Sustainable mobility by buses
– consequences of public procurement of today

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Abstract

The tendering process for competitive bus transports has been used since 1985 in England and thereafter used in several European countries. The most common method for selecting the winning bid in a public tendering process is to select the bid with the lowest price. In order to guarantee a certain quality the public traffic authority, PTA, often specifies a number of minimum requirements that the bidders must meet to have a chance to win the bidding. The process of choosing the best bid is easier if the demands of the qualifications are well specified and detailed. On the other hand, detailed contracts can force the entrepreneurs to use less environmentally friendly and uneconomical alternatives. The purpose of this paper is to investigate environmental effects of using less specified contracts regarding bus sizes in public bus transports. A mathematical model with binary variables is developed to evaluate the environmental effects of more optimized bus sizes. Data from two different areas in Sweden has been collected, compared, and evaluated in terms of levels of CO_2-emissions. The results of the mathematical model indicate that all parts involved in the public procurement process, the public authority, the entrepreneur and the customers, will gain from more flexible and less detailed contracts. The CO_2-emissions can be reduced by over 30% if the bus operator freely can choose which bus type to use on each tour. The process of choosing the best bid in the public procurement process will be more complicated when the contracts are less detailed compared to current situations. Indeed, if less detailed contracts are used, there is potential that it could lead to more sustainable transports.

Keywords environmental sustainability; bus transports; public procurement; mathematical modelling

1 Introduction

The public bus transport market in Sweden is deregulated and there is a process for the regulations for procurement of public bus transport based on EU public-procurement guidelines. The resulting contracts are very detailed and there is not much inbuilt flexibility regarding for example the bus sizes. The primal goal is that all people which demand bus transport can be offered a seat on the buses. Using large buses with many bus seats for transporting few persons is expensive, both in economical terms and most important in emission terms. It is better for the environment to use buses instead of cars, but that statement is based on the fact that the buses are full or almost full. There is a need for testing other public procurement processes that could result in less specified contracts and that could in turn lead to reduced CO_2-emissions because smaller buses can be used for different trips.

Earlier studies have showed that contracts resulting from the process of public procurement of bus transports, often are very detailed and that can in turn lead to unnecessarily high CO_2 emissions and costs (Lidestam and Abrahamsson, 2010; Lidestam 2011b). The contracts often contain detailed information of what kind of bus size that has to be used on what tour. By eliminating these kind of restrictions and let the bus entrepreneur choose what kind of bus to use on what tour, based on the number of passenger, the CO_2 emissions can be reduced by, as much as, 34% (Lidestam and Abrahamsson, 2010). There is potential to also reduce the costs by using fewer details in the contracts (Lidestam 2011b). The fixed costs for purchasing buses are actually very small in comparison to the variable costs for driving the buses (Lidestam, 2011b). The results from the specific case indicate that the costs could be reduced as well, depending on how efficient the additional smaller buses can be planned. The results indicate that the emissions can be reduced up to 47 % by using smaller buses in traffic and the costs can in worst case increase by 10 %. Anyway, there are possibilities to decrease the costs as well if the operations planning changes. That could be done for example by expanding the planning area for the buses in order to increase the possibility to make use of returns to scale and coordination advantages. Other kinds of entrepreneurs, such as taxicabs, could also be used in addition to the ordinary buses.

An overview of issues in transit economics in general can be found in Gwilliam (2008). The study traces the development of issues in transit economics over the last 50 years and it is concentrated on public land transports. A number of relevant areas within public procurement of bus transports are viewed and discussed in Lidestam (2011a). A general overview of procurement of transports in Sweden can be found in Nilsson (2011). The author has collected information regarding procurement of railway investments, road investments and of public transports. The research is financed by the Swedish Competition Authority. A minor part of the collected research yields public procurement of bus transports. Nilsson (2011) emphasizes the problem of getting the information from the traffic authorities and he also meant it therefore was very time consuming. Around 90 procurements from the year 2000 to 2009 have been identified but only 45 of them contained complete information. The collected information regarding the procurements is for example which kind of contract form that is used, the extension of the procurement, the involved traffic authority and how many bids that have been received and the related prices of the bids.

The aim of the paper is to use optimization models to test and evaluate the effects of using less specified contracts in order to achieve more sustainable bus transports in two areas, with different physical and organizational conditions, in Sweden. A mathematical model is used and real data provided by a Swedish bus entrepreneur for evaluating the public procurement of bus transports is exposed. The objective is to minimize the CO_2-emissions with preserved public welfare and with preserved service for the bus passengers.

