DECOMPOSITION OF TECHNICAL EFFICIENCY OF SELECTED CITY LIBRARIES FROM THE CZECH REPUBLIC

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Abstract: *The aim of this article is the determination of the gaps of efficiency of 33 city libraries using decomposition of technical efficiency to pure technical efficiency and scale efficiency. The first model estimates the technical efficiency of city libraries from the perspective of the traditional mix of inputs and outputs that are applied in the DEA models; the inputs are represented by the so-called production and technological resources, and the output is represented by the actual demand given by the number of customers. The second model estimates the technical efficiency of operating conditions of selected city libraries against the actual number of visitors, whilst it is based on the assumption that a city library shall have an appropriate space, optimal access in the form of operating time, and optimal number of places for studying. The results depend on the input or output orientation of models and on the expected returns to scale. As the key gaps of efficiency, the models marked – non-topical and large library collection, number of readers and visitors, and also unutilized spaces of city libraries.*

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Keywords: *City libraries*, *DEA models, Pure technical efficiency, Scale efficiency, Total technical efficiency.*

JEL Classification: *H10, C67.*

Introduction

Public libraries are the most numerous cultural facilities in the Czech Republic providing public services. According to the National Information and Consulting Centre for Culture (NIPOS), there were, to the date of 31. 12. 2015, 5,354 public libraries in the Czech Republic, of which 5,338 were established by municipalities (it is the case of municipal and city libraries). Public libraries provide public services according to the Library Act (a. n. 257/2001 Coll.), concerning library and information services, but also cultural-educational services.

Public libraries established by municipalities depend on the limited resources of public budgets, and subsequently on the amount of interest of citizens in their services. Comparable experience is shown by professional foreign researches. Stenström and Haycock (2014) researched the factors that influence political decision making on funding of public libraries in Canada, and they point out the strong position of good-quality relationships of libraries with the local community. According to Michnik (2015), public libraries usually have low political priority; nevertheless, specific local approaches of politicians towards libraries in Sweden are mostly given by the political composition, library's plan, and by the number of population.

Thus, it is no surprise that efficiency belongs to the key issues of municipal libraries. Efficiency is from the biggest part influenced by the amount of demand, which is represented by visitors and readers of libraries, especially among citizens of a given

municipality, but also among people working or studying in the given municipality. On the other hand, the amount of demand is determined by the modernity and topicality of the supply, which means the library collection and the educational and cultural events.

Considering that it is difficult to express efficiency by financial inputs and outputs in case of public services, and that due to the absence of direct payments for provided services by customers, the technical efficiency can be used to express it. Technical efficiency belongs to the set of so-called input-output models of performance. Theoretical basis of the input-output model consists of works by Debreu (1951) and Farell (1957). In the conception of the above-mentioned authors, the technical efficiency of a decision-making unit can be measured by the ratio of its inputs and outputs, nevertheless, always considering the differences in technology of production, production process, and in environment of assessed decision-making units (Lovell, 1993). Abdourahmane, Bravo-Ureta and Rivas (2001) determine the technical efficiency as an ability of an organization to produce the maximal amount of output with the given amount of inputs, and by the given technology.

The measurement of technical efficiency is a very urgent topic of many theoretical and research works during last fifty years. During this period, a group of various methods was developed for the measurement of efficiency. To main, and outstanding in popularity, methods, which are based on the estimation of production frontier while calculating the efficiency, belong – Stochastic Frontier Analysis and Data Envelopment Analysis (DEA), (Čechura, 2009). For the needs of the modelling of technical efficiency of city libraries, the non-parametric DEA model was chosen. It uses the tools of mathematical linear programming.

The aim of this article is to determine the gaps of efficiency of city libraries using the decomposition of technical efficiency to pure technical efficiency and to scale efficiency.

The decomposition of technical efficiency is estimated using the basic DEA models, by two models that are determined by specific input and output variables of selected 33 city libraries, corresponding to the number of population served in the range of 15-35 thousand of inhabitants.

