Effective school networks

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Abstract

Schools are the most expensive public service after the social and health care in Finland. Education provided by the schools is essential to the renewal of the workforce and to the development of the national economy. Educational services are produced in a network of school facilities. The size of schools, the distance between them and the quality of the facilities are most important drivers of the quality and cost of the education. The article is based on empirical data from 19 primary and secondary school networks in Southern Finland. Networks studied have neither high quality nor reasonable cost. A simulation model was created to study the potential for enhancement of the networks. The model was created based on the fact that there is a connection between the size of the school and the average size of the classes. Savings were the differences between the given model and the present costs. Simulation models showed that there is a remarkable potential for savings by redesigning the networks. The savings of school networks varied between 775 € per pupil to 3120 € per pupil. The average saving was 134 € per capita**.** On a national level the savings would be approximately 0,7 billion € a year.

Keywords: school networks, school size, facility cost, educational economics

1. Introduction

Finnish schools are mainly owned and operated by municipalities. The State supports municipalities, but they are wholly responsible for arranging and offering education and other services. This article studies the cost and quality of Finnish primary and secondary school networks. There has been a lot of discussion about the quality and cost of individual units in Finland, but seldom about the whole network. However, it is the network, not the units which provide the service to the citizens. If equality between taxpayers and users are wanted a few well functioning units are not enough. The level and cost of service should be somewhat constant everywhere.

Finnish schools are small. The average size of all schools (primary and secondary) is 195 students in Finland (FNBE 2013) when in US, the average size is 550 (Keaton 2012). In EU countries median primary school size is approximately 350 students (Bolam 2000). US National Center for Educations Statistics considers 300 pupils the smallest category, 500 to 1200 is medium and over 1200 large category (Keaton 2012). There are no schools in Finland which are in Keaton’s large size category.

Finland is sparsely populated country and there are many small schools in the rural areas. 41% of Finnish schools have less than 100 students when only 10% of the pupils study in them (FNBE 2013). Such a network of small schools is expensive, and there are serious doubts whether the small schools are able to provide high quality educational services. There is an ongoing debate about the benefits of the small schools to the pupils and to the community (Kalaoja & Pietarinen 2009). The amounts of small rural schools have dropped dramatically during the last decades (ibid.). The closures of small schools always raise fierce public debate, even though they impact only a minority of the pupils. The quality of larger schools or the network as a whole is seldom discussed.

What we are interested in is the quality and cost of the networks. This study is based on our work on 19 school networks in Southern Finland. We studied the cost of tuition, the cost and quality of the facilities and formed alternative or simulated models for networks. We were able to show remarkable savings as a difference between the existing networks and simulated ones.

1.1 Research questions

The research tries to find an answer to following research questions:

1. What is the overall quality and cost of school networks in the municipalities studied?

2. What would be the ideal school networks for the municipalities studied?

3. What would it cost to build and operate such networks compared to the cost of operating the existing networks?

The costs of transportation were not included, because they are minimal compared to other costs.

2. Methodology

Research is based on material gathered during the years 2011-2013 from 19 municipalities, population of which is a total of 450 000. The municipalities studied are small or medium size municipalities in Finland, population of which are between 2000 and 50 000 inhabitants. They form 8,34 % of Finnish population.

The empirical part is based on the simulation model. The simulation model was created to study the potential for enhancement of the networks. The simulation model was created based on the fact that there is a connection between the size of the school and the average size of the classes. The average class-size is one of the most important factor behind the total cost of a school, because teachers’ salaries are the biggest single expense of a school and the amount of teachers in a school is dependent on the amount of classes. Using the simulation model, three different service networks per city or municipality were created based on the school size and average class size. The simulation model is presented more carefully in 4.3.

2.1 Structure of the work

This research consists of 8 sections. Firstly, chapter three concentrates on the theory and introduce previous researches related to the topic. Chapter four focuses on the empirical part of the study. The chapter describes in detail the data collection, research method and simulation model. In chapter five the results of the study are presented and in chapter six results are discusses more carefully. Finally, in chapter seven strings are pulled together in the form of a conclusion.

3. Theoretical background/Literature review

Theoretical background of this study is divided into two sections. In the first section different kinds of networks are presented. The section also introduces optimization methods for school network planning and typical characteristics of the school networks in Finland. The second section concentrates on size of the units i.e. how to school size and class size affect learning outcomes.