By using a mathematical model, the very detailed contracts resulting from the process for public procurement can be compared to more flexible contracts with fewer specified rules for planning the bus transports. The results from the optimization model show that detailed rules in the public procurement process may lead to increased CO_2-emissions, and therefore it would be high motivated by the politicians to evaluate the Swedish system. The research will therefore contribute to the overall aim to reduce CO_2-emissions.

The outline of the paper is as follows. In Section 2 some general comments of public procurement of bus transport services are given. In Section 3 the mathematical model for the problem is formulated. Data from two real-life cases is studied and presented in Section 4. The solution method, as well as, the computational results from five different scenarios are presented in Section 5. Finally, in Section 6, some concluding remarks are viewed.

2 Public procurement of bus transport services

A number of nations has converted their public transport systems from monopoly transit systems to competitive tendering. One of the first regions to use fully-tendering regime was London in 1985 (Hensher and Wallis, 2005). An overview of the general competition for public transports in the world is presented in Cox and Duthion (2001). They have studied in what way the conversion to the system of competitive tendering has affected the productivity within the public transport sector in different countries. The tendency has during the last two decades been to use competitive tendering for public transports and the new system has led to lower costs. In average for the places in their study (Köpenhamn, Denver, London, San Diego and Stockholm) the productivity has increased by 2.7% (Cox and Duthion, 2001).

Hensher and Wallis (2005) give an overview of international successful and less successful ways to use competitive tendering as a possibility to decrease the subsidies within the business of public bus transports. They present a rigorous comparison between a number of countries where among others the level of decrease in costs in the bus transports depending on the transfer to competitive tendering. The level is an average 20-30% when the administration costs have been excluded (Hensher and Wallis, 2005). They emphasize, however, that the costs have a tendency to be low at the first time competitive tendering is used and the instead increase for the second and third time the system is used. This form of tendering often leads to changes of the structure of the actors involved in the process. Going from a market including many small actors, the actors are now few and large (Hensher and Wallis, 2005). The competitive tendering system has worked satisfactory in most of the European countries. Two exceptions are Italy and France where the transfer to the competitive tendering system has not affected the transports costs at all (Boitani and Cambini, 2006).

Estache and Mez-Lobo (2005) describe how the competitive tendering in public transports has affected the circumstances in developing countries. In countries where the citizens in general have higher wages, the interest of using buses is greater than in countries where most of the people have low wages (Estache and Mez-Lobo, 2005). They also present a hybrid model which combines the advantages with a monopoly situation with the advantages with increased competition, but they point out that there are a lot of risks by developing such a system (Estache and Mez-Lobo, 2005). If one has to choose between a system of monopoly and a system of perfect competition, the authors still advise a system with competition, because that such a system will gain the users (Estache and Mez-Lobo, 2005).

The system for public procurement in Sweden started through a national resolution in 1985, which led to a law coming into effect in 1989 (Elvingson, 2005). The market in Sweden is deregulated and there is a process for the regulations for procurement of public bus transport based on EU public-procurement guidelines. The part of traffic being involved in the public procurement processes has been drastically increased since and is now (2009) around 90%. The structure of the traffic market in Sweden has as well as in others countries that have transit to competitive tendering, changed from many small actors to few large actors (Elvingson, 2005, SLTF, 2002).

The contracts regarding bus transports can be of different types. The three most common contract forms are gross contract, net contract and incentive contract. Gross contract imply that the bus entrepreneur gets paid for the related costs regarding the bus transports. The contract states that the operator is only paid for the number of kilometers or hours driven. All ticket revenues are paid directly to the public transport authority. If the net contract is used all the revenues from the ticket sales go directly to the bus entrepreneur and can therefore be seen as an incentive to get more passengers on the buses. The incentive contract form is a combination of a gross contract and a net contract. The form has been used for example in Norway (Carlquist, 2001, Dalen et al., 2006). The revenues from ticket sales go to the public transport authority, but some kind of poundage based on either the number of passengers or the level of the quality accrues the entrepreneur. The most common contract form in Sweden is gross contract. Sonesson (2006) describes the contract forms in detail and he also analyzes their advantages and disadvantages in what way they affect the citizens. Sonesson (2006) also raise the question of which aim to strive for; the aim of the businesses or the aim of the society and he means they are not the same.