The first model estimates the technical efficiency of city libraries from the perspective of the traditional mix of inputs and outputs that are applied in the DEA models; inputs are represented by the so-called production and technological resources, and the output is represented by the actual demand given by the number of customers. The second model estimates the technical efficiency of operating conditions of the selected city libraries towards the actual number of visitors, while it follows the Standard for a Good Library (2015), according to which a library shall have an appropriate space, optimal access in the form of operating time, and optimal number of places for studying.

Within the article, two research questions are being traced:

RQ1: Are basic production resources of city libraries, with regard to the amount of demand, being used in an efficient way?

RQ2: Are technical conditions of city libraries, with regard to the actual number of visitors, being used in an efficient way?

The basic DEA models and their modifications represent a relatively popular tool of estimating efficiency under conditions of libraries, especially of university and public libraries. Vitaliano (1998) modelled efficiency of 184 public libraries in New York; his

work is based on the assumption that the production of public libraries has an exogenous nature, i.e. it is determined by the demand of users on services of libraries (a library cannot decide on the number of loans, or a reading room on the number of visits). Sharma, Leunh and Zane (1999) modelled efficiency of 47 public libraries in Hawaii, and they added the so-called inputs that cannot be influenced by management to conventional variables. Hammond (2002) subjected 99 public libraries in the UK to a research, and he modelled the total and net technical efficiency using the basic DEA models. Miidla and Kikas (2009) modelled technical efficiency of 20 public libraries in Estonia (established by the state) using the DEA models. De Witte and Geyes (2011) published the results of evaluation of technical efficiency using the DEA models on the example of 290 Flemish public libraries. Stroobants and Bouckaert (2014) evaluated efficiency of 79 public libraries in Flanders using the DEA and FHD models. Li and Yang (2014) defined efficiency of public libraries in the USA according to aggregate indicators under conditions of 51 states of the USA also using the DEA model.

1 Technical efficiency: basic models

From the perspective of application, the DEA model is considered to be a universal assessing tool, which means that it can be used, on condition of homogeneity of decision-making units, in the production sector as well as in the sector of services of profit-making and non-profit-making nature. Homogenous decision-making units (DMUs) are created by such set of units that are occupied with the production of identical or equivalent effects, which are denoted as outputs of these units, Jablonský, Dlouhý (2015).

Cooper et al. (2007) and Toloo (2014) consider the CCR model (name by surnames of model's authors – Charnes, Cooper and Rhodes) as the basic DEA model, which assumes the constant returns to scale (CRS). And also, the BCC model (name by surnames of model's authors – Banker, Charnes and Cooper), which assumes variable returns to scale (VRS).

The calculation of efficiency according to the CCR model is performed using the Charnes-Cooper's transformation and converted from linear-fractional programming into a standard programming task. The CCR model assumes constant returns to scale (CRS). In case of the CCR model oriented on the inputs, the calculation is formulated as follows:

$$\text{maximize} \qquad z = \sum_i^r u_i y_{iq,} \tag{1}$$

$$\text{on conditions} \qquad \sum_i^r u_i y_{ik} \leq \sum_j^m v_j x_{jk,} \qquad k = 1, 2, \ldots, n,$$

$$\sum_i^r u_i y_{iq} = 1,$$

$$u_i \geq \varepsilon \qquad i = 1, 2, \ldots, r,$$

$$v_j \geq \varepsilon, \qquad j = 1, 2, \ldots, m.$$

If the z value equals one, the U_q unit is efficient. For inefficient units, it applies that their degree of efficiency is lower than one, i.e. $z < 1$ (Coelli et al., 2005).

The CCR model oriented on the outputs (2) follows the same assumptions as the above-mentioned model (1). Again, in this model, the coefficient of efficiency is determined by the ratio of weighted sum of inputs and weighted sum of outputs; however, such weights are being looked for, so that the g coefficient's value is higher or equal to one. So, for an efficient unit U_q, it applies that the coefficient $g = 1$, and for an inefficient unit that $g > 1$.

