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The Effect of Overcrowding in the US School System, A Simulation Approach

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Abstract

Education leaders face extraordinary challenges as the nation's schools struggle to rise to the challenge of the No Child Left behind Act of 2001. Education leaders are now expected to be instructional leaders, show a strong commitment to closing the achievement gap between majority and minority students, and use data to improve teaching and learning. This study applies a simulation to analyze overcrowding (congestion) in a school system. This work aims to analyze the overcrowding and to describe a decision support system that needs to be developed to help in assessing the need for classrooms in different schools and to develop a systematic approach to improve such overcrowding.

Keywords: *overcrowding, schools, simulation, congestion*

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Introduction

Over the last thirty years, growing public support for giving parents increased autonomy in deciding what kinds of schools their children will attend is indicated by the increase in curricular choices in schools (D. Ready, V. Lee, Kevin G. Welner, 2004). An examination of school choice research literature shows that discussions of the trade-offs between excellence and fairness control debates about school choice. Many studies document increased demand in school systems where parental independence over school selection has increased (D. Ready, V. Lee, Kevin G. Welner, 2004).

There is great evidence in the school choice research literature that unless admission and transportation policies give all students an equal chance to participate in choice programs, choice schools are likely to “skim” the most motivated, wealthy, and able students from existing neighborhood schools. By 2015, 75% of all students will be served by neighborhood schools while 25% of them will be attending choice schools. School choice has been considered as a popular idea (D. Ready, V. Lee, Kevin G. Welner, 2004).

Our model aim to analyze the overcrowding in the school system. The approach that we are seeking is to assess and identify the percentage of students of the total population at each school that will be turned away because of overcrowding, and estimate the required number of seats at each level. Since the school system is not static; new students are constantly arriving and the need level changes over time

School size and school overcrowding are two different terms. School overcrowding is measured in terms of the number of students enrolled compared to the number of students the facilities were designed to serve. A shift in focus was driven by this difference away from such matters as bureaucratic or public organization or constrained curriculum toward a concern about basic resources. School overcrowding is concerned with justice in that limited educational opportunities are implied by inadequate facilities.

School Overcrowding

Schools, districts, and states vary widely in how they characterize and measure overcrowding, making large-scale investigations difficult. A school or district is generally asked by national survey personnel limited and subjective questions such as, "Is this school overcrowded?" (NCES, 2000). Such a question might be answered differently by respondents at otherwise identical schools. Some school districts define school capacity in district-wide terms, rather than at the individual school level, this presents a challenge: districts with both under enrolled and overcrowded schools may indicate that their schools are not overcrowded overall (Muraskin & Stullich, 1998).

The relationship between school overcrowding and student or teacher outcomes has not been well quantified. Although the relationship between various social and academic outcomes for students and school size was explored by several empirical studies, size is not necessarily related to overcrowding. For example, sometimes very small schools can be above capacity while schools with large enrollments may be below capacity.

Overcrowding Transfer Model

A few basic concepts and definitions used by school districts need to be explored in order to engage in a meaningful discussion of overcrowding.

When a school's enrollment is equal to or exceeds 80% of the school's permanent capacity it is considered to be overcrowded. This definition has been used consistently by schools districts for almost thirty years with few modifications although some have argued that it may be arbitrary. As such, it is possible to make valid comparisons from year to year and from school to school.

The number of students waiting to enter each type of school in the system and the associated waiting time at the steady state are the two performance indicators. Figure 1 illustrates some of the possible transfers and flows of the students in the school system.

The small arrows pointing outside represent the return to society because of completion of the identified stage or a decision to return to a home-based school. The dotted lines represent the students transferred from one school type to another (i.e., public to private and vice versa). The solid arrowhead lines represent the movement between different types of schools.

For example a student may follow the path, society $\rightarrow$ ELM $\rightarrow$ Middle $\rightarrow$ High $\rightarrow$ society $\rightarrow$

This path means that the student was at home and placed in a public elementary school first, and then the student spent some time in the elementary school before the student transferred to the middle school. After finishing the middle school, the student transferred to the high school and then back to the society. If no place for the student in the assigned school is available, the student is waiting

to be transferred to another school. We call such a student a waiting student. It may happen that the student transferred from public to private school instead of going to a public school because the student does not like or want to attend a school far from the student's residence.