3.1 Networks

According to Merriam-Webster (2016) dictionary network is "an interconnected or interrelated chain, group, or system *<a network of hotels>"*. A group of schools owned by a municipality form a network because:

- they are interrelated: there is a limited number of students and they all have to go to a school, if one school grows bigger, the others have to decrease in size
- they are interconnected: there is a limit to a distance between two schools
- they form a system: not one school but all the schools are needed to provide school services to a municipality

Network theory studies all kinds of networks: air traffic networks, computer networks, social networks, to mention just a few. Typical to all kind of networks are that they are formed by nodes and links connecting the nodes. The basic type of a network is a *random network* (fig 1), where nodes and links are evenly distributed. Highway network is a typical example of a random network. The problem with a random network is that one has to go through many links to get from one place to another. This is called *network distance*: the amount of links between two places. (Barabási 2002)

The degree of separation describes the overall quality of a network: how many links there are on average between two randomly chosen points. The degree of separation of the internet is nineteen: any two internet sites are nineteen links or "clicks" away from each other (on average). This is possible, because these networks are not random: there are short-cuts which make the world smaller.

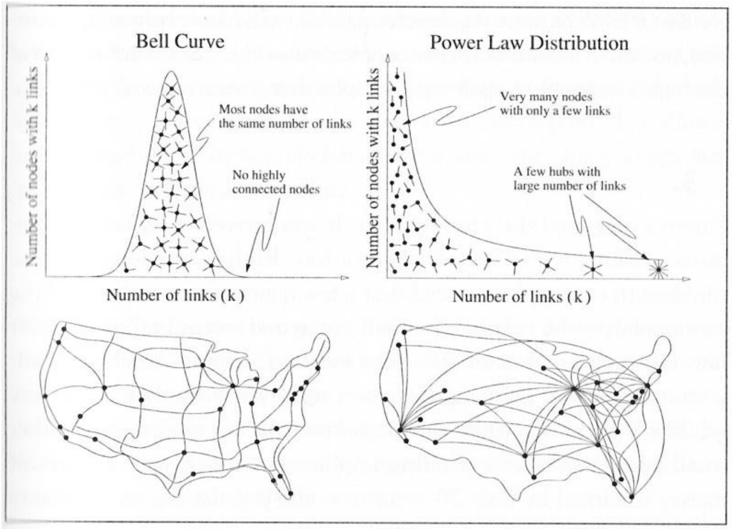

Figure 1. *The degree distribution of random network (top left) follows a bell curve. Most nodes have the same number of links, and nodes with a very large number of links do not exist. Scale-free network (top right) has a power law degree distribution of links. Most nodes have only a few links, held together by a few highly connected hubs (Barabási 2002: 71).*

The internet has a small degree of separation, because it has "hubs": super-nodes to which there is a link from most of the other nodes. A network based on few hubs and plenty of nodes with only a few links are called *a scale-free network*. Air traffic network is a typical example of a scale-free network. There are hubs like Heathrow and Paris De Gaulle and lots of unimportant small airports. If you can get to Heathrow from one of the small airports, you can get to almost anywhere from there. The internet is another example of a scale-free network.

Are public schools random or scale-free networks? Statistics of schools in Finland would suggest that they resemble more random network than scale-free one. If each pupil and each school are considered nodes, the distribution of links is the same as the amount of pupils in one school. The distribution of links in Finnish school network is more bell curve than a power degree distribution (fig 2)

