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Implementing visum technology within the framework of school transportation planning: A case study in Klaten Regency, Indonesia

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Abstract

The lack of adequate and reliable school transportation services in Indonesia poses significant challenges, particularly in regions with diminishing public transport options. This study investigates the application of advanced transportation modelling tools, specifically PTV Visum, in addressing the mobility and safety concerns of school students. Using Klaten Regency as a case study, the research integrates origin-destination surveys and secondary data to model transportation demand and optimize routes for school transport systems. The findings recommend two optimized school transport routes and the deployment of Isuzu mid-sized buses, each with a capacity of 45 passengers. The study provides operational schedules tailored to student mobility patterns, highlighting the potential of Visum technology to create efficient, safe, and sustainable school transportation systems. This work demonstrates the broader applicability of data-driven planning to improve student mobility across urban and rural contexts in Indonesia.

Keywords

PTV Visum, School transportation, Sustainable mobility, Traffic safety, Urban planning

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Introduction

In 2023, the number of middle and high school students in Klaten Regency reached 75,337, indicating a substantial demand for school transportation services [1]. However, public transportation infrastructure in this region is insufficient, with only two school buses provided by the local government in 2020 clearly inadequate for the growing student population. What exacerbates this problem is the inadequate public transportation options, which are increasingly declining, with vehicles already exceeding their age limit, causing students to rely on private vehicles or unsafe alternatives [2].

This dependency not only increases traffic congestion but also elevates the risk of road accidents. Between 2017 and 2021, Klaten reported 8,995 traffic accident victims, with approximately 19.26% being students. These alarming figures underscore the urgent need for a safer and more efficient school transportation system. Safe and efficient transportation for students is very important to support their mobility [3].

Given the constraints, this study explores the integration of PTV Visum technology, a macroscopic traffic simulation and assignment tool, into school transportation planning [4]. By leveraging this technology, the research aims to optimize routes, vehicle selection, and operational management for school buses, adhering to safety standards and regulatory frameworks outlined in the Ministry of Transportation's regulations.

Method

The research focuses on three zones in Klaten Regency: Central Klaten (Zone 1), North Klaten (Zone 2), and South Klaten (Zone 3). Five schools were selected as samples: SMKN 3 Klaten, SMKN 1 Klaten, SMAN 1 Klaten, SMPN 3 Klaten, and SMPN 6 Klaten. Each of the location is mentioned on the Figure 1 and Table 1.

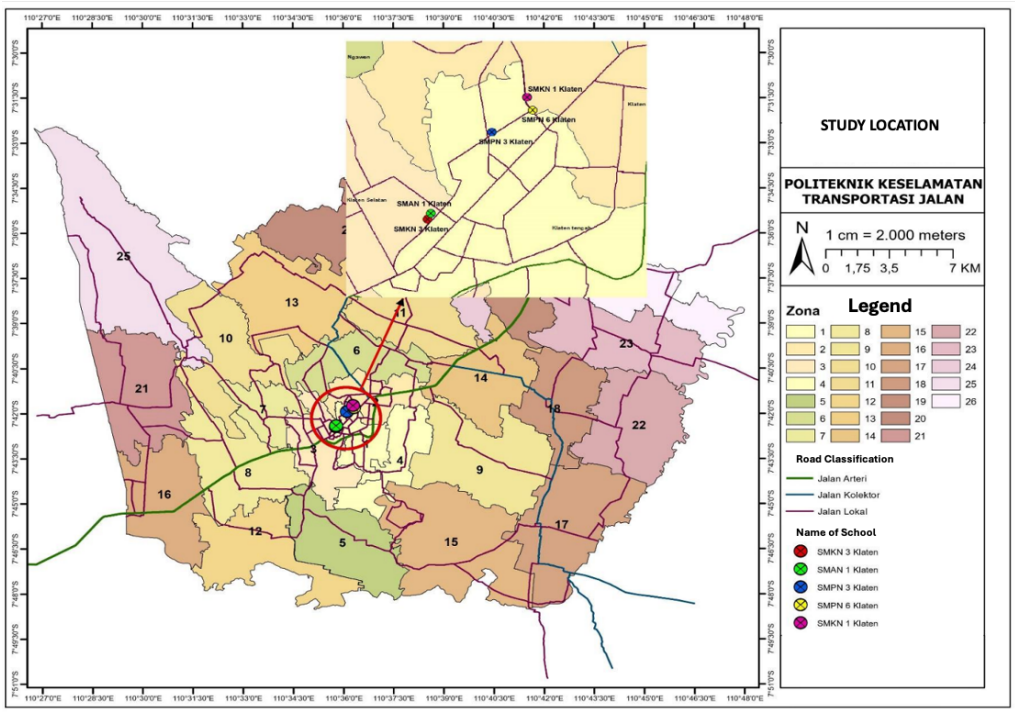

Figure 1. Study Location of the School Samples

Data sources include to the primary data that recorded the origin-destination (OD) surveys and willingness-to-switch data among students. In another hand, the secondary data collected form the road network maps, administrative boundaries, and school profiles. Sampling technique of this study use a simple random sampling method was applied using Slovin's formula with a 5% margin of error. This resulted in 373 respondents distributed across the five schools.