The primary CCR model oriented on the outputs is formulated this way:

$$\text{minimize} \qquad g = \sum_j^m v_j x_{jq}, \tag{2}$$

$$\text{on conditions} \qquad \sum_i^r u_i y_{ik} \leq \sum_j^m v_j x_{jk}, \qquad k = 1, 2, \ldots, n,$$

$$\sum_i^r u_i y_{iq} = 1,$$

$$u_i \geq \varepsilon \qquad i = 1, 2, \ldots, r,$$

$$v_j \geq \varepsilon, \qquad j = 1, 2, \ldots, m.$$

The calculation of efficiency according to the BCC model has one additional variable in its objective function (in comparison with the CCR), which corresponds with the restricting condition – condition of convexity, and which will not be restricted by conditions of non-negativity. The BCC model assumes variable returns to scale (VRS).

The on the inputs oriented BCC model's calculation has the following form (3):

$$\text{maximize} \qquad z = \sum_i^r u_i y_{iq} + \mu, \tag{3}$$

$$\text{on conditions} \qquad \sum_i^r u_i y_{ik} + \mu \leq \sum_j^m v_j \quad k = 1, 2, \ldots, n$$

$$\sum_j^m v_j x_{jq} = 1,$$

$$u_i \geq \varepsilon, \qquad k = 1, 2, \ldots, r$$

$$v_j \geq \varepsilon, \qquad k = 1, 2, \ldots, m,$$

$$\mu - \textit{free}.$$

The on the outputs oriented BCC model's calculation has the following form (4):

$$\text{minimize} \qquad g = \sum_i^m v_j x_{jq} + v, \tag{4}$$

$$\text{on conditions} \qquad \sum_i^r u_i y_{ik} \leq \sum_j^m v_j x_{jk} + v, \quad k = 1, 2, \ldots, n,$$

$$\sum_i^r u_i x_{iq} = 1,$$

$$u_i \geq \varepsilon, \qquad i = 1, 2, \ldots, r,$$

$$v - \textit{free}.$$

The degree of technical efficiency, which is calculated according to the CCR and BCC models, is a basis for the calculation of the so-called scale efficiency (SE) according to the formula (5). Cooper et al. (2007) define the scale efficiency as the ratio of the degree of efficiency of a decision-making unit gained by the CCR θ_{CCR}^* and the BCC θ_{BCC}^* model, where the degree of the decision-making unit's SE is lower or equal to one. The formula (5) stated below, considers the orientation on the inputs, whilst the same indicator and procedure can be applied in case of the orientation on the outputs.

$$SE = \frac{\theta_{CCR}^*}{\theta_{BCC}^*} \tag{5}$$

The decomposition of the technical efficiency (6) allows to express the so-called pure technical efficiency (PTE) and the scale efficiency (SE).

$$CCR\ \theta_{CCR}^* = \theta_{BCC}^* \times SE, \tag{6}$$

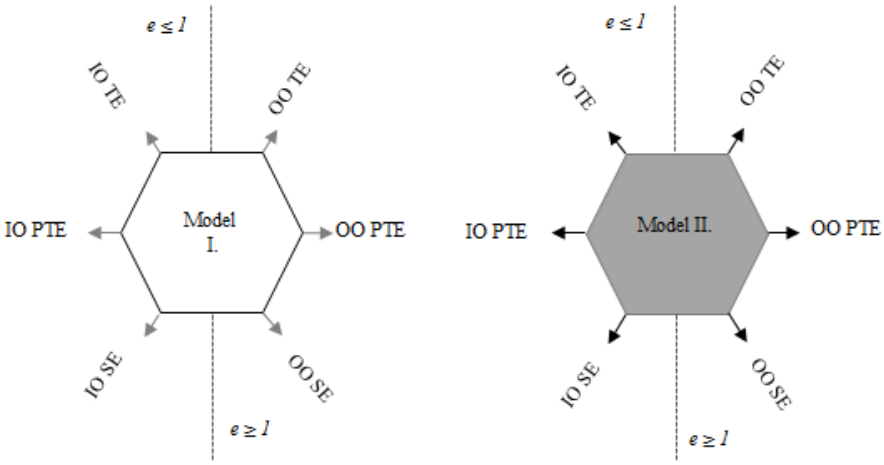
The above-stated facts show that the degree of efficiency calculated by the CCR model is being noted as the total technical efficiency (TE), and the degree of efficiency calculated by the BCC model as the pure technical efficiency (PTE). This specific decomposition explains the sources of inefficiency, thus whether the cause of inefficiency lies in the operation (pure technical efficiency), or in unfavourable conditions (scale efficiency), or in both.