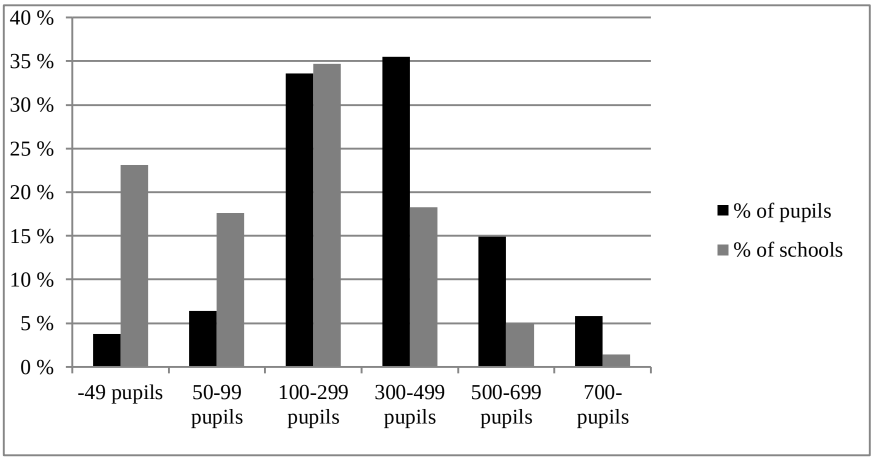

Figure 2. *The distribution of Finnish schools and pupils according to the schools size in 2013 (Finnish National Board of Education FNBE 2013).*

3.2 School networks

3.2.1 Optimization methods for school network planning

Schools can be seen as the physical infrastructures used to produce educational services. Together with teachers, whose responsibility is to supply labour for the process, schools constitute the determining production factors used in educational sector. (Antunes & Peeters, 2000) The main target of educational network planning is to satisfy demand as much as possible. When that target is reached, the objectives will generally involve maximizing socio-economic benefits which is basically the same as minimizing costs. There can also be other objectives such as maximizing accessibility, which has been the main idea behind the development of the Finnish compulsory school network (Kuikka, 1996; Antunes & Peeters, 2000)

From the society point of view, one of the key problems in the educational sector is how the educational network should be planned so that it could serve educational demand in a certain region in the short, medium and long term. However, during the last decades, planning processes of educational networks have become increasingly complex. The educational network planning problem consists of many questions which should be solved: where schools should be located, what their size should be, which schools should be kept open and which ones should be closed, whether it is necessary to build new schools, what class sizes should be and so on. (Antunes & Peeters, 2000; Teixeira & Antunes, 2008) The planning problem has been researched on general level by several authors (see e.g. Erlenkotter, 1967; Roodman & Schwartz, 1975; Roodman & Schwartz, 1977; Fong & Srinivasan, 1981; Van Roy & Erlenkotter, 1982; Jacobsen, 1990; Shulman, 1991; Marianov & Serra 2002). Two separate research fields have focused on studying school network problems: “multi-regional capacity expansion” and “dynamic facility location”. These approaches are based on different kinds of mathematic optimization models which try to determine optimal network structure. (Erlenkotter, 1967; Roodman & Schwartz, 1975; Roodman & Schwartz, 1977; Fong & Srinivasan, 1981; Van Roy & Erlenkotter, 1982; Jacobsen, 1990; Shulman, 1991; Marianov & Serra 2002). The literature review shows that there are also several articles which deal specifically with school networks. Henig & Gershak (1986), Greenleaf & Harrison (1987), Tewari & Jena (1987), Viegas (1987) Beguin et al. (1989), Pizzolato (1994), Antunes & Peeters (2000) and Teixeira & Antunes, (2008) present different kinds of optimization models for school network planning purposes, just to mention a few. However, the optimization models are typically very detailed and contain just a few variables, are designed for specific conditions, respond for specific needs, or contain other restrictions. They are often too complex for practical planning purposes.

3.2.2 School network in Finland

The main idea behind the development of the Finnish compulsory school network has been to have schools close to the pupils which mean that the distance from home to school should be less than 5 km. This has led to a situation where almost every village in rural area has its own school. However, reduced birth rates, migration, changes in the economic structure, and improvement of rural road conditions started the closure wave of small rural schools in the late 1960s. The founding of the current comprehensive school system which ensured equal educational opportunities for all citizens improved the position of small rural schools for a while, but deep recession at the end of 1980s and early 1990s put the future of the small rural schools under threat. (Kuikka, 1996; Laukkanen & Muhonen, 1981; Kalaoja & Pietarinen, 2009)

In the early decades of the 2000s the demographic structure has changed in Finland. The National Board of Education (2004) predicted that the number of children of compulsory school age will fall approximately 10 % in every ten years at the beginning of the 2000s. In addition the trend towards rural-urban migration intensifies and regional centralisation will continue. (National Board of Education, 2004). Also the economic difficulties of Finland due to the downturn of past years create pressure for savings in public expenditure. In addition, Finland is already sparsely populated country (340 000 km^2 with population of approx. 5 million) so it is evident that there will be the growing need to cut the costs of the school network in Finland. To make the cost savings possible the unit size of schools needs to be increased and more effective school network to be planned. (Kalaoja & Pietarinen, 2009)

