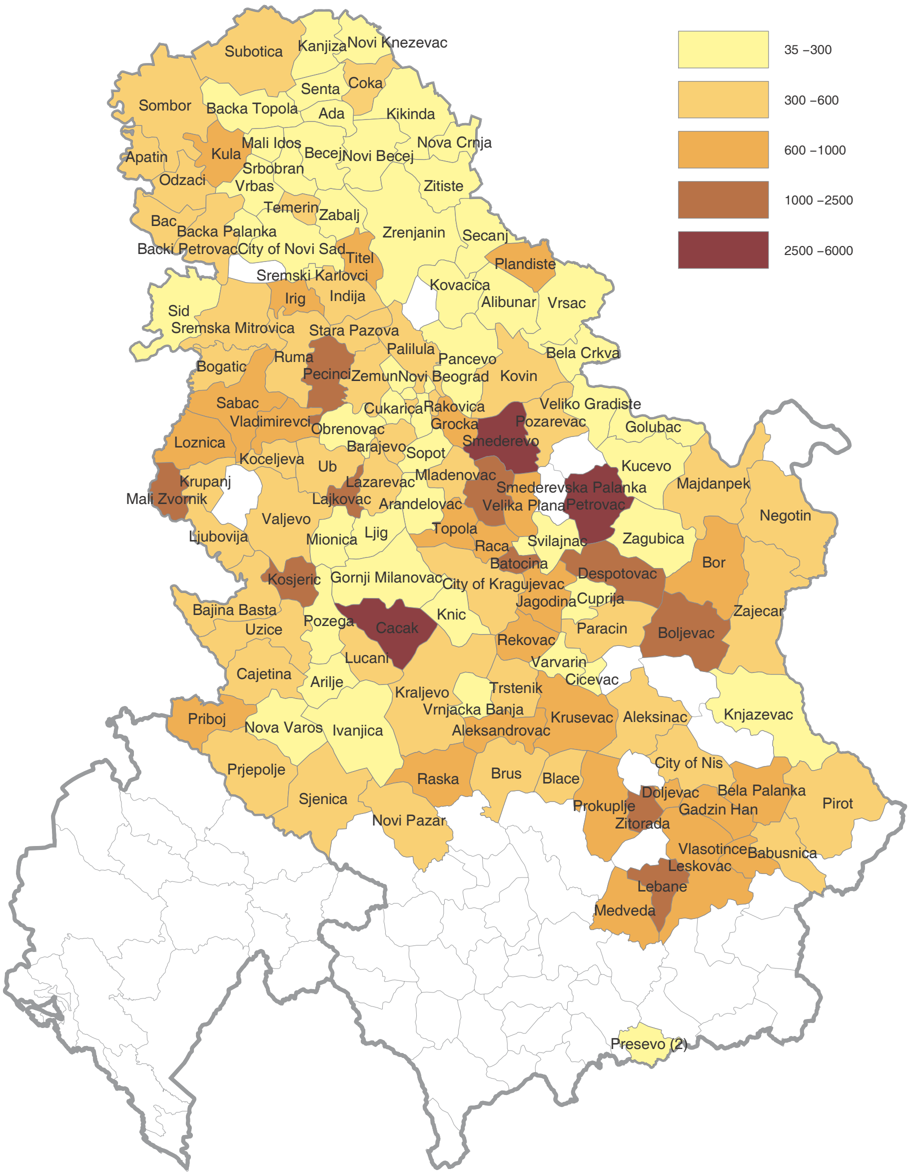


Map 21:
Municipality average of the number of students per PC. This map shows the distribution of newer generation PC’s, e.g. Pentium II and newer (2001/2002 school year).

