Campus solar roads: Stochastic modeling of passenger demand

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1.Introduction

In the era of rapid technological advancements, innovations have started to reshape the field of transportation and energy management. University Campuses are considered as the ideal venue for implementing and testing innovative transportation services, as they usually encompass a closed form small-scale transportation infrastructure, and mainly involve users highly receptive to emerging technologies, due to their academic background.
Nevertheless, the assessment of such services is a complex task, which should take into consideration issues related to energy sufficiency, passengers' demand estimation and routing specifications.
The present paper addresses the problem of stochastic passenger demand estimation under the uncertainties introduced by the implementation of a novel university bus service operated by solar vehicles under the concept of "opportunity charging" and solar powered buses. Aspects such as the relationship between the passengers' need to move around the campus and parameters, such as time schedules, are adressed. The passenger demand series generated by the models are linked to bus dwell times, which in turn determine the available charging time at each bus stop.

AIM?

→Which statistical distribution best describes the arrival of the students at the bus stops?
→ What percentage of the students will probably use the solar buses?
→ How many students will each bus stop approximately serve each day?
→ When do the peak hours for each bus stop appear?

2. Methodology

Number of undergraduate students

+

Timetables of each school

+

Students already using transportation in order to move around the campus

+

Statistical distribution best describing the passengers' arrival at the bus stops

➡

Poisson distribution for the passengers' arrival at every bus stop and diagrams describing the results

3. Timetables

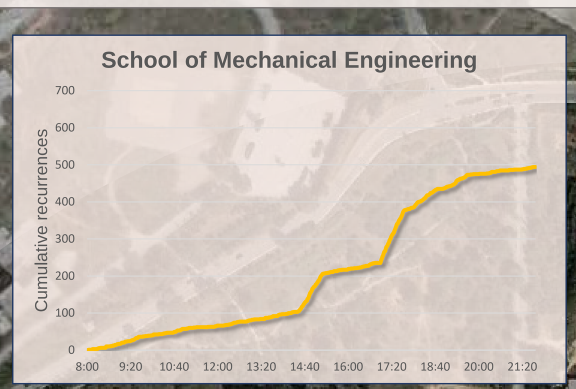
At the timetable below is presented the total number of university's students that reach and leave the campus at each hour of the day.

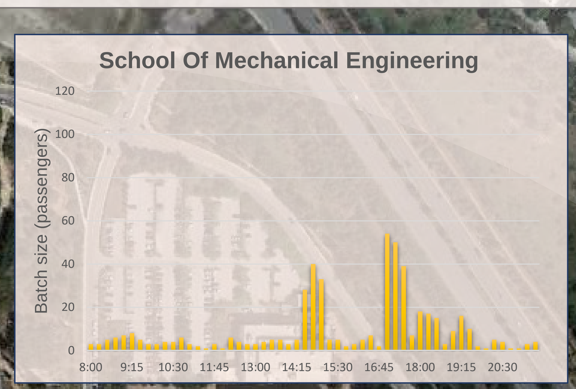
	Monday	Tuesday	Wednesday	Thursday	Friday
08:00-08:15	0	0	0	0	0
08:15-08:30	0	0	0	0	0
08:30-08:45	7533	6459	6695	7161	8200
08:45-09:00	2836	1874	1875	1750	2562
09:00-09:15	0	0	0	0	0
09:15-09:30	0	0	0	0	0
09:30-09:45	3253	2336	3331	2889	2515
09:45-10:00	0	125	125	0	0
10:00-10:15	0	0	0	0	0
10:15-10:30	0	0	0	0	0
10:30-10:45	2203	3016	2504	2708	1665
10:45-11:00	250	750	725	937	187
11:00-11:15	0	0	0	0	0
11:15-11:30	0	0	0	0	0
11:30-11:45	0	729	252	398	185
11:45-12:00	0	0	38	0	460
12:00-12:15	0	0	0	123	0
12:15-12:30	0	0	0	371	0
12:30-12:45	287	1537	1201	544	1102
12:45-13:00	990	284	697	515	978
13:00-13:15	0	0	0	0	0
13:15-13:30	0	0	0	0	0
13:30-13:45	124	0	0	0	0
13:45-14:00	1280	261	480	760	1063
14:00-14:15	0	0	0	0	0
14:15-14:30	0	0	0	0	0
14:30-14:45	373	1280	1741	428	752
14:45-15:00	2078	4985	3811	3042	3647
15:00-15:15	0	0	0	213	0
15:15-15:30	200	0	0	0	0
15:30-15:45	0	426	0	0	0
15:45-16:00	1649	519	837	870	123
16:00-16:15	0	249	213	0	0
16:15-16:30	780	317	371	192	192
16:30-16:45	704	0	0	853	1343
16:45-17:00	357	668	134	223	468
17:00-17:15	1768	1720	1174	2479	889
17:15-17:30	1307	1600	2216	2152	1400
17:30-17:45	0	0	0	125	0
17:45-18:00	200	192	399	667	268
18:00-18:15	806	680	597	1023	619
18:15-18:30	500	1820	1086	571	771
18:30-18:45	0	125	213	0	739
18.45-19.00	399	134	0	134	319
19.00-19.15	441	676	1107	462	426
19.15-19.30	500	250	450	1271	125
19.30-19.45	0	214	0	0	192
19.45-20.00	0	0	0	0	399
20.00-20.15	640	0	0	213	213
20.15-20.30	200	0	0	0	0
20.30-20.45	0	0	0	0	0
20.45-21.00	0	0	0	0	0
21.00-21.15	1066	0	214	0	0
21:15-21:30	0	0	0	0	0
21:30-21:45	0	0	0	0	0