Regardless of which form of contract that has been constituted, the resulting contracts will be very detailed and therefore include a low level of inbuilt flexibility. Everything, from which colour of the curtains to choose, to which kind of engine to use in the bus, can be specified in the contracts. Nilsson (2011) states that one reason for increased costs for public transports in Sweden can be the trend to put more and more instructions in the requests for public procurements. The demand for newer buses together with more environmental demands could have caused higher costs in the business. While these possible demands are affecting the resulting contracts there is a need for a better understanding of the current requests which originate from the foundation for the process of public procurement of bus transports.

In summary there is some research done in the area of public procurement and different kind of methods for choosing bids and what kind of contract form to use, but there is a lack of research done in the area of studying the consequences of the effects on the environment using different levels of specifications in the contracts.

3 Mathematical model

In this section we present the mathematical model for the problem of evaluation of public procurement of bus transports. The results of the model will give a solution that uses as small bus sizes as possible. The model consists of an objective function, binary variables, parameters and constraints. We first describe the parameters and the variables. Thereafter the objective function is presented and finally, the constraints are described.

Parameters

h_i = CO_2 emissions measured in kilogram per kilometer from bus type *i*.

a_{kj} = the distance from stopping place *k* to the next stopping place at line *j*.

e_{kj} = the number of people getting on the bus at stopping place *k* at line *j*.

r_{jk} = the number of people getting off the bus at stopping place *k* at line *j*.

P_i = the capacity for bus type i measured in number of seating places.

Variables

$$B_{ijk} = \begin{cases} 1, & \text{if bus size } i \text{ is used from stopping place } k \text{ to the next stopping place on line } j \\ 0, & \text{else.} \end{cases}$$

i = 1..m
j =1..n
k = 1..h

Objective function

Min $\sum \sum \sum a_{jk} h_i B_{ijk}$

Constraints

$$\sum_i P_i B_{ijk} \geq e_{1j} \quad \forall j,\ \forall k : k = 1 \quad (1)$$

$$\sum_i P_i B_{ijk} - \sum_{k=1}^{k-1} e_{kj} + \sum_{k=1}^{k} r_{jk} \geq e_{kj} \quad \forall j,\ \forall k : k \geq 2 \quad (2)$$

$$B_{ijk} \geq B_{ijk-1} \quad \forall k \geq 2, \forall i, \forall j \quad (3)$$

$$B_{ijk} \in \; 0,1 \quad (4)$$

The objective function minimizes the CO_2-emissions. The distance between all stopping places at the lines is multiplied with the CO_2-emissions from the different bus types, respectively. The constraints (1) make sure that the capacity of the used buses is enough that is that all of the people that get on the bus at the starting point have a seat on the bus. The constraints (2) ensure that all the people getting on the buses at the forthcoming stopping places gets a seat on the used buses. The fact that one bus has to follow the whole line after it has started is described in the constraints (3). The constraints (4) express that all variables are binary, that is they could either be 1 or 0. Constraints (3) also allow buses to start on a later stopping place along the line, but it has to continue to drive to the end of the line. If there is no possibility to add buses along the line the constraints (3) can instead be described as constraints (5) given below:

$$B_{ijk} = B_{ijk-1} \quad \forall k \geq 2,\ \forall i,\ \forall j \quad (5)$$

Some of the parameters are illustrated in Figure 1. The line *j* includes four stopping places, *k*, where the first one is a starting place with no people getting off the bus. One bus of size *i* is used in the example and we can see that three passengers, r_{kj} , have get off the bus at the second stopping place and three passengers, e_{kj} , are waiting for the bus at the third stopping place along the line.

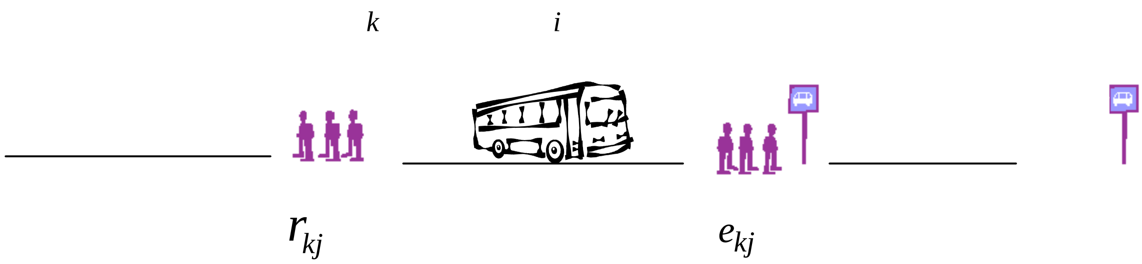

Figure 1. Illustration of a bus line *j*.