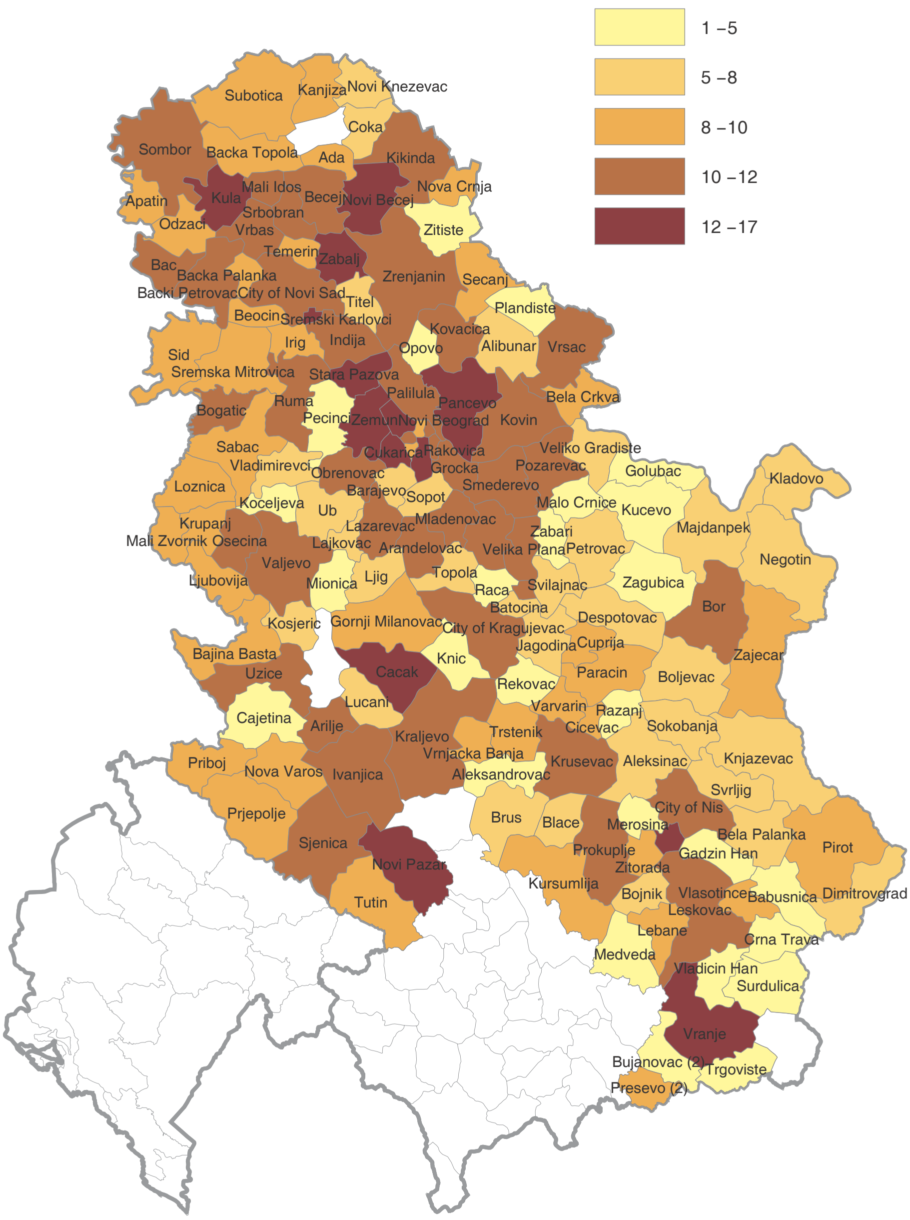
though severely under equipped in ICT Serbia's network of schools does not start from zero. Maps 18 and 19 show the distributions of schools that are already connected to the Internet in one way or another. The connections are still extremely slow by European standards, but the system is moving in the right direction. The situation is better than what one might expect considering that there has been no country wide initiative to put Serbia's schools on the net.

Maps 20 and 21 show the municipality average of the number of PC's per student. Map 20 gives the distribution of an older generation of PC's (Pentium I and older), while Map 21 does the same thing for newer models (Pentium II and newer). In a sense these maps give us two time slices (spaced roughly three years apart) to the process of school investment in computers. The fact that the two maps are so similar tells an important thing - those municipalities whose schools invested more in computers three years ago continue to invest more today.