3.3 Size of units and economies of scale

Size of units is closely related to the term *economies of scale*. The basic idea behind economies of scale is that enterprises can get the cost advantages due to size or scale of operation. Increasing the size of units typically leads to economies of scale because fixed costs are spread over more units of outputs. In the educational unit context, economies of scale means that fixed costs could be spread over a larger pupil base (Lee & Smith, 1997). In this chapter optimal sizes of educational units and impact of a class size on learning outcomes are presented.

3.3.1 The optimal size of a school

According to Leithwood's and Jantzi's (2009) review of 59 post-1990 studies related to school size, pupils in small schools perform better than pupils in large schools. There is a lot of evidence in favour of smaller schools in the studies. However, the term "small school" and "large school" vary between the studies so it would make more sense to ask what the optimal size of a school is and is there difference between the optimal size of an elementary school and a high school (Cotton, 1996; Lee & Smith, 1997; Leithwood & Jantzi, 2009)

The exact size of an optimal school is difficult to determine, because the optimal school size depends on many different variables such as diversity of pupil background and differences between elementary schools and secondary schools. In an elementary school, where lots of pupils have diverse disadvantaged backgrounds, the size shouldn't be more than 300 pupils. In an elementary school with heterogeneous or relatively advantaged pupils the size should be smaller than 500 pupils. The size of an elementary school, where pupils are of diverse or disadvantaged background, should not be more than 600 pupils and with heterogeneous or relatively advantaged pupils, the size should be smaller than 1000 pupils. (Cotton, 1996; Lee & Smith, 1997; Leithwood & Jantzi, 2009)

In the previous paragraph the recommended upper limits of school sizes were presented, but there are minimum limits as well. Where the bigger schools tend to be more formal and bureaucratic, reducing school size too much leads to constrain courses and to reduced ability to respond to the special needs of pupils (Lee & Smith, 1997). Many researchers have reached the conclusion that an appropriate and effective size for an elementary school is 300-400 pupils and for a secondary school 400-800 pupils. (Cotton, 1996; Lee & Smith, 1997; Lee & Loeb, 2000). According to these studies 76% of Finnish schools are undersized.

3.3.2 The impact of a class size on learning outcomes

It is very typical that parents and teachers assume that reducing class size leads automatically to better learning outcomes. It increases pressure on politicians to reduce class sizes or at least prevent them from increasing in many countries, also in Finland. (Pedder, 2006) Class sizes are one of the most discussed and most researched topics in pedagogical field of science. It is easy to find arguments for and against the claim that reducing class sizes would lead to better learning outcomes. Those who support class size reduction typically argue that reducing class size leads to higher quality instruction, student-centred teaching, more individualized instruction, fewer disruptions and so on. On the other hand, there is a huge amount of studies which claim that there is no evidence that reducing class size would lead to improved learning outcomes. (Hattie, 2005)

One of the most impressive and the most discussed study on class size was Project STAR (Student-Teacher Achievement Ratios) which began in Tennesee in 1985. Project STAR involved 6500 students in 329 classrooms in 79 schools. The students were divided into a regular class (22-26 students) or to a small class (13-17 students). The students were held in classes of same size for the next 3 years and teachers didn't get any special instructions for teaching different size of classes. The study showed that reducing class size had only a small effect on learning outcomes. The overall effects were 0,15-0,27 in favour of small classes on a scale of 0,0-1,0 according to a meta-analysis of Project STAR. The benefits of small classes were greater for students who had worse socio-economic background. (Finn & Achilles, 1990;

Word et al., 1990; Finn et al., 1991; Achilles, 1999, 2002; Ritter & Boruch, 1999; Achilles & Finn, 2000; Achilles et al., 2002).