The model does not consider any limitations of the number of buses that can be used for different lines. The distance between one stopping place at one line and a starting place at another line and the distance to the bus garage is not regarded in the problem. The different times for the lines are counted only as different lines so the time aspect and any possible limitations of the use of different bus types has not been considered as well in the problem.

4 Case studies

Nobina Bus AB is the largest bus transport company in the Nordic countries and one of the ten largest in Europe. Its market share in Sweden is 30% and it has 7 700 employees (Nobina Bus AB, 2010/2011). Nobina Bus AB works for different public authorities in Sweden. All data in this study is public but data is in these cases provided by Nobina Bus AB. The two public traffic authorities used in this study are Västtrafik and SL (Storstockholms Lokaltrafik) and they are further described below.

4.1 Västtrafik

The case study from Västtrafik is based on data on people getting on and people getting off at each stopping place collected from a so called RUS- investigation. The RUS- investigation was done in the autumn 2007 and the data regarding the number of people getting on and off the bus at each stopping place has been collected during two weeks presenting a 24-hour workday. The parameters for distances are from the database at Västtrafik and the data regarding CO_2 -emissions is based on the estimates from SLTF (Svensk kollektivtrafik, 2009).

The data in this study is collected from the area of Skaraborg in Sweden. The region is placed between the two biggest inland lakes, Vänern and Vättern and includes 15 smaller municipalties. Around 255 000 citizens are living in Skaraborg and the largest town with 33 000 citizens is Skövde. Other towns with more than 10 000 citizens are Lidköping, Falköping, Mariestad and Skara. 27% of the population lives in the countryside and the rest of the population lives in the towns.

4.2 SL

SL is a public traffic authority that is controlling the traffic supply of the area of Stockholm. Stockholm is the capital of Sweden and the area is very populously compared to other towns in Sweden. Around one million Swedes are living in Stockholm. The public transport in Stockholm consists of buses, trains and an urban railway system. The area in this study is called Kallhäll and is placed in North West of Stockholm. Only buses are used in this area. The name of the municipality is Järfälla. The largest city in the area is called Jakobsberg and the number of citizens is over 67 000.

4.3 Data

The number of lines is 103 and 19 in Västtrafik and SL, respectively. The lines are divided into several sub lines depending on the number of stopping places along the line. For each line there are different variants of the line. The variants differ regarding the included stopping places and their order. Each variant of a line is used several times in a 24 hour. The number of the different objects in the cases and sizes of the problem symbolized in number of binary variables and constraints are presented in Table 1.

Table 1. The size of the test problem

Object	Västtrafik	SL
Lines	103	19
Variants	664	102
Times	2 059	1 292
Bus types	7	2
Additional bus types	2	3
Stopping places	2 037	292
People getting on (and off) the buses	34 312	37 411
Binary variables	388 680	55 550
Constraints	501 731	105 932

The types of buses used by Västtrafik and SL are presented in Table 2. For each bus type, the related seat capacity and CO_2 emissions are given.

Table 2 Different type of buses used by Västtrafik and SL

Type of Bus	Seat capacity	CO_2 emissions
Västtrafik		
City bus diesel	32	0,98
Low built bus	51	0,83
Express bus, small	53	0,86
Express bus, large	56	0,96
Countryside bus	54	0,94
Low built bus service bus	29	0,79
Service bus	23	0,99
SL		
Normal bus	34	1,09
Articulated bus	50	1,34

The CO_2-emissions are defined by kilogram per kilometer. The calculations of the emissions are based on road driving with few stops. The most important factor to consider in this paper is the difference in emissions due to the size of the bus type, which in this case is measured in number of seats in each bus type. Therefore the other depending factors, for example type of engine and driving properties are equal in of all the bus types. The considered engine in all of the bus type is a euro3 engine. The newer engine euro5 has fewer emissions but the difference is mostly related to the NOx-emissions and SOx. The buses used in the area of SL have higher levels of emissions.

That depends mostly on the physical conditions at the current area. This area is much hilled and therefore the levels of CO_2-emissions are counted higher. Although the area is hilled the average speed is higher compared to the area of Västtrafik. Higher speed also makes the CO_2-emissions higher.

In this project, we have been working with average figures on fuel-consumption and CO_2-emissions, where CO_2-emissions are considered proportionate to fuel-consumption. The major factors effecting fuel-consumption for heavy vehicles are friction losses in transmission, air-resistance, road-condition and drivers behavior, while the difference in fuel-consumption between a maximum loaded and empty vehicles are minor (Forsberg & Löfroth, 2002). Therefore, the fact that a full bus has more CO_2-emissions in comparison with an empty bus has not been considered in the optimization, however, it can be calculated be evaluated after the optimization has been made if needed.