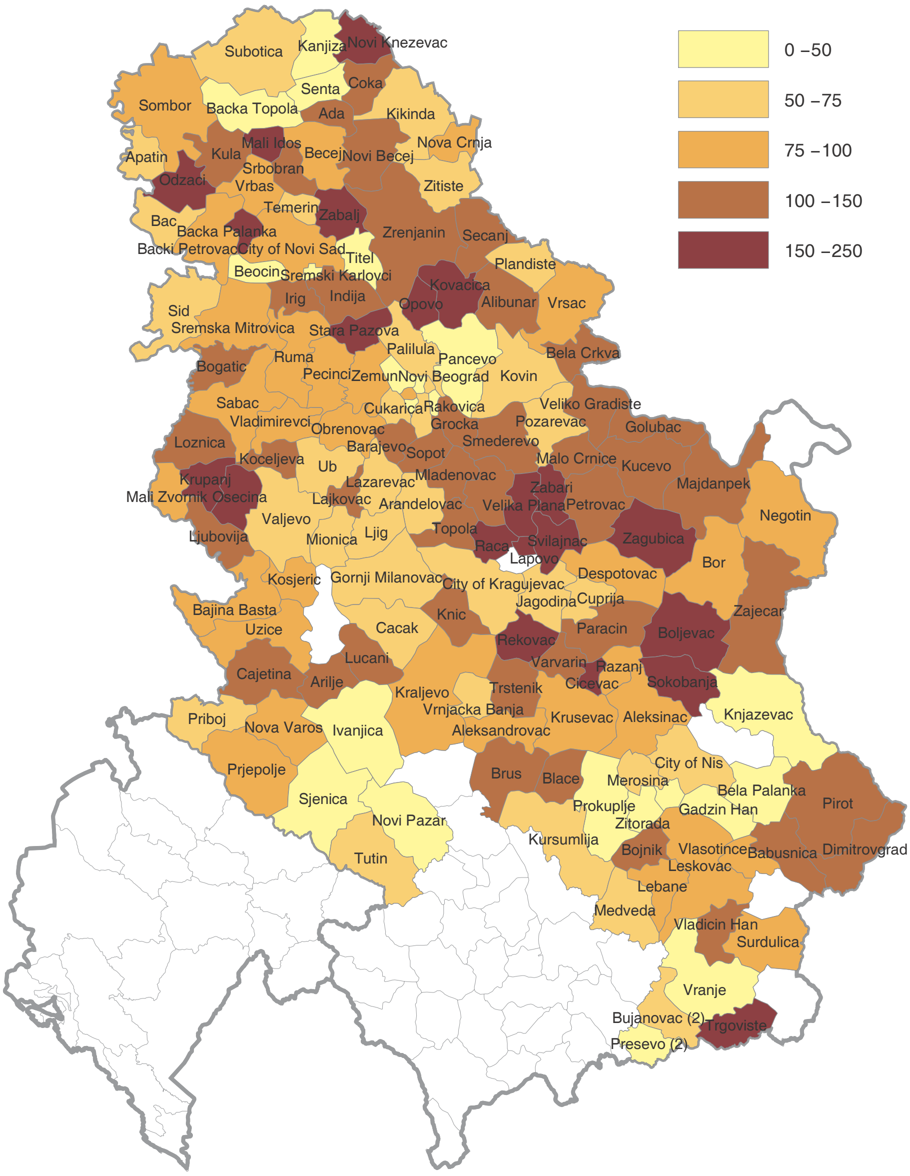
Distributions of student/teacher ratios and of the age of schools

We end this section by looking at two indicators that have important consequences for the economic side of the functioning of the network of schools. Map 22 displays the spatial variation of the principle parameter related to the cost of running of the network, e.g. the number of students per school employee given as a municipality average. The areas of extremely low student/employee ratio are the ones in which satellite schools dominate over central schools. As we have already seen, it is very important to truly understand the cause of the low student/employee ratio. We will leave the details of this for a later section where that will be at the hart of a cost-benefit analysis comparing the functioning of small and large schools

Map 23 looks at the age of central schools - an important parameter related to the real estate values of these schools as well as to the costs of keeping the schools running. From the map we see that Serbia has several clusters of municipalities in which the average age of schools is from 150 to 250 years. In addition, almost a third of the country has schools that average more than one century in age. Some of these old buildings are in good shape, many however are in desperate need of repair.