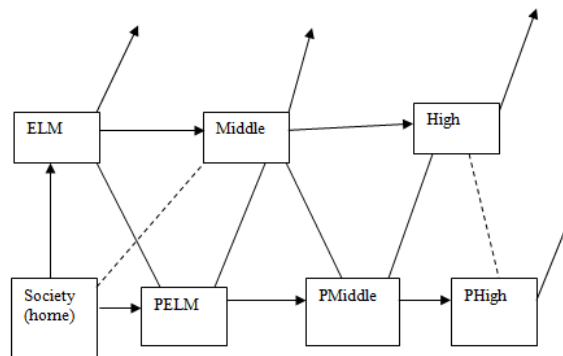


Figure 1. School systems in the United States of America (ELM: public elementary school, middle public, and high public school. PELM: private elementary, PMiddle: private middle, and PHigh: private High school)

Data Collection

The given data consists of Enrollment of students in Elementary, Middle and High Schools in Volusia County state of Florida US. The students who enrolled in each type of schools may come from various schools or institutions and also they may move from these three types of schools to any other schools or institutions. As such, the enrollment of students has been classified into four different categories which describe the incoming and the outgoing of the students in each type of schools. That is, for each type of schools, the number of students entered from private schools, the number of students entered from home education, the number of students withdrawn to non-public school and the number of students withdrawn to home education have been separately given. Using this enrollment data, we need to construct a simulation model based on some assumption. That is, the mean and standard deviation of the number of incoming and outgoing students have been calculated using Excel function and assuming that these incoming and outgoing patterns follow normal distribution with corresponding mean and standard deviation.

Construction of Simulation Model and its Results

Using Microsoft Excel, the mean and standard deviation for enrollment of students in each type of schools has been calculated and are shown in Figure 2. Based on the incoming and outgoing pattern of the students in the school, the present number of students in each type of schools has been calculated by subtracting the total outgoing from the total incoming students. The formula that is used for calculating the “Present Number” is given as follows:

Present Number = (Entered from Private School + Entered Home Education) – (Withdrawn from Non-Public School + Withdrawn from Home Education)

By assuming that the incoming and outgoing pattern of students in each type of school follows Normal distribution with respective mean and standard deviation, the Simulation model has been constructed after fixing the “Present Number” as the “Forecasting Cell” in Microsoft Excel.

From the simulation, it has been observed that the average number of students presently in the Elementary school is 9.696 with standard deviation 17.586; the average number of students presently in the Middle school is 0.764 with standard deviation 9.741; and the average number of students presently in the High school is 0.935 with standard deviation 32.734.

This indicates that after the income and outgoing of the students, on average there would be approximately 10 students remaining at present in the Elementary School. Similarly, on average, the number of students at present in the middle school would be approximately 1 with the standard deviation of 9.741; and on average, the number of students at present in the High school would also be approximately 1 with standard deviation of 32.734. By comparing the present number of the three schools, it can be clearly seen that there would be more number of students at present in the Elementary school than that of Middle school and High school.

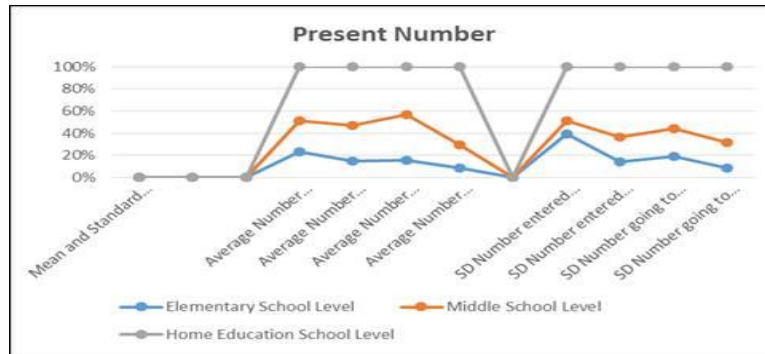


Figure 2. Present Number for three Schools

In other words, the number of students coming from Private School and Home Education to the Elementary School is more than the number of students going out from Elementary School to Non-public school and Home Education. Going by the mean values of Middle and High school, we can say that the number of incoming students is less than the number of outgoing students in both Middle and High schools. From this simulation result, one can say that the enrollment pattern in “Elementary School” is seems to be more efficient than that of “Middle school” and “High school”.

Using Microsoft Excel, the simulation model has been constructed for the given data which produces the summary results for the incoming and outgoing numbers and are shown in Figure 3.