Restrictions given in the contract regarding which type of bus to use on which traffic line in the cases of Västtrafik and SL are presented in Table 3. It can be noted that several bus types can be used in the case of Västtrafik and even the restrictions on what bus type to use are more compared to the case of SL.

Table 3. Demand of a bus type on a certain line.

Bus type, Västtrafik	**Number of lines**
City bus diesel	2
Low built bus	16
Express bus, 15	3
Low built service bus	4
Service bus	2
Bus type, SL	**Number of lines**
Normal bus	11
Articulated bus	8

5 Solution method and computational results

The mathematical programming model presented in Section 5 is a model that includes only binary variables. We have used the program, AMPL (AMPL, 2006), for modeling of the problem and the program CPLEX (Ilog, 2009), version 10.2.0, is used to solve the model. These programs are suitable when the mathematical model includes binary or integer variables.

We have generated five different scenarios in order to test the influence of the CO_2 -emissions. The scenarios are presented and described below:

Basic is the basic scenario and shows the current situations. There are rules describing that the City bus diesel, for example, has to be used at two lines. The demand on which type to use at different lines is presented in Table 3. At all other lines, whichever bus types are allowed to be used. In order to force the bus type to be used at a certain line, the connected binary variable is fixed to one before the solution process begins.

Add buses – The possibility to use additional buses along the lines is tested. Sometimes a large bus can drive empty from the starting place to the second last stopping place and then it can get a lot of passengers for the last part of the line.

Figure 4 shows the possibility to use additional buses along the line. In the case illustrated in Figure 4 one large bus is used from the beginning of the line, then a smaller bus is in addition used at the end of the line.

Figure 4. Example of a bus line where two buses are used on the last part of the line.

Free – No restrictions regarding choice of bus type. The results in this scenario show the level of CO_2 emissions when as small buses as possible, with respect to CO_2 emissions, are used. Only the buses used by Västtrafik are included in the scenario.

Add bus types – The same circumstances as in scenario *Free* but the possibility to use other bus types, one large bus taking 65 passengers and one small bus taking only eight passengers, is also tested. The additional bus types by Västtrafik and SL and the related capacity and CO_2 emissions are given in Table 4 and Table 5, respectively.

Table 4 Additional type of buses at Västtrafik

Type of Bus	Seat capacity	CO_2 emissions
Countryside bus _2	65	1,15
Service bus _2	8	0,3

Table 5 Additional type of buses at SL

Type of Bus	Seat capacity	CO_2 emissions
Boggie bus	45	1,17
Middle bus	20	0,85
Mini bus	12	0,48

Due to the additional bus types, the number of variables in this scenario is 437 265 instead of 388 680 and the number of constraints is now 546 228 instead of 501 731 as in the other cases regarding the area of Västtrafik. In the area of SL the number of variables is 166 650 instead of 55 550 and the number of constraints is 222 200 instead of 105 932.

Hard – We have started with the position in *Basic* and then tested to add restrictions on what type of bus to use at every line. The added restrictions tell that the Expressbus_15 has to be used on all other lines besides the lines presented in Table 3 (the basic case).

A summary of the scenarios and their properties are presented in Table 6.

Table 6. The properties of the scenarios.

Scenario	Possibility to add buses along the line	Bus sizes for some lines are fixed	Bus sizes for all lines are fixed	Possibility to add other bus sizes
Basic		x		
Add buses	x	x		
Free	x			
Add bus types	x			x
Hard	x		x	

The resulted levels of CO_2-emissions from the different scenarios are presented in Table 7 regarding Västtrafik and in Table 8 regarding SL. The level of CO_2 per year is calculated based on the level of emissions per 24 hours workday. The bus traffic on workdays is on average four times more intense compared to the bus traffic on Saturdays and Sundays. We have estimated the number of workdays in a year to 245 and the official holidays, including Saturdays and bridges days, to 120.