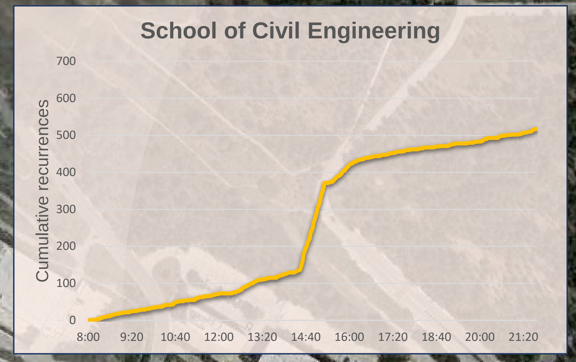
It is assumed that every registered student attends all the classes regarding his academic year.

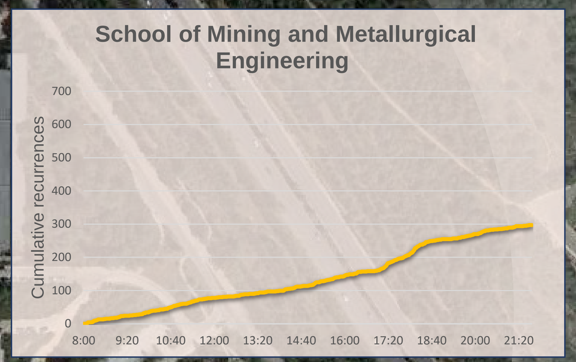
After conducting measurements for a month (February-March) it is evidenced that approximately the 12.6% of the students uses transportation for moving around the campus. As a result, it is reasonable to conjecture that the same students will constitute the future passengers of the new solar buses.