Map 22:
Municipality average of the number of primary school students per school employee (2001/2002 school year).



Map 23:
Age of central schools averaged by municipality (2001/2002 school year).

B3. Basic cost-benefit analysis

It is not possible to carry through a generic economic cost-benefit analysis relevant to the functioning of schools as there are many local variables that enter the problem. Still, it is possible to construct a simplified model on which to base the generic cost-benefit analysis. In fact, we believe that such a simplified model can do much to increase our understanding of the economics behind the functioning of the network of schools. However, it is imperative to understand that such a simplified model gives only a qualitative understanding of the relation of cost to benefit for a specific school.

Do we have such a model? We lack a simplified model for the benefit side of the equation, i.e. for the assessment of financial gain from the selling of buildings and land of closed down schools. The price of real estate varies in a complicated way as one goes from one location to another. That is the case everywhere. What is specific to Serbia at this point in time is that real estate prices are in huge fluctuation once one gets out of the largest cities.

In the cities it is possible to get a handle on what would be the financial benefit of the selling of a school. On the other hand, the price one would get in towns, and particularly in villages is far from equilibrium. Nobody is buying, nobody is selling, so how may one guess what some real estate is worth?

A small positive change in the economy of a given area, or better yet of the country as a whole, over a period of a few years can change this situation to a great degree. Once there is a general market for real estate it will be straight forward to calculate what is to be gained from the selling a school.

At this time, with the exception of larger cities, real estate in Serbia is seriously undervalued. In the smallest villages the economic benefit of selling the local school would effectively be zero. Speaking purely from an economic standpoint, this is not a good time to sell the smallest schools.

So, as far as the benefit side of the sought after model, we can only gauge the gain that would accrue from the firing of teachers and staff that worked in the closed down schools.

Let us now look at the cost side of the equation. Here things are much simpler. The Ministry of Education knows how much money it is spending on each school and what that money goes for. What we want is a simplified model that works fairly well for all schools. That is not so difficult to construct.

In our simplified model the per student cost of running a school is the sum of three terms: the first term is proportional to the number of employees per student (this takes into consideration the salaries of teachers and of other employees), the second term is proportional to the total area of the school per student (this takes into consideration all the costs that scale linearly or roughly linearly with school are - for example: heating costs, utility charges, etc.), the third term is due to transportation costs to and from school (for students and teachers). The formula is simply:

$$C = \alpha * E/S + \beta * A/S + t,$$

where C is the cost per student, E the number of school employees and A the school' s total area. In the formula α and β are appropriate proportionality constants, i.e. assumed to be the same for all schools. The quantity t is the per student transportation cost.

We will distinguish two types of schools in our simplified model. The first is a caricature of Serbia's central schools - a fraction f of the schools students live in nearby villages and need transportation, while no teachers need transportation. We will assume that f is the same for all central schools. If γ denotes the cost of moving one person to and from school then in this case

$$t = \gamma * f.$$

The caricature of a satellite schools is as follows - the children all live near the school, while the teachers are all transported from the nearby town or city. We now have

$$t = \gamma * E/S.$$

The simplification comes from the fact that in both cases the same distance is traversed (the distance from central to satellite school), hence γ is the same for both types of school. We will also simplify thing by assuming that the distance traversed is always the same (which is not really a bad approximation). In this case γ is just another proportionality constant having the same value for all schools.