2 Construction of models of technical efficiency of city libraries

The object of the modelling of the technical efficiency, and of its decomposition according to the formulation (6), consists of 33 public libraries from the Czech Republic that correspond to the number of population served in the range of 15-35 thousand of inhabitants. Thus, it is the case of the city libraries. For the needs of the modelling of the efficiency of city libraries, and that according to the basic CCR and BCC of the DEA models, six input variables (x1 – x6) and two output variables (y1 and y2) were selected; their combinations create two models: Model I. (x1, x2, x3; y1, y2) and Model II. (x4, x5, x6; y1). Both models take the input orientation (IO) as well as the output orientation (OO) into account. The schemes of both models are shown in the Fig. 1. In the input-oriented models, an assessed unit (city library) is efficient when $e = 1$, and it is inefficient when $e < 0$. In the output-oriented models, an assessed unit (city library) is efficient when $e = 1$, and it is inefficient when $e > 0$.

The further characteristics of variables (inputs and outputs) are as follows: x1 the number of library units (books, pieces of periodical literature, documents): represents the range of library's collection; x2 the number of employees: expresses the re-calculated number of professional employees of a library to eight-hour employment; x3 educational and cultural events for the public: represents the number of activities organized by a city library for the public during a year; x4 area for users in m^2: includes the total usable area of a library intended for visitors (in the main building and in subsidiaries), for example the free choice, study halls, reading rooms including summer reading rooms, lecture (theatre) halls, and so on; x5 the number of places for studying: represents places for studying for adults, children and for youths, where users can work with library documents and information sources, and that individually or in a group; x6 the number of hours for the public weekly: represents weekly operating hours of city libraries; y1 the visitors (persons): indicates the number of physical visits, thus registered and unregistered users of library's services per year; y2 the number of loans in total: represents the number of loans of library units per year.

Fig. 1: Schemes of Model I. and Model II.



Source: Own processing.

The data for modelling of the technical efficiency were provided from the internal (non-public) database of the Benchmarking of Libraries Project, and that with the agreement of the engaged libraries. Therefore, the selected city libraries are not unequivocally identified; for the needs of the research, they were marked as k1 – k33. The modelling of the efficiency was performed based on the data for the year of 2015, according to the methodology stated below, in the DEAFrontier Add-In for Microsoft Excel program.

3 Results

The results of Model I. and Model II. are described according to the decomposition to the technical efficiency (TE), pure technical efficiency (PTE), and the scale efficiency (SE). Both models follow the input orientation (IO) and the output orientation (OO), and that according to the schemes in the Fig. 1.

3.1 Results: Model I.

The results of Model I. give the answer to the first research question: RQ1 "Are basic production resources of city libraries, with regard to the amount of demand, being used in an efficient way?"

Model I. estimates the efficient production frontier of three inputs and two outputs. The case of inputs is represented by the traditional mix of inputs used in models of technical efficiency; those are: the capacity (capital) – the number of library units; human resources – the number of employees; supply of services – in the form of educational and cultural events. Outputs are represented by the demand, that is the utilization of services of city libraries by their users, and that in the form of the number of loans carried out per year, and the number of visitors of city libraries per year.

The results show that in the models assuming constant returns to scale (TE), the results of efficiency of city libraries are worse than in the models assuming variable returns to scale (PTE), and that both by input- and output-oriented models. In the TE models, 24% of city libraries are efficient (respectively 76% are inefficient), in case of the PTE models, 39% of city libraries are efficient (i.e. 61% are inefficient). By the scale efficiency model (SE), the results are comparable to those in the TE model. Thus, the presented results show that the basic production resources of city libraries, with regard to the amount of demand, are being used in a rather inefficient way.