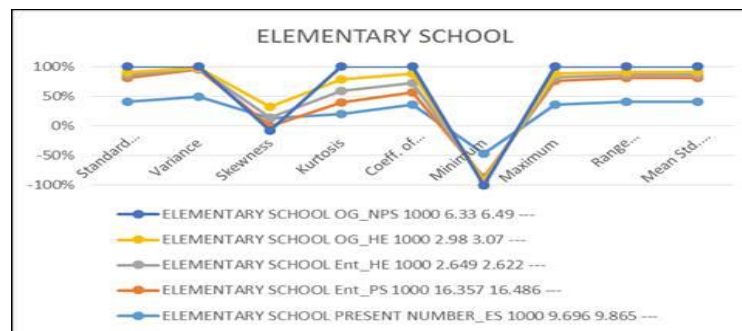


Figure 3. Present Number for Elementary

From the simulation results, it has been observed that the average number of students entered from Private School to Elementary school is 16.357 with a standard deviation of 16.931. Similarly, the average number of students entered from Home Education to Elementary school is 2.649 with the standard deviation of 2.041; the average number of students withdrawn from Elementary school to Home Education is 2.98 with a standard deviation of 2.41; and the average number of students withdrawn from Elementary school to Non-Public school is 6.33 with a standard deviation of 3.88.

Similarly, we have Figure 4 shows that the average number of students entered from Private School to Middle school is 19.093 with a standard deviation of 5.256; the average number of students entered from Home Education to Middle School is 5.760 with a standard deviation of 3.156; the average number of students withdrawn from Middle school to Home Education is 7.60 with a standard deviation of 6.16; and the average number of students withdrawn from Middle school to Non-Public School is 16.49 with a standard deviation of 5.12.

In Figure 5 we can see that the average number of students entered from Private School to High school is 33.929 with a standard deviation is 21.813; the average number of students entered from Home Education to High School is 8.950 with a standard deviation of 8.764; the average number of students withdrawn from High school to Home Education is 24.87 with a standard deviation of 18.52; and the average number of students withdrawn from High school to Non-Public School is 17.07 with a standard deviation of 11.62.

From these simulation results, it can be clearly seen that the average number of students entering to and going from the High school is highly more than that of Middle school which is more than that of Elementary School. This indicates that the number of incoming and outgoing students is

seems to be increasing as the Level of Education increases. This is due to the reason that most of the students may decide to change their school as their level of education increases.

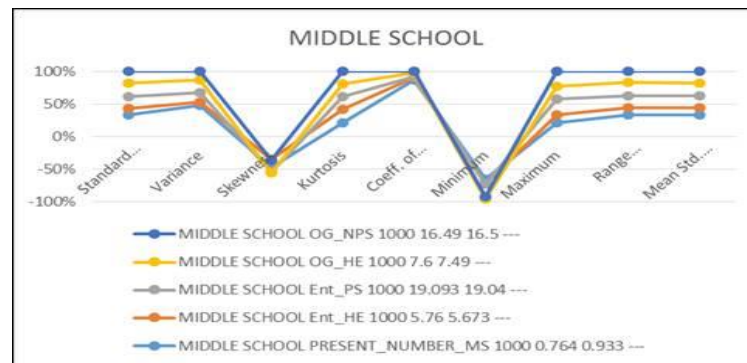


Figure 4. Present Number for Middle

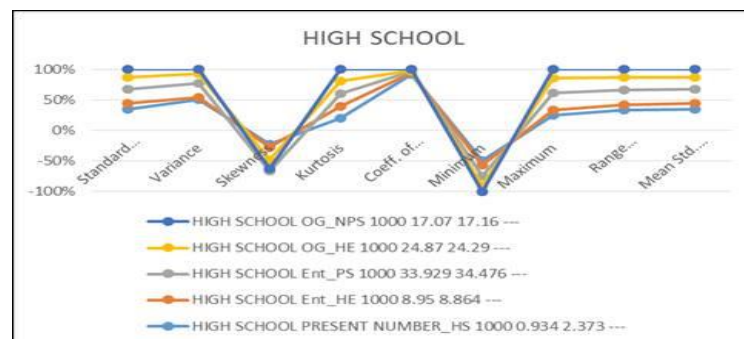


Figure 5. Present Number for High

Simulation Models with SEED Values of 1, 2, 3, 4, and 5

In the above, the simulation model has been constructed without fixing any seed values with Run length of 1000. In order to get more efficiency in the result, the simulation model can be constructed by varying the SEED values and taking the average of the resultant means from those various simulation results. In our case, the simulation has been carried out with the assumption of normality for the incoming and outgoing of students in each type of school. Further, the Present Number has been taken as a forecasting cell (as earlier) with the run length of 1000. But, before running the simulation, the initial SEED value has been given as 1 and the simulation results has been obtained. Then, by changing the SEED value as 2, 3, 4 and 5, the simulation has been carried out with for each type of school.