Now we need to go to our database

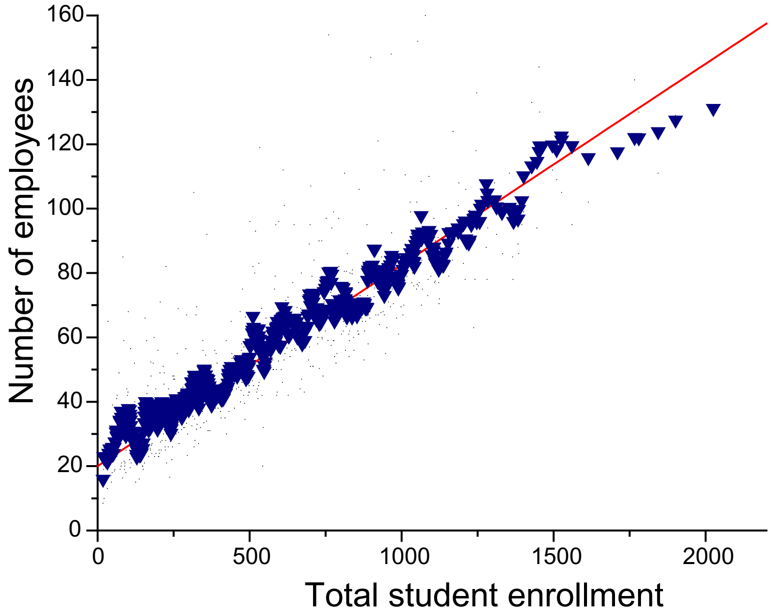


Figure 29:
Relation between the total number of school employees and the corresponding student enrollment for central schools for the 2001/2002 school year.

and ask it how E (number of school employees) and A (total area of a school) depend on S (schools total enrollment). These functional dependencies are given in the following four figures. Figure 29 looks at how the number of school employees depends on the number of students for central schools.

There is a technical point here that we briefly mention and that is valid for this figure and the three figures that follow. The data relating these variables is extremely noisy - there are examples of schools with a small number of students and a relatively large number of teachers and vice versa. This strange occurrences should be systematically studied as they could well be a good place for cost cutting. At this point we just want to find average relations. We have done this by using the well-known technique of curve smoothing that goes by the name of FFT (fast Fourier transform). We won't go into details regarding this - suffice it to say that it allows us to smooth out the data and more easily determine average trends.

The blue triangles in the figure represent raw data that has gone through a five parameter FFT. The red line gives the average trend for central schools - a linear law relating E and S:

$$E = S / 16 + 20.$$

The underlying average law is quite simple and is the result of a previous educational standard: for every 16 students employ one further person. The additional 20 in the formula is related to things that do not scale with the number of students such as the school administration, librarians, maintenance staff, etc.

This example might be called sense out of nonsense. The fact that one uncovers a simple behavior is a simple consequence of the fact that the system "remembers" better times when there existed educational standards. The last decade has been a time when standards were not bothered with - hence the noise. The deviation of each central school from the above average law measures a deviation from these standards. Deviation on the side of a smaller E/S ratio is an indicator of a poorer quality of teaching environment (e.g. large classes). On the other hand, deviation on the side of larger E/S is an indicator of schools that are relatively less efficient than the average.

The best source of cost cutting lies not the closing of schools but in the reinstating and enforcing of standards. The current project database could easily be used as a tool for this.

Our simplified model for per student cost considered satellite schools as well. In this case the relation between number of employees (E) and number of students (S) is quite different, as one would expect. The data is shown in Figure 30. Again we have the same story: the raw data is extremely noisy signifying non compliance with standards, the raw data is smoothed using the FFT procedure (blue triangles) and from that one again easily obtains a simple average law (red line). The law is:

$$E = S / 10,$$

for schools with more than 20 students, and E = 2 for all schools with 20 students or less. These numbers are again extremely easy to understand. Large satellite schools behave much like central school and have E and S proportional. The proportionality is 10 students for every new employee. It differs from that of central schools because here the