Table 7. The results from the different scenarios - Västtrafik

Scenario	**CO_2 kg/24 hours**	**CO_2 kg/ year**	**Difference**
Basic	42 346	11 645 150	0%
Add buses	41 820	11 500 500	-1,2%
Free	36 141	9 938 865	-14,7%
Add bus types	27 832	7 653 800	-34,3%
Hard	45 582	12 079 230	+3,7%

Table 8. The results from the different scenarios - SL

Scenario	**CO_2 kg/24 hours**	**CO_2 kg/ year**	**Difference**
Basic	20 639	5 675 725	0%
Add buses	20 628	5 672 700	-0,05%
Free	20 372	5 591 520	-1,5%
Add bus types	14 418	3 964 950	-30,1%
Hard	24 605	6 766 375	+19,2%

The results from the different scenarios, indicate a clear relation between CO_2-emissions and contract-flexibility. The difference between the scenario with the lowest level of CO_2-emissions, scenario *Add bus types*, and the scenario with the highest level of CO_2-emissions, scenario *Hard* is as much as 4 425 430 kg based on a year in the area of Västtrafik. By defining specifications of what bus size to use on different lines the CO_2-emissions can increase by 57 % based on a year. If we compare the current situation at Västtrafik, scenario *Basic*, representing a rigid contract with defined bus-sizes and scenario *Add bus types*, representing a more flexible contract where the bus-company is using a bus-size adapted to actual demand, is 34% less CO_2-emissions, indicating a significant potential in a more CO_2-optimized bus-system. There is no possibility to add buses along the line in scenario *Basic* and scenario *Hard*. That condition explains the fact that fewer, but larger, buses are used compared to the other scenarios. More buses on a line results of course in more bus drivers and there is a trade-off between the fixed costs of having several bus drivers and the ambition to drive as small buses as possible in order to reduce the CO_2-emissions.

The results regarding the area of SL show that the CO_2 -emissions can be reduced by 1,5% if there were no restriction at all regarding which bus type to use at which tour. The difference in this area is not so big compared to the case of Västtrafik. On the other hand, the possibility to use other bus types as considered in scenario *Add bus types,* shows that the emissions can be reduced considerably. The CO_2 –emissions are reduced by 30% by using smaller bus types. There are only two types of bus to use in the area now, articulated buses and normal buses.

The importance of deciding which bus size to use on which line is illustrated in Figure 5 and 6. The same line is considered in Figure 5 and Figure 6. In the scenario *Basic*, *Add buses* and *Hard*, the Express bus with 56 seats had to be used on the line in our example. The highest number of passengers on the bus was eleven on the first part of the line and then it decreased to five and six passengers respectively. That led to more than 80% empty seats along the whole line. In scenario *Free* the restrictions on bus types were removed and the smallest bus size as possible could be chosen. In Figure 6 we can see that the bus type with 29 seats had been chosen. That reduced the number of empty seats along the line from 80% to 62%. In scenario *Add bus types* other kind of bus types could be used, but in this case there was no appropriate bus size to use other than the one with 29 seats used in scenario *Free*. The examples are taken from Västtrafik.

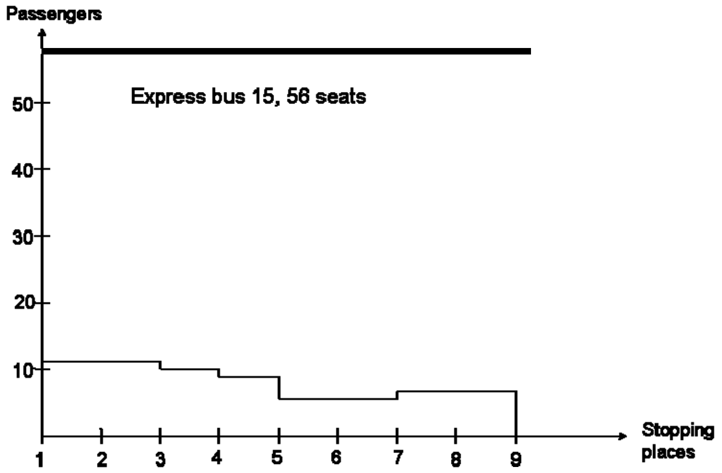

Figure 5. Illustration of the difference of the seat capacity and the number of passengers on a line in scenario *Basic*, *Add buses* and *Hard*.

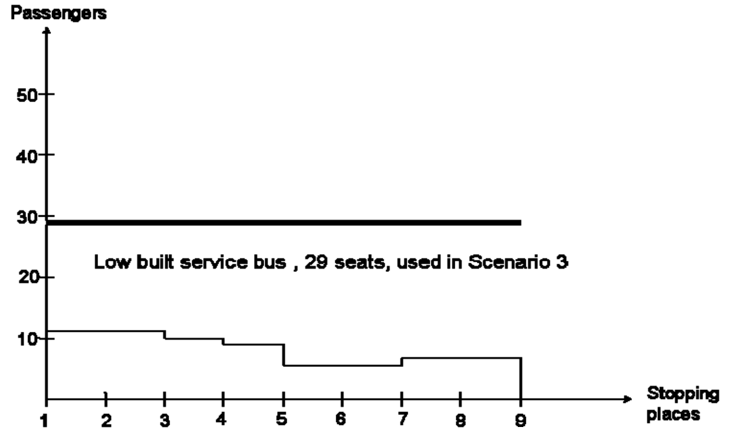

Figure 6. Illustration of the difference of the seat capacity and the number of passengers on a line in scenario *Free* and *Add bus types*.