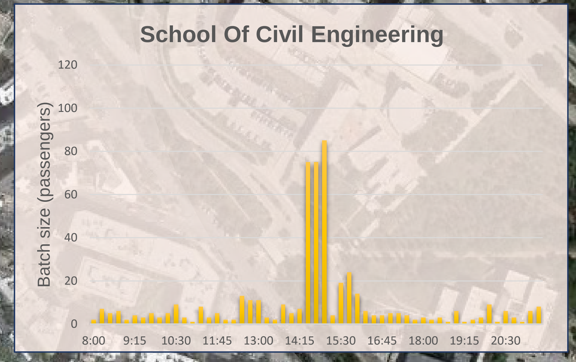
4. Process and Results

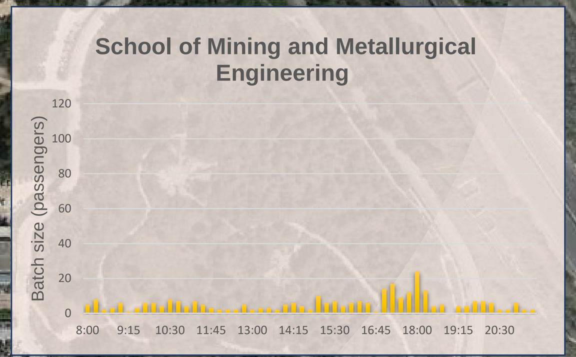


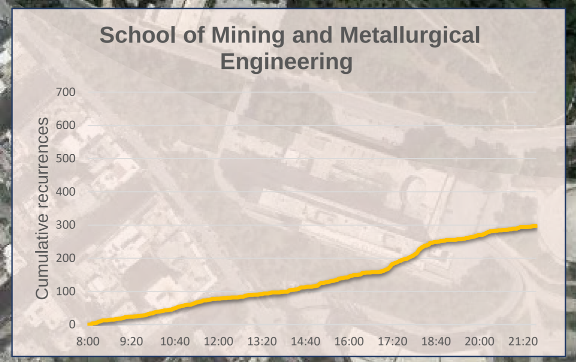


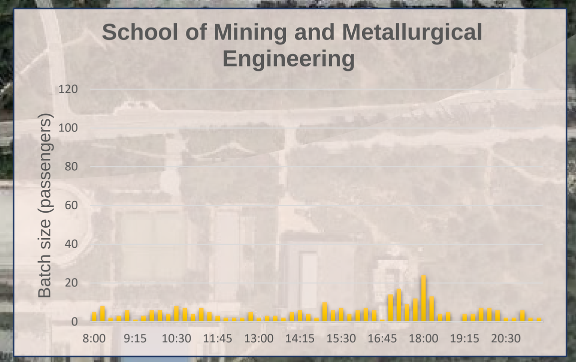


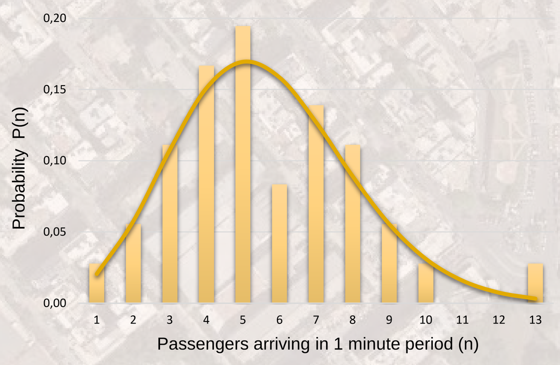












Although most existing studies assume that the most widely accepted passenger arrival model is the Poisson process, a survey has been performed to determine if this assumption holds in the particular circumstances.

The survey was conducted at the Zografou gate of the NTUA campus, where student arrivals have been counted in time intervals of 1' during the period of peak traffic. Following the data collection, a statistical analysis was performed where expected frequencies obtained by the Poisson distribution were compared to the observed frequencies. The existing discrepancies between observed and expected frequencies were measured by the application of the Chi-squared test.

The results are presented at the displayed diagram.

The passenger arrival process is the Poisson Process which can be defined as follows:

Assuming n_T is a sequence of independent and identically distributed random variables with constant parameter $\lambda > 0$, which define the number of passengers arrive in fixed intervals of time T=1', then $N_{sum} = \sum_{T=1} n_i$. N_{sum} is the total number of students in each school that are expected to arrive in transit stops, while λ varies according to the passengers expected each time period of 15'. The peak traffic time was considered and observed to occur 30' before and 15' after the start of the classes. Therefore, for each interval of 1' a random number is generated $u(0,1)$ which defines the probability of the number of passengers arrive according to the distribution. On that account the process is stochastic.

The figures above demonstrate the cumulative recurrences of passengers' arrival and adjusted batch arrivals throughout the day.

5.Conclusion

CONCLUSION

The bus stop that serves the highest number of passengers in the evening is the one close to "Electrical and Computer Engineering" School.

The bus stop that serves the highest number of passengers in the morning is the one close to the "Kokkinopoulou" gate.

The results given by the above method (based on timetables) are reasonable and may be used to plan the route and time schedule of the solar buses.

Due to the frequent bus transit, the arrival of the students at the bus stops is considered random and appears to follow the Poisson distribution.

The peak hours of each day can be easily identified through the diagrams.

6.References

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The present work is part of a larger project based on solar roads and conducted in collaboration with [3], [4].

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