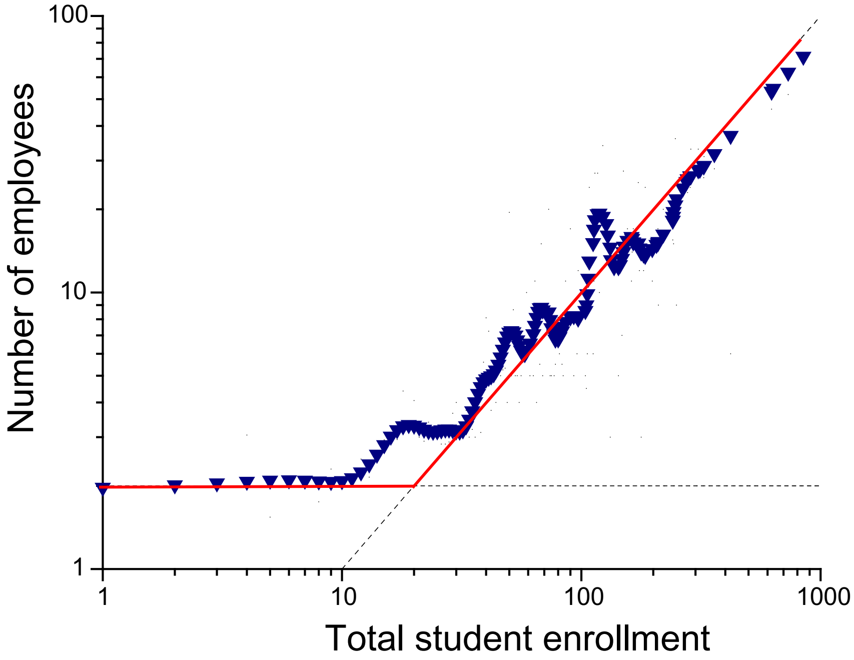


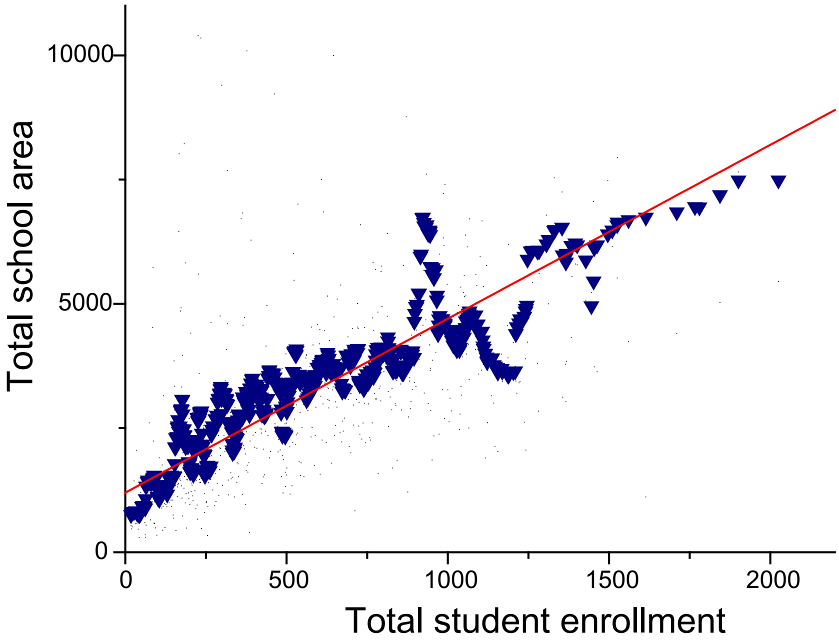
Figure 30:
Relation between the total number of school employees and the corresponding student enrollment for satellite schools for the 2001/ 2002 school year.