The number of passengers on the buses between all stopping places on all tours is given in Figure 7. The y-axis shows the number of passengers and the x-axis expresses the number of sub tours for all buses. As can be seen in the figure, most of the time the number of passengers on the buses is below 30. That indicates a need for smaller buses in addition to the big articulated buses. The data is taken from the case of SL.

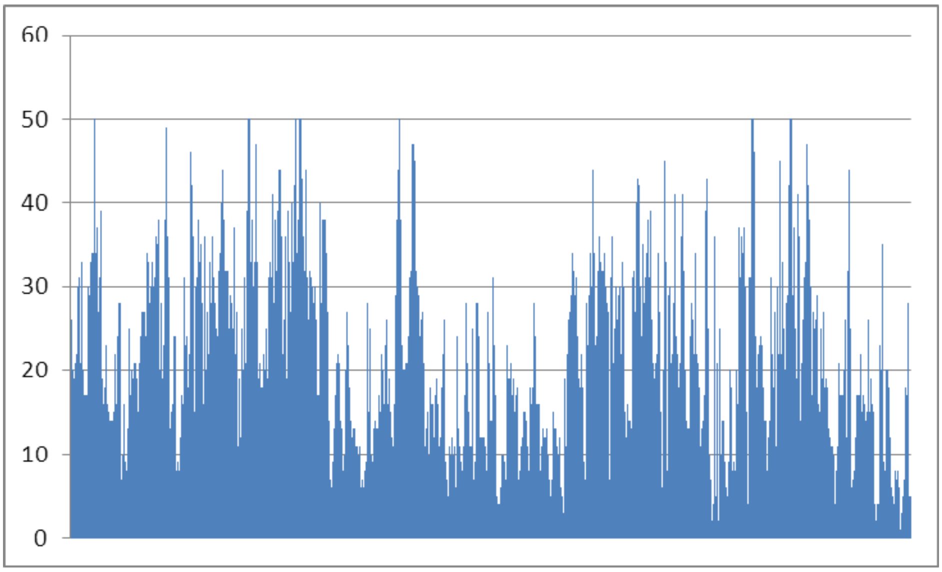

Figure 7. Illustration of the number of passengers on the buses on the tours in the area of SL.

6 Concluding remarks

The purpose of the paper was to use optimization models to test and evaluate the effects of using less specified contracts in order to achieve more sustainable bus transports in two areas, with different physical and organizational conditions, in Sweden. The effects on the CO_2-emissions derived from using different kind of rules for which bus types to use on which lines were investigated. Real data was provided by a Swedish bus entrepreneur, Nobina Bus AB, and the regions of Skaraborg and Kallhäll, were tested and analyzed. The names of the public authorities at these regions are Västtrafik (Skaraborg) and SL (Kallhäll). The results indicated that the CO_2-emissions can be reduced considerably if the bus operator (Nobina Bus AB in this specific case) can choose whatever bus type it wants. The CO_2-emissions can decrease by 34 % in the area of Västtrafik and by 30 % in the area of SL. Despite different physical and organizational conditions between the areas the results were almost the same regarding how much to earn from more freedom regarding which bus type to use on which line.

The mathematical optimization model is developed in order to be used as a decision support tool in the process of deciding how much the flexibility of public procurement can join the process. The model will also be used as simulation model for testing different scenarios in the planning situation for bus operators. This kind of decision support tool can be very important in the process of developing a sustainable transport system where the political decisions can be based on more environmental facts.

By using mathematical models for subsystems and components, the very detailed contracts resulting from the process for public procurement can be compared to more flexible contracts with fewer specified rules for planning the bus transports. Components that can be compared and evaluated are the use of different bus sizes, finding the best bus sizes, using and coordinating demand responsive transports and using more flexible timetables for buses. The results from the optimization models show that detailed rules in the public procurement process can lead to increased CO_2-emissions, which is interesting direct for the involved company Nobina Bus AB, but also for other bus operators as well as for the society in arguing for a reevaluation of the Swedish public procurement system. Using less detailed instructions in the foundations for public procurement of bus transports can however make it more difficult for the PTA to choose the winning bid in the tendering process. Instead of only choosing the bid with the lowest price, they may have to consider both price and quality and decide appropriate weights them between.