Tab. 1: Summary results of Model I.

k = 33	Input-oriented models			Output-oriented models		
	TE	PTE	SE	TE	PTE	SE
	a	*b*	*a/b*	*c*	*d*	*c/d*
average	0.831	0.906	0.919	1.246	1.143	1.096
number of efficient	8	13	8	8	13	8
standard deviation	0.141	0.129	0.098	0.264	0.236	0.139

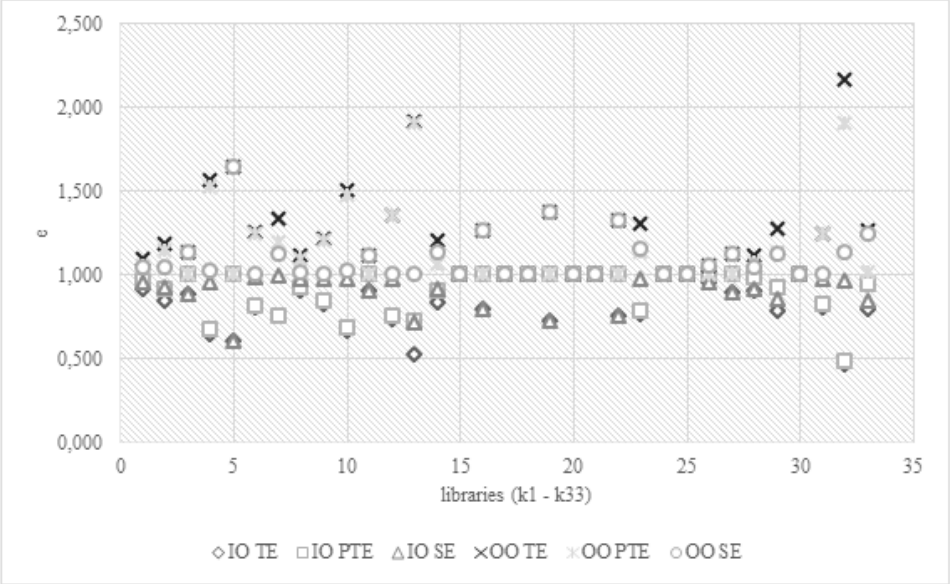
Source: Own calculations.

City libraries that are inefficient in the input-oriented models, should reduce their inputs – so in the case of Model I., it is about reducing the number of library units in the library collection, the number of employees, and also the number of cultural and educational events, because they are not being sufficiently used (productive), regarding the number of visitors of city libraries and the number of loans carried out. City libraries that are inefficient in the output-oriented models, should increase the number of registered readers

and the number of loans carried out, if they want to keep the original values of inputs. The solution lies in the changes on both sides simultaneously, and that by the adequate reduction of inputs and increase of outputs.

The decomposition of the technical efficiency of Model I. is shown in the Fig. 2. This specific decomposition explains the sources of inefficiency, that is whether the operation is the cause (pure technical efficiency), or whether it is about unfavourable conditions (scale efficiency), or both. By the input-oriented model, the source of inefficiency consists of operating resources as well as of operating conditions.

Fig. 2: Decomposition of the technical efficiency of Model I.



Source: Own processing.

The reduction of the number of employees of city libraries has to be approached wisely, and it has to be based on the deeper analysis. Library staff, especially those professionally qualified (librarians), are the key asset, but also the limiting factor of public library and information services. The National Library of the Czech Republic has been monitoring changes in staff in libraries in the Czech Republic in a long term, especially from the perspective of qualification, age, and salary of librarians. The last published research is from the year of 2011, and for example, it follows that the number of employees in libraries has the decreasing trend, although the requirements for quality and quantity of demanded and provided services of libraries rise.

3.2 Results: Model II.

The results of Model II. give the answer to the second research question: RQ2 "Are technical conditions of city libraries, with regard to the actual number of visitors, being used in an efficient way?"

Model II. estimates the efficient production frontier of three inputs and one output. Selected inputs follow the operating background (technical conditions) of city libraries – the area for users, the number of hours for the public, and the number of places for studying. These inputs were set also considering their presence within the Standard for a Good Library (2015).

There is only one output, and that the number of visitors using traditional services of a city library (loans and information) as well as other services, such as cultural and educational events, and others. Tab. 2 presents summary results. Again, they show that

in the models assuming constant returns to scale (TE), the results of efficiency of city libraries are worse (only 15% of efficient units) than in the models assuming variable returns to scale (PTE), and that both in the input- and output-oriented models (24% of efficient units). Scale efficiency (SE) in case of the input-oriented model is approaching results of the TE, and in case of the output-oriented model it is approaching results of the PTE. Thus, the presented results show that technical conditions of city libraries, with regard to the actual number of visitors, are being used in an inefficient way.