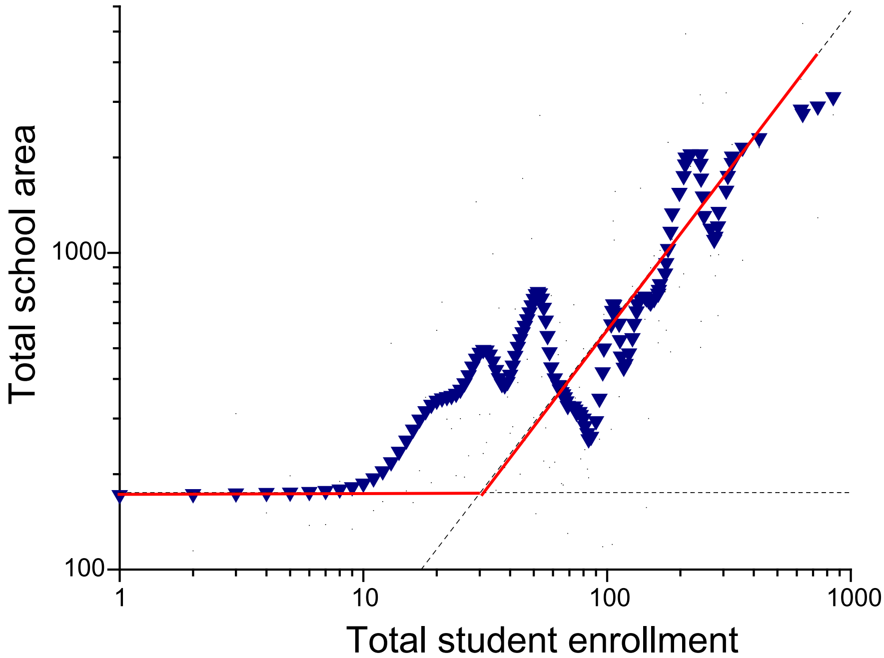
average class size is lower than in central schools.

Once we go down to 2 employees (one teacher and one maintenance worker) you can't go down any further, i.e. you can't have half a teacher. For this reason, once the demographics in the village decreases the number of children of primary school age to 20 or less there is no further change in the number of teachers (until the number of students goes to zero and the school closes).

Another way to say this is that the ratio E/S is very nearly constant for central schools (E/S = 16) and for larger satellite schools (E/S = 10). Once a satellite school goes bellow the critical enrollment of 20 the ration E/S starts growing (E doesn't change, while S decreases). This strongly affects the cost per student as we can see in our formula.

Let us now go through the same thing but now looking at the relationships between total school area (A) and student enrollment (S) for the case of central and satellite schools. The results are shown in Figures 31





Figures 31 and 32:
Relation between school area and student enrollment for central schools (top) and satellite schools (bottom) for the 2001/2002 school year.

and 32. As we can see they are quite similar to the previous two graphs. For central schools we have:

A = 3.5 * S + 1,200.

Each student gets, on the average 3.5 square meters of his or her own space. The non scaling area (1200 square meters on the average) represent the common space shared by all students such as sports gymnasiums, auditoriums, halls and school yard.

In satellite schools, on the other hand, we have

A = 5.8 * S,

for schools with more than 30 students and E = 174 for schools with 30 or less students. As we can see the critical number as far as area is concerned is 30.

Again all of this makes sense. Larger satellite schools have a bit more space per student than central schools, however there are no gyms or auditoriums or halls. Once student enrollment goes down sufficiently then all the students are in one (multi-grade) classroom, hence area doesn't change. The thing that effects cost is the ratio A/S. It is constant in all cases except for that of extremely small satellite schools when it increases with the decrease of student enrollment.

The last step in our model is to assess the values for the constants α, β, γ and *f*. This is not very difficult to do - one gets the values from asking a few schools about teacher salaries, heating costs, various utility costs, etc., by gauging the per person transportation costs and by estimating *f* from our database.

Figure 33 was obtained by inputting values for these parameters into the formula for per student cost for our simplified model. The final result is well approximated by the following monthly per student costs (in dinars). For central schools with S students the monthly per student cost is:

C = 1,835 + 380,000 / S.