Also the other studies after Project STAR have lead to the same kind of results. Typically the overall effects of class size reduction has been something between 0,1 and 0,2. For example Goldstein et al. (2000), Dustmann et al. (2003), Johnson et al. (2004), Blatchford et al. (2005) and Urquiola (2006) have studied the impact of learning outcomes when reducing class size from 25 to 15 pupils and they have come to a 0,1-0,2 effect-size. The effect-size of class size reduction could be considered small or even tiny, when compared to many other possible enhancement solutions. Hattie (2005) has listed 46 influences on student achievement and the place of class size (place no. 40) is clearly among the smallest effect-sizes. Average effect-size of different influences on learning was 0,40 according to Hattie's meta-analyses. One of the most popular explanations of why effect-size of class size reduction is so small (0,1-0,2) is that actually teachers of smaller classes adopt the same teaching methods they use in larger classes and are not optimizing the opportunities of fewer students in classroom. (Hattie, 2005) It can be said that class size reduction is an expensive educational reform, its positive effects on the learning outcome are uncertain and there is no scientific evidence that smaller class sizes automatically lead to better learning outcomes.

4. Methods

4.1 What are the quality and cost of a network?

In this study the quality and cost of a network consists of:

<u>The quality and cost of the individual units and buildings</u>

- The technical quality of the buildings and other constructions
- The quality of the individual buildings measured by square meters per student
- The cost of the buildings measured by the cost per square meter or cost per pupil
- The cost of the individual operational units measured by the cost per pupil

<u>The quality of a each municipal school network of units and buildings</u>

- The variation of the quality of the whole network of buildings measured by square meters per pupil or child
- The variation of the cost of the individual building units measured by the cost per sq meter or cost per pupil
- The variation of the cost of the individual operational units measured by the cost per pupil

The cost or length of transportation to and between units is not part of this research. The costs of transportation are minimal compared to other operational costs.

4.2 Empirical data

Research is based on material gathered during years 2011-2013 from 19 Finnish municipalities population of which is 450 000 together. The municipalities studied are small or medium size municipalities, population of which are between 2000 and 50 000 inhabitants. They form 8,34 % of Finnish population.

4.3 Simulation model

Usually school networks are approached from the inductive point-of-view: the enhancement starts from the existing school networks. Existing schools are analyzed and the proposals for embetterment are about closing units or creating new ones. However, this approach has some weaknesses. The schools are built for multiple reasons throughout the one and a half century history of Finnish public education. Nobody would build the school network today the way it has been built. In philosopher David Hume's words, we cannot derive "ought" from "is".

We have chosen a more deductive kind of an approach. Instead of existing school facilities we take the existing population only as the starting point. We do not speculate with the future changes in population but try to answer the question: "What would the quality and expenses be if we had built a more effective network in the past?" This gives us a possibility to compare today's expenses with what they *ought to be*. This method we call "a simulation model". The savings of a model are the difference between the existing costs and the possible costs.

The models are created based on the fact that there is a connection between the size of the school and the average size of the classes. The average class-size is the one of the most important factor behind the total cost of a school. Teachers' salaries are the biggest single expense of a school and the amount of teachers in a school is dependent on the amount of classes.

The amount of class series in a school is an important variable. The bigger the school, the more classes it has on any given grade (i.e. 1A, 1B, 1C, 1D and so on). The more classes a school has in one grade, the higher the average size of a class can be without any one class being oversized.

Three different models per municipality were created based on the school size and average class size. The new schools were sized ideally only based on the population data in each area. There operational costs were calculated. All of the school buildings were sized according to the Finnish norms. The facility cost per m^2 was the same as the existing cost, so all of the savings resulted from the diminished area. Simulation models were validated by comparing the results with the school size and cost database of Finnish Ministry of Education.

The savings in central costs (administration, catering, ICT and so on) were included. The investments needed to build the new networks were calculated on following assumption:

- half of the buildings would be either new or extensions to existing facilities

- half of the buildings would be completely renovated old buildings and the rate of their repair would be 80%

5. Results

5.1 The age of the facilities

More than 50% of the facilities studied are more than 40 years old. Only one quarter of the facilities were build after the year 1990. Half of the schools were built after the year 1970 and half of the day-care centres were built after the year 1990 (appendix 1).

5.2 Indoor air quality

According to the user surveys more than 25 percent of the pupils are studying in facilities which have serious indoor-air problems. Only 33% were satisfied with the indoor air quality.