Tab. 2: Summary results of Model II.

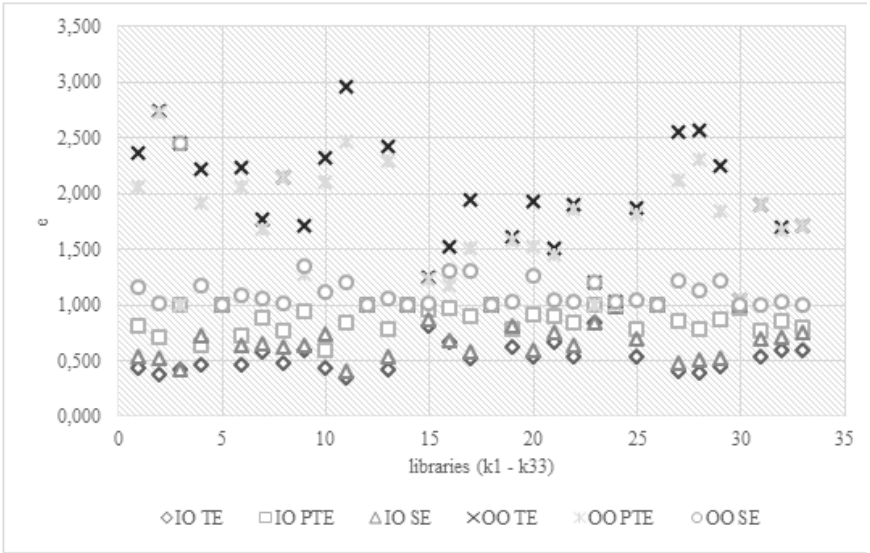
k = 33	Input-oriented models			Output-oriented models		
	TE	PTE	SE	TE	PTE	SE
	a	b	a/b	c	d	c/d
average	0.621	0.863	0.708	1.807	1.614	1.132
number of efficient	5	8	5	5	8	8
standard deviation	0.222	0.113	0.184	0.570	0.496	0.255

Source: Own calculations.

Inefficient units in the input models do not use the area of city libraries, the number of hours for the public, and the number of places for studying, regarding the reached number of visitors, in a sufficiently efficient way. Nevertheless, reduction of the area intended for visitors cannot be easily influenced by the management of public libraries. More possibilities for the management are represented by the changes of operating time (number of hours for the public), and the number of places for studying, but it does not mean to restrict the operation and services of a library. The increase of efficiency in Model II. can be implemented by the increase of attendance, i.e. the output – as it is shown by the output-oriented model.

The decomposition of the technical efficiency is shown in the Figure 3, where a significant variance of efficiency results is obvious in case of the output-oriented models in comparison with the input-oriented models. Based on this, it can be concluded that the operating background of city libraries is being used by visitors with various intensity, whilst city libraries that have smaller operating area and lower number of places for studying, are able to provide services for a comparable and higher number of visitors than city libraries with larger operating backgrounds.

Fig. 3: Decomposition of the technical efficiency of Model II.



Source: Own processing.

4 Discussion

Estimating the technical efficiency according to the basic DEA models and its subsequent decomposition show that basic production resources of city libraries – library collection, employees, and educational and cultural events, regarding the amount of demand – loans and visitors, are being used inefficiently by the majority of city libraries. The results of Model I. show that the library collection fulfils the current needs of readers and visitors of city libraries insufficiently. Notwithstanding that making library documents accessible by a public library, from the perspective of law as well as the visitors of library services, can be considered as the key service, especially by public libraries. The stated facts are also supported by the research of library services of public libraries, which revealed that readers consider the loan service to be the most important service of every library, Stejskal et al. (2013). The example of city libraries from the Czech Republic also confirms the theses of authors Stroobants and Bouckaert (2014), who state that library collection is the main and the key source and tool of provision of library services. The range, content, diversity, topicality and accessibility of the library collection predetermines the supply of services, as well as it limits the demand of services of libraries. In general, it can be stated that the gained knowledge is in unity with the knowledge of Richter (2015), who states that public libraries in the Czech Republic, in comparison with libraries in Germany, have large but non-topical library collections at their disposal, and they experience lower attendance. German public libraries renew their library collections usually three times faster than libraries in the Czech Republic.

