matthew Reyers. 2019. The walking school bus routing problem. *Analytics Now* (2019), 66–91.
[2] Peter A Hastie. 2007. Physical activity opportunities before and after school. *Journal of Physical Education, Recreation & Dance* 78, 6 (2007), 20–23.
[3] Alexander Hayes, Judith YT Wang, and Alexandros Nikitas. 2022. Spatial multi-criteria decision analysis for Walking School Bus target development strategies. *Journal of Transport & Health* 26 (2022), 101481.
[4] Noreen C McDonald and Annette E Aalborg. 2009. Why parents drive children to school: implications for safe routes to school programs. *Journal of the American planning association* 75, 3 (2009), 331–342.
[5] Ken-ichi Tanaka, Ryuhei Miyashiro, and Yuichiro Miyamoto. 2016. A Bi-objective optimization model for designing safe walking routes for school children. *Geographical Analysis* 48, 4 (2016), 448–464.
[6] Emanuele Tresoldi, Federico Malucelli, and Maddalena Nonato. 2021. A personalized walking bus service requiring optimized route decisions: A real case. *European Journal of Operational Research* 289, 3 (2021), 855–866.
[7] Judith YT Wang, Zhengyu Wu, Yating Kang, Edward Brown, Mengfan Wen, Christopher Rushton, and Matthias Ehrgott. 2023. Walking school bus line routing for efficiency, health and walkability: A multi-objective optimisation approach. *Journal of Multi-Criteria Decision Analysis* 30, 3-4 (2023), 109–131.