Table 1. The Number of Samples Each of School

No.	School Name	Zone	Number of Students	Proportion (%)	Samples	Expansion
1	SMKN 3 Klaten	2	1235	22,17	83	14,88
2	SMAN 1 Klaten	2	1082	19,43	73	14,82
3	SMPN 3 Klaten	1	766	13,75	51	15,02
4	SMPN 6 Klaten	3	794	14,25	53	14,98
5	SMKN 1 Klaten	3	1693	30,39	113	14,98
	JUMLAH		5570	100	373	

The analytical framework of this study employs a Four-Step Model: The first is trip generation, which estimates the volume of trips from student origins to destinations. The second is trip distribution, which allocates trips across the transportation network. Thirdly, mode choice determines the transportation modes students prefer. Lastly, trip assignment assigns trips to specific routes within the network.

The method that use to analyse the data are stated below, potential demand analysis, route determination analysis, vehicle type determination analysis, bus stop location and quantity analysis and operational management analysis. The potential demand analysis aims to determine the number of students willing to shift from private transportation to school transport services. This demand is represented in the form of Origin-Destination (OD) Matrices, which provide a detailed depiction of student travel flows between origins and destinations [5]. The determination of school transport routes employs the Plotting Demand technique using the PTV Visum software. This method identifies travel assignments by prioritizing road segments with the highest potential demand, ensuring that the route network aligns with demand hotspots and maximizes operational efficiency. The selection of vehicles for school transport in this study ensures compatibility with passenger capacities and regulatory compliance. Vehicle specifications adhere to the Regulation of the Directorate General of Land Transportation Number SK.967/AJ.202/DJRD/2007, which defines the standards for capacity and safety in student transportation [6]. The determination of bus stop locations and quantities is based on travel distances and land-use characteristics. This analysis complies with the Directive of the Directorate General of Land Transportation Number 271/HK.105/DRJD/1996, ensuring that stops are optimally placed to enhance accessibility and support operational efficiency [7]. Operational management calculations are conducted in accordance with the Directive of the Directorate General of Land Transportation Number SK.687/AJ.206/DRJD/2002. The analysis encompasses critical operational parameters, including: Vehicle operating hours, Planned operational speeds, Vehicle travel times, Load factor assessment, Vehicle circulation time, Headway intervals, Fleet requirements, Vehicle frequency, and Scheduling [8].

These parameters collectively ensure a structured and efficient operational framework for school transport systems. The comprehensive framework integrates demand estimation, route planning, vehicle selection, bus stop placement, and operational

management to develop a sustainable and effective school transportation system. The methodology can serve as a valuable reference for transportation planners and policymakers in urban school mobility planning.

Results and Discussion

Demand analysis

The percentage of students willing to switch to school transportation services is 94.1%, equivalent to 351 students who expressed their willingness. The results of the origin-destination survey are presented in the form of a Sample Origin-Destination (OD) Matrix of Potential Demand. This sample matrix was then converted into a population matrix by multiplying the student origin-destination sample by the expansion factor for each school. The result is a Population Origin-Destination (OD) Matrix of Potential Demand, as shown in Table 2.

Tabel 2. Origin-destination matrix of potential demand population

	Zona 1	Zona 2		Zona 3		TJ
	SMPN 3	SMPN 6	SMKN 1	SMKN 3	SMAN 1	
1	226	70	268	182	153	900
2	170	169	169	98	70	676
3	99	141	113	210	167	730
4	57	99	197	112	98	562
5	14	42	56	70	56	239
6	57	99	226	70	70	520
7	28	42	14	28	28	141
8	14	14	14	70	56	168
9	14	14	155	0	56	239
10	14	28	99	98	84	323
13	14	14	197	154	126	505
14	14	14	85	70	56	239
AJ	721	747	1593	1162	1018	5241

School transportation route determination analysis

The route determination used the demand plotting technique from the Population Origin-Destination (OD) Matrix of Potential Student Demand, utilizing the PTV Visum software. Two proposed school transport routes were identified based on the analysis using Visum 2021 software. Route 1 has a potential demand of 407 students and follows the trajectory of Jl. Banjarejo-Beteng – Jl. Merbabu, with a total length of 9.5 km. Meanwhile, Route 2 serves a potential demand of 353 students along the trajectory of Jl. Raya Ngemplak – Jl. Andalas, spanning a total length of 8.5 km.