Also, the operating background – the area for users, the number of hours for the public, and the number of places for studying of city libraries, regarding the actual number of visitors, are not being used efficiently by most libraries. Nevertheless, the Standard for a Good Library (2015), intended also for city libraries, states that (a) "A library shall have an adequate space, so that it can provide services to the full extent, in compliance with its strategic plan, and local, regional or national standards or directives. A library shall have space for services for the adults, children (including infants and toddlers) and youths, and also for using by the whole families."; (b) "The optimal approach to library services requires that a library is open in the time that is maximally suitable for those living, working, and studying in the place of its operation. This approach should be spread to maintaining telephone connection 24 hours a day, or to assure the access to web pages of selected services."; (c) "A library offers places for studying for the adults, children and youths, where users can work with library documents and information sources, and that individually or in a group. Where it is possible, regarding local conditions, it is appropriate to create reading rooms, studying rooms, and places for a focused studying."

In case of the results of Model II., it can be taken into consideration that the results of the technical efficiency are also influenced by the fact that classic services of public libraries (loans and provision of information) are being moved into online space; paper form of documents is being replaced by the electronic one. This phenomenon is exhibiting also by the lower interest of visitors in using places for studying that are equipped with PCs with the Internet connection. Regarding this, the gained knowledge is in compliance with an international comparison of authors Quick et al. (2013), which confirms that even though the Czech Republic has an above-standard, dense network of municipal libraries, their attendance is lower than the average attendance of municipal libraries in the whole Europe. According to authors Dickinson and Smit (2016), accessibility of library collection is in these days still more an issue of online conditions, and that considering the fact that

online and offline worlds are becoming still more and more interconnected. Memory institutions – libraries are an important source of information, nevertheless they are rarely an initial point for searching for information, as it is shown by the research under conditions of Canadian public libraries.

Based on the results gained from both models, it can be stated that selected city libraries react, within the studied inputs, on the requirements of their customers (readers, visitors) in an inflexible manner and with a delay. Although this research was not tracking qualitative parameters of selected input and output variables, it can be deduced that the causes of inefficiency of a city library consists of not topical library collection, unmodern equipment of public libraries, inappropriately focused educational and cultural events, and inflexible opening hours of libraries. The recommendation for the management of libraries is at least to seek also for the support and interest of the public and communities in the city, beside active communication and cooperation with their establishers. The management of city libraries should apply and develop at least two sources of information as well. The first source should be permanently focused on the needs, wishes and opinions of customers of a city library (readers and visitors). The second approach should be focused on maintaining active partnership with other public libraries in the form of benchmarking. Information gained from both these sources and its correct analysis is the best foundation not only for strategic planning of development of a city library, but also for the needs of communication and negotiation on financial and material support from the involved parties, including the establisher.

Conclusion

This article presents the results of the research that was focused on the determination of efficiency gaps of city libraries using the decomposition of the technical efficiency. The results show that among the key efficiency gaps, affecting achieving efficiency on the example of 33 city libraries, there are too large and non-topical library collection, large and by visitors not sufficiently used spaces, and the studying background of city libraries.

The evaluation of efficiency of 33 city libraries, according to the basic DEA models, clearly shows that the explanatory power of the results depends on the right and justified choice of the input and the output variables. Focusing on a specific variable (e.g. the library collection or the area of a library) changes not only the point of view, but also the results of the efficiency of city libraries. Specific selection of the input variables has to be supported by arguments in relation to the outputs, and vice versa. Selected input and output variables are the limiting factors of the evaluation of efficiency at the same time, and that has to be taken into account in the description and assessment of the results.

The article brings new perspectives for the evaluation of technical efficiency of city libraries, whilst it uses real, non-public data of selected city libraries. Regarding this, the results are valuable not only for academic readers, but above all for the management of municipal libraries, and also for political bodies at the level of municipalities.

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