Directions for future research can for example be to examine the environmental effects on other restrictions in the contracts. Very detailed environmental demands on the buses could for example lead to unnecessary high costs spending on buying new buses and discarding functional not new buses. The possibility to use buses only for parts of the lines can also be tested and evaluated. Another adjacent problem is to find the optimal size of the buses and in addition to consider a bus fleet of a certain size.

References

AMPL (2009), "AMPL: A modeling language for mathematical programming", available at: http://www.ampl.com
(accessed 15 June 2012).

Boitani, A. and Cambini, C. (2006), "To bid or not to bid, this is the question: the Italien experience in competitive tendering for local bus services", European Transport, Vol. 33, pp 41—53.

Carlquist, E. (2001), "Incentive contracts in Norwegian local public transport: The Hordaland model", Institute of Transport Economies, Oslo, available at: http://www.thredbo.itls.usyd.edu.au/downloads/thredbo7_papers/thredbo7-workshopD-Carlquist.pdf
(accessed 15 May 2012).

Cox W. and Duthion B. (2001), "Competition in urban public transport- a world view", paper presented at 7 th International Conference on Competition and Ownership in Land Passenger Transport, June, Thredbo 7 Molde, Norway, available at: http://www.publicpurpose.com/ut-thredbo7.pdf

Dalen, D. M., Moen, E. R. and Riis, C. (2006), "Contract renewal and incentives in public procurement", International Journal of Industrial Organization, Vol. 24 pp 269—285.

Elvingson, P. (2005), "Bättre kollektivtrafik", ISBN 91 558 6951 3, Svenska Naturskyddsföreningen, Stockholm.

Estache, A. and Mez-Lobo, A. (2005), "Limits to competition in urban bus services in developing countries", Transport Reviews, Vol. 25 No. 2, pp 139—158.

Forsberg, M., and Löfroth, C. (2002), "TRANSMIT – kvalificerad IT i fyra virkesfordon", Skogforsk Resultat, nr 18 ISSN 1103-4173, Skogforsk, Uppsala.

Hensher, D., A. and Wallis, I.,P. (2005), Competition tendering as a contracting mechanism for subsidising transport – The bus experience, Journal of Transport Economics and Policy 39, pp. 295-321.

ILOG CPLEX (2009), "IBM ILOG Optimization Products", available at: http://www-01.ibm.com/software/websphere/products/optimization/
(accessed 15 June 2012).

Lidestam, H., 2011a. Public procurement of bus transports – a literature review, in Proceedings of the 23th Anniversary NOFOMA 2011 logistics conference held in June 2011 at the University of Harstad, Norway.

Lidestam, H., 2011b. Sustainable bus transports through less detailed contracts, in Linköping Electronic Conference Proceedings, No. 57. World Renewable Energy Congress 2011, May 8-13, Linköping, Sweden.

Lidestam, H., Abrahamsson, M., 2010. Mathematical modelling for evaluation of public procurement for bus transports in terms of emissions. Management of Environmental Quality 21(5), 645-658.

Nilsson, J-E., 2011. Kollektivtrafik utan styrning. Expertgruppen för studier i offentlig ekonomi, 2011:6, Finansdepartementet, Regeringskansliet. (in Swedish), available at http://www.eso.expertgrupp.se/Uploads/Documents/Rapport_2011_6.pdf (accessed 26 June 2012).

Nobina Bus AB (2012), Annual Report 2010/2011, available at: http://investors.nobina.com/files/press/nobina/Nobina_Annual_Report_2010_sv.pdf (accessed 10 May 2012).

SLTF (2002), ”Kollektivtrafiken i Sverige – samordning och konkurrens”, available at: http://svenskkollektivtrafik.se/Global/Fakta%20och%20publikationer/publikationer/Kollektivtrafiken%20i%20Sverige_2002_06_10.pdf (accessed 30 May 2012).

Sonesson, T. (2006), “Optimal System of Subsidization for Local Public Transport”, VINNOVA Report, Series #: VR 2006:09, Vinnova, Stockholm.

Svensk kollektivtrafik (2009), ”Miljökalkyl 2009”, available at: http://www.svenskkollektivtrafik.se/Medlemsservice/Vart-miljoprogram/ (accessed 15 June 2012).