The selection of vehicle types for these routes considered road classifications and the total potential demand of 760 students across both routes. The most appropriate and efficient vehicle for school transportation is a medium-sized bus, specifically the Isuzu NQR 71 EC E2-1 Variant 6, with a capacity of 45 passengers (25 seated and 20 standing).

The determination of bus stop numbers and locations was based on the Decree of the Directorate General of Land Transportation No: 271/HK.105/DRJD/1996, while also

accounting for Land Use Characteristics (LUC) of the road segments along the proposed routes. Each route requires nine bus stops, as detailed in Table 3 and Table 4.

Table 3. The Number and Locations of Bus Stops on Route 1

Route Street Name	Number of Stops	Stop Location
Banjarejo-Beteng	2	SMPN 2 Jatinom, Gilangmart
Sangkal Putung	2	Simpang Pasar Ngupit & Nasi Padang KawanLamo
Ki Ageng Panjawi	1	Simpang TuguPandawa
Dr Wahidin Sudiro	1	Hutan Kota Sungkur
Andalas	1	SMPN 3 Klaten
Bali	0	-
Pemuda	1	Alun-alun KotaKlaten
Merapi	0	-
Merbabu	1	SMAN 1 Klaten

Table 4. The Number and Locations of Bus Stops on Route 2

Route Street Name	Number of Stops	Stop Location
Ngemplak	1	Kantor Kades Ngemplak
Ngindrokilo	1	SDN 1 Jomboran
Kendalisodo	2	SMPN 5 Klaten & Simpang Sragu
Borobudur	0	-
KH Samanhudi	1	Minimarket Samanhudi
Pramuka	1	BRI
Pemuda	0	-
Merapi	0	-
Merbabu	1	SMAN 1 Klaten
Andalas	2	SMPN 3 Klaten & Hutan Kota Sungkar

Operational management analysis

The results of the operational management analysis, based on the Decree of the Directorate General of Land Transportation No: SK.687/AJ.206/DRJD/2002, are as follows:

The school transport will operate on school days, from Monday to Saturday, with an operational time of 75 minutes per shift. The operation is divided into two shifts: they are shift I (morning): from 05:45 to 07:00 WIB, Shift II (afternoon): from 13:30 to 14:00 WIB, and Shift III (evening): from 14:30 to 15:15 WIB.

1. The minimum speed for the school transport is 20 km/h, and the maximum speed is 40 km/h. Therefore, the planned operating speed for school transport in Klaten Regency is 30 km/h.
2. The expected load factor for the operational plan is 100% of the vehicle capacity.
3. The travel time for Route 1 is 18.97 minutes, while for Route 2, it is 17.15 minutes.
4. The vehicle circulation time is 43.63 minutes for Route 1 and 39.45 minutes for Route 2.
5. The vehicle headway is 6 minutes and 38 seconds for Route 1 and 7 minutes and 39 seconds for Route 2.
6. The required number of vehicles is 7 for Route 1 and 6 for Route 2. The vehicle frequency is 9 for Route 1 and 8 for Route 2.

7. The scheduling is divided into 3 shifts for each route: Shift I (morning), Shift II (afternoon), and Shift III (evening).

Conclusion

The potential demand for school transportation in Klaten Regency reaches 94.1% of the total student population in the schools surveyed. Based on this data, an analysis was conducted using PTV Visum, which included road network development, creation of a trip matrix, adjustment of demand data, and transportation requirements calculation. The analysis results identified two optimal school transport routes. The first route serves 407 students, following the path from Jl. Banjarejo-Beteng to Jl. Merbabu, with a route length of 9.5 km. The second route serves 353 students, following the path from Jl. Raya Ngemplak to Jl. Andalas, with a length of 8.5 km.

The chosen transport vehicle for both routes is a medium-sized bus, the Isuzu NQR 71 EC E2-1 Variant 6, which has a capacity of 45 passengers (25 seated and 20 standing). The selection of this bus type takes into account the road classification and the potential demand for each route. The school transport will operate Monday through Saturday in three shifts: Shift I (morning) from 05:45 to 07:00 WIB, Shift II (afternoon) from 13:30 to 14:00 WIB, and Shift III (evening) from 14:30 to 15:15 WIB, with an operational duration of 75 minutes per shift. Future research could explore integrating real-time data and expanding the model to encompass multimodal transport options for broader applicability.

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