For satellite schools with more than 20 students the formula is:

C = 1,956,

i.e. the answer does not depend on the enrollment. Finally, for the smallest satellite schools, those with a total of 20 students or less we have:

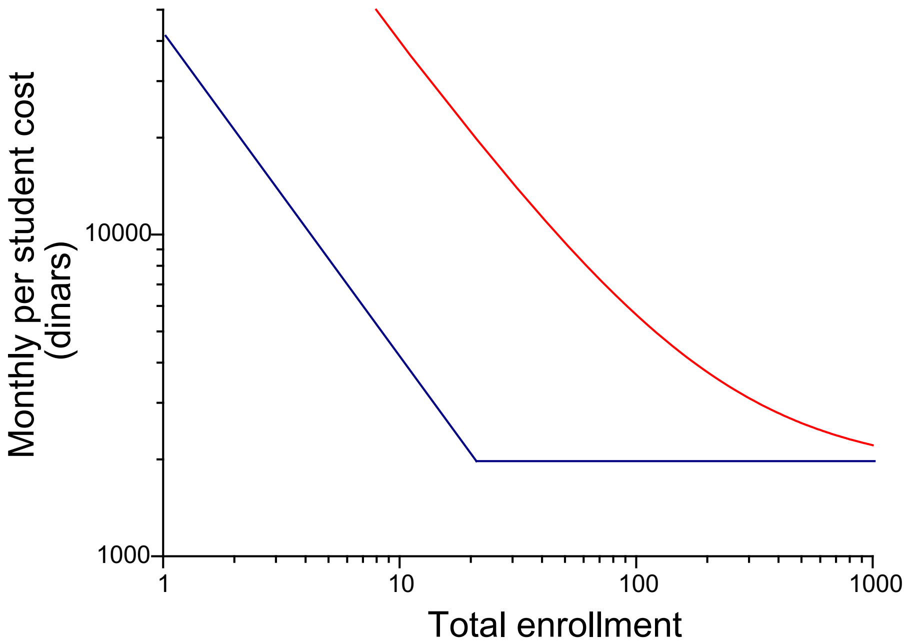


Figure 33:
Simplified monthly per student cost estimate for central and satellite schools.

C = 42,070 / S.

Figure 33 shows that the highest per student cost is for the extremely small satellite schools. This is to be expected. The single most important reason is that for these the number of employees is already minimal (one teacher and one maintenance employee). In the current situation the greatest effect on the per student cost is from salaries.

On the other hand, medium sized and larger satellite schools are more economically efficient than central schools, even more efficient than the largest central schools. The primary reason is that they have no administrative staff.

What have we learned from all this? We have not uncovered a place for cost cuts - the closing of the smallest satellite schools. Though per students costs are highest for the smallest of these schools only a very small percent of Serbia's student population attends such schools, hence the total saving would be insignificant. On the other hand, the negative consequences of such cuts would be manyfold. More of this will be given in the following section on optimization strategies and models.

The true result of the above analysis is that we see the main reason for the decrease of the student/teacher ratio that has been going on steadily since the sixties. That decrease is not a result of the education system living beyond its means in a time of economic austerity, rather it is a direct consequence of the depopulation of many rural areas in Serbia.

One direct consequence of the above simplified model is to serve as a benchmark when looking at the economics of the running of any particular school. Figures 29 through 33 give the averages over all appropriate schools. These average laws, as we have seen, are quite sensable. In that sense, they represent a very concrete benchmark to be used for assessing the level of economic efficiency of the functioning of any specific school. For example, there exist individual schools with employeed/student ratios twice that of our benchmark - the functioning of these schools must immediately be looked into in detail. Examples of converse behaviour also exist - schools where the employee/student ratio is much smaller than the appropraite benchmark. Such instances also need to be analyzed in more detail in order to see if they represent examples of lower educational quality or of pedagogical inefficiency.

It must be stressed that these benchmarks need to be used with care. There exist many valid reasons why an individual school's functioning may vary significantly from these average laws - still, there is no evidence that Serbia has ever investigated the causes of these variations. This investigation can now be one of the first and most straight forward uses of the educational information system created by the network optimization project.

To conclude this section, let us once again get back to questions of efficency of the running of small schools. The above analysis indeed shows the need for a careful reconsideration of the efficiency of running the subnetwork of small schools. In the following section we will see how that economic efficiency may be bought, but not at the price of pedagogic efficiency. In fact, a judicial choice of the presented strategies will in many cases allow the increase of both economic and pedagogic efficiency.