From the result of the simulation, we can see that the values of each statistic is varying due to the variation in the SEED value.

From Figure 6, it can be clearly seen that on average the Average number of students at present (PRESENT NUMBER) in the “Elementary School” would be 9.499 (approximately 10). It has already been seen that the simulation results without any SEED value produced the mean of 9.696, which is slightly greater than the one (9.499) obtained above from Simulation by varying the SEED values.

From the simulation results, it can be clearly understood that both the methods (simulation with and without SEED values) would produce approximately the same result.

In our analysis, it should be noted that the simulation model has been constructed using Microsoft Excel with Run length of 1000. This is a default value in the Run preference of simulation. It can also be seen that the number of runs that we have used for simulation is 5. That is, the simulation model has been constructed for 5 runs with the run length of 1000. Then the results obtained from the simulation without varying the SEED values had been compared with the average value obtained from the simulation models with various SEED values. By both the methods, we can see that the average number of students at present would be 1 (rounded value) in both the Elementary School and the Middle School, whereas it would be 2 (rounded value of 1.227) in High school.

In order to make the run most efficient, the simulation model has been constructed by varying the Random Seed and takes the average of all the mean values. For all the three types of schools, the averages of all the means (of Present Numbers) have been presented below:

Average number of students presently in the Elementary School would be 9.499

Average number of students presently in the Middle School would be 0.819

Average number of students presently in the High School would be 1.222

The forecasting graphs for the Present Numbers of all the three types of schools are obtained from the simulation and are presented in Figure 7, 8, and 9.

Conclusions

The given data consists of Enrollment of students in Elementary, Middle and High Schools in Volusia County, the state of Florida in the US. The students who enrolled in each type of schools may come from various schools or institutions and also they may move from these three types of schools to any other schools or institutions. The enrollment of students has been classified into four different categories which describe the incoming and the outgoing of the students in each type of schools. The simulation model has been constructed using Microsoft Excel and it has been observed that the average number of students entering to and going from the High school is considerably more than that of Middle school which is more than that of Elementary School. This indicates that the number of incoming and outgoing students is seems to be increasing as the Level of Education increases. It has also been observed that the average number of students presently in the Elementary School would be 9.499; the average number of students presently in the Middle School would be 0.819; and the Average number of students presently in the High School would be 1.222. Further, by comparing the coefficient of variability, it has been observed that the variation is very high in “High school” and it is very low in Elementary School. The variation in Middle School is moderate as compared with Elementary and High school. Thus, the enrolment of students in Elementary school is more consistent than that of other two schools. In other words, we can say that the variation is very high in High School and hence it is less consistency.

From the analysis of simulation results, it has been observed that the average number of students entering to and going from the High school is highly more than that of Middle school which is more than that of Elementary School. This indicates that the number of incoming and outgoing students is seems to be increasing as the Level of Education increases. Also, in order to make the run most efficient, the simulation model has been constructed by varying the Random Seed and takes the average of all the mean values. While running the simulation to forecast the Present Number of students in each type of school, it has been observed that the average number of students at present would be nearly 1 in both the Elementary and Middle Schools, whereas it would be nearly 2 in High school. Finally, by comparing the risk efficiency for the three schools, it has been observed that the Enrollment of students in Elementary school is seems to be more consistent than that of other two schools.

On the whole, we can see that the variation is very high in High School and hence it is less consistency. Hence, it can be suggested that the enrollment pattern has to be monitored and it is advisable to increase the strength of the students and to reduce the number of outgoing students in High School.

We believe that the research contribution is dual in that it presents policy implications as well as a methodological approach.

From a policy standpoint, the model provides guidance for overcrowding management in the condition of school system, although the work presented in this paper applies the simplest blocking model and a simplified structure of the real world school system in the US.