5.3 Amount of space

According to Finnish norms there should be between 7,5 - 10 m^2 of net floor area per pupil in schools. Finnish norms allow much more space per user than many other norms. According to British Metric Handbook (Littlefield 2005) there should be 3,8 gross m^2 per pupil plus additional 200 m^2.

In the data there are no networks even near the norm. The smallest average space in a school network is 14 square meters and the largest 20 square meters. The average is 14,37 m^2. There is plenty of space in Finnish schools. This could be seen as an asset, but the problem is the great variation. In the whole data the amount of space per pupil varies between 3 m^2 to 57 m^2.

Does more space per user always mean higher quality? The amount of space can be seen as a benefit only to a certain extent. After certain limit the interaction between individuals suffers due to long distances. According to the user survey there seems to be little correlation between the amount of space and user satisfaction. The huge variation inside networks cannot be seen as a positive factor. The space is one important resource which should be shared in equal amounts between users.

5.4 Cost of facilities

The average cost of facilities (capital costs not included) was 61,5 € per gross m^2 a year. The least expensive network cost 46,2 € per gross m^2 a year and the most expensive network cost 114,3 € per m^2 a year. The highest school building was 223 € and the lowest 27 € per year. Expenses were lower and the variation smaller in bigger units. Bigger units cause less travelling between the units for facility staff, less maintenance objects and so on than smaller units.

Cost per pupil is product cost per m^2 and amount of m^2 per pupil. Because of the excessive use of space, the cost of facilities per pupil was high in all networks. The average expense per pupil was 1,218 € per year. The lowest expense was 216 € and the highest 3,810 € per pupil.

The cost per m^2 is an indicator of the effectiveness of the maintenance organisation and the quality of the structures. However, the most important factor is the total cost per user in a year. The goal of a municipal organization is not to own property but to provide services of high quality on reasonable cost. Whatever measurement we use, the conclusion is that the facilities are too expensive and the variation of the cost is too big.

5.5 Cost of education

However, the cost of facilities is only 20%-25%[1] of the total cost according to our database of 19 municipalities. The biggest expense is the cost of education. This includes salaries, meals[2], transportation, administrations and so on, salaries being the biggest single cost. The cost of education varies between 4,500 € a year per pupil to 32 000 € a year depending mainly on the size of the school.

5.6 Savings

Simulation models were made for all 19 municipalities. The savings of school networks varied between 775 € per pupil to 3 120 € per pupil. The average saving was 134 € per capita, which would mean one percentage point lower taxes. This would mean more than 2,7 M€ yearly savings in a city of 20,000 inhabitants. The savings are big enough to allow complete replacement or renovation of the entire network of public building infrastructure.

On national level the savings would be 0,73 billion € a year. The investment needed would be 1868 € per capita. On national level it would mean 10,2 billion € investment. There would be 3,7 million gross square meters smaller area in buildings, which would have a great impact on carbon footprint.

6. Discussion

The variation and the level of the cost per pupil of either the facilities or the education are unacceptable. Citizens pay the same taxes and some of them get considerably more services per pupil than the others. The quality of services is often related to smaller and less effective units. Many factors of higher quality service environment are only present in reasonably sized units (better ICT, work teams, student support and so on). There is a serious doubt whether the quality of the services has any correlation with the money spent, which makes things even worse. The networks studied have neither high quality nor reasonable cost.

[1] Including capital costs. The expenses are only 10%.

[2] There are free meals in all Finnish schools and day-care centers for everybody

If the service networks had been designed only based on the demography and optimization of the size of the units they would consist of a few larger units in urban centres, accompanied by medium size units in rural areas. No school should be smaller than 300 pupils

This kind of network would resemble scale-free network (Barabási 2002) and would be less vulnerable to either decline or increase of demand. The present networks are random ones based on the optimization of the distance. Distances have lost their importance today, due to downfall of transportation cost and digital revolution.

7. Conclusions

The costs related to facilities are only 20-25% compared to the operative costs. The main conclusion of the study was that the service structure should be studied and planned first; the facilities have only a supportive function. This has not been the approach in municipalities so far. The focus has been on individual buildings and their construction, the operational school networks have been forced to fit into the existing building network.

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Appendices

Appendix 1. Age distribution of facilities per square meter and their cumulative age.