From an economic perspective, it can help to identify cost-efficient solutions to improve system overcrowding; this would happen by knowing the overcrowding stream and addressing it in the school district budget instead of just expanding all the school’s buildings unnecessarily. Methodologically, simulation may be the most reliable approach to understand the behavior of upstream nodes that are affected by the overcrowding at all downstream nodes.

We believe that this study should be of interest to the educational leaders who seek to find solutions to practical problems and thus improve the educational system. As a result, the significance of the study lies not in the mere creation of the model or testing of a theory, but rather in the prospect that a new tool of inquiry, queueing theory, may be understood widely in the educational community.

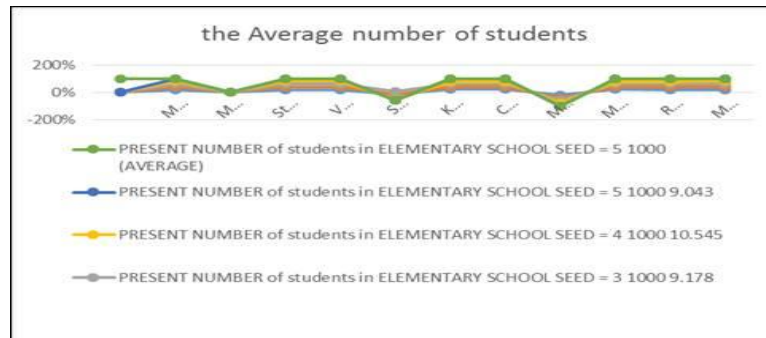


Figure 6. Average Number of Students

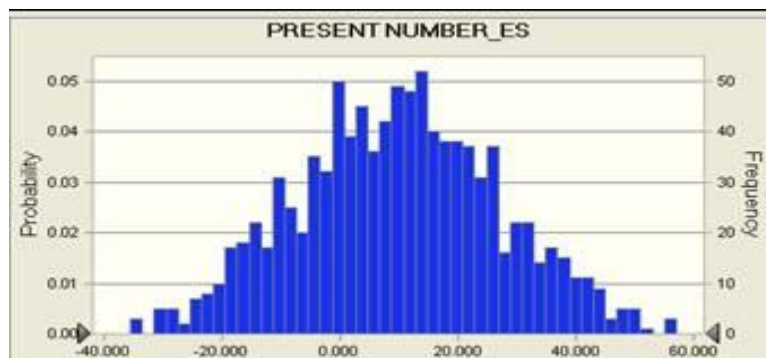


Figure 7. Elementary School

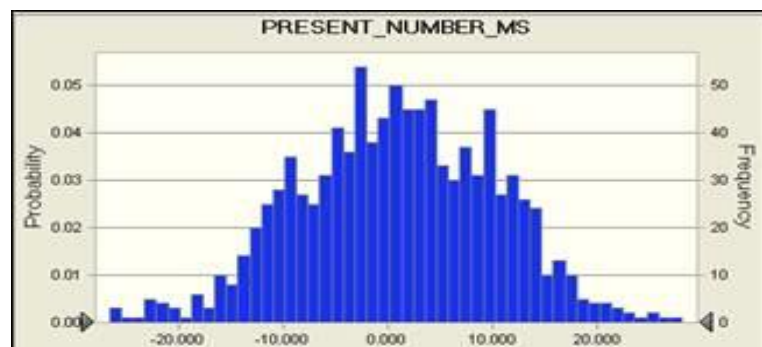


Figure 8. Middle School

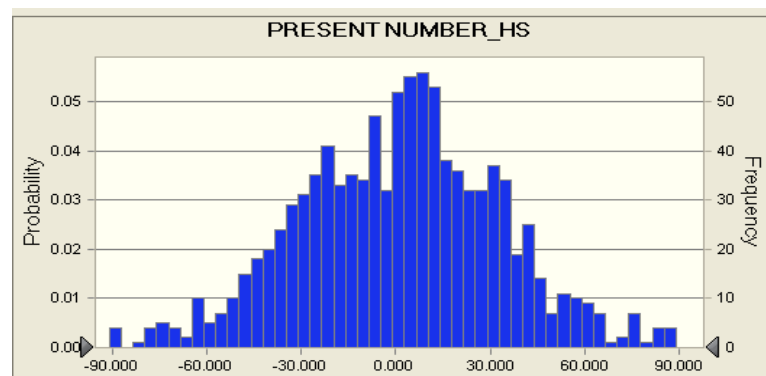


Figure 9. High School

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