

MUSEUM ASSESSMENT AND FDH TECHNOLOGY: A GLOBAL APPROACH

François Mairesse¹ and Philippe Vanden Eeckaut²

Abstract

This paper presents a global approach for museum assessment. We define a museum as an entity which needs to be evaluated according to three well defined tasks: preservation, research and communication, and outcomes. We propose a methodology based on the determination of efficiency frontiers. This method assumes a deterministic non parametric and non convex technology (Free Disposal Hull). We analyse technical efficiency, but also scale efficiency with a new restrictive scale approach. We present an ordering of museums into classes representing a level of performance with respect to the three required tasks. We illustrate our analysis using a three year database of museums from the French speaking region of Belgium.

Keywords: FDH, technical efficiency, scale efficiency

JEL Classification: D24

¹ Université Libre de Bruxelles, Bruxelles, Belgium

² CORE and Institut de Statistique, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

We are highly indebted to Victor Ginsburgh for his constant encouragement and dedicated advising on this paper. The usual disclaimer applies.

This text presents research results of the Belgian program on Interuniversity Poles of Attraction initiated by the Belgian State, Prime Minister's Office, Science Policy Programming. The scientific responsibility is assumed by

Introduction

“All public institutions, and museums are not exceptions to this rule, should give returns for their cost; and those returns should be in good degree positive, definite, visible, measurable. The goodness of a museum is not in direct ratio to the cost of its building and the upkeep thereof, or to the rarity, auction-value or money cost of its collections. A museum is good only in so far as it is of use” (Dana, 1920: 13).

Although these sentences were written some 80 years ago, by one of the most influential American museologists of that time, curators would still strongly oppose them today. Different reasons can explain this rejection phenomenon, one of which being that there is no single definition of a museum, an institution with multiple missions. How, therefore, can one calculate the return of such an institution when one does not define exactly what its missions are? And how can one evaluate its achievements, if these are expressed in qualitative terms?

These difficulties make the museum a very peculiar organisation to study, but also a very interesting testground for economic analysis and management methods: if a method can be used successfully for museums, it can most probably be used with any other organisation. And the museum structure can also reveal the limits of the method.

In this paper, we propose to focus on three well defined objectives. First, in order to assess the performance of museums, we define an acceptable representation of their multiple activities. Museums could be seen as research as well as educational or conservation centres. These complementary activities should be identified separately but analysed jointly. For each of these activities, we propose to use a specific production model, based on a nonparametric deterministic reference technology (Free Disposal Hull, abbreviated as FDH). This choice of technology is motivated by the minimal number of assumptions needed. In our model a museum will be evaluated with respect to museums performing well within this technology and therefore considered as “best practice” museums. Second, since many activities can hardly

be undertaken frequently (for example, a medium-sized museum can hardly produce a large exhibition every year), we suggest to base the analysis on several years (possibly moving windows). Third, since the size of an organisation influences its future performance and size cannot be changed in the short run, we suggest to introduce the new concept of restricted scale efficiency, to deal with medium term considerations, while the classical concept of scale efficiency is used to study the long run.

The first section is devoted to a general exploration of the different tools used to assess museum activities. Section 2 focuses on the most recent evaluation tools proposed in the museum literature: performance indicators and the first approaches using efficiency frontiers. In section 3, we develop a multiple mission model for the analysis of museum activities, which we base on a FDH technology. The data used for the analysis are also described there. Section 4 gives a general introduction to FDH technology and a definition of scale efficiency with the restricted approach. In Section 5, we discuss the results of our analysis, and we conclude in section 6.

1. A general introduction to the assessment of museums

According to the International Council of Museums (ICOM), a museum is “a non-profit making, permanent institution, in the service of society and of its development, and open to the public, which acquires, conserves, researches and communicates, and exhibits for the purpose of study, education and enjoyment, material evidence of people and their environment”.³ This definition, generally admitted in the museum world, emphasises clearly the non-profit character of the museum, describes its main activities (acquisition, conservation, research, communication, and exhibition) and, in a very broad sense, its purposes (study, education, and enjoyment). It is very easy, at this stage, to perceive the difficulty of measuring the performance of a museum: profits, as Dana (1920) had already remarked, are not expressed in financial terms. But if “profit is quality” (Di Maggio, 1985), many curators –especially art curators– would never admit that quality could be measured: how would it be possible to

measure such things as study, education or enjoyment? It is mostly for that reason that alternative tools were introduced in order to assess the quality of museum work, but also to legitimise public subsidies. This evolution was not straightforward and may be described by four important steps:

1. The most common use of the term “evaluation” appears with the first public surveys, at the end of the 19th century. Its purpose was to prove that museums were worth receiving subsidies and, as they were public institutions, that “the public was learning something”. This approach is of course mainly connected with the educational mission of the museum. At the end of the 1920s, as American museums were under pressure to prove their utility and justify their funding, more specific studies were developed by psychologists and, later on, by sociologists. The concept (called *museums visitors evaluation*) was then used an impressive number of times. Hundreds of articles were written on the topic, and bibliographies or historical surveys encompassing this trend appeared during the 1980s (Lawrence, 1991; Samson and Schiele, 1989).
 2. In the early 1970s, the American Association of Museums conceived an accreditation program. In opposition with public surveys, the idea of evaluation is developed *from and for* the museum community. The concept of accreditation is much broader than the first one; collections, as well as conservation measures and research programs are taken into account in the process. But the general meaning of the term remains the same. It is another way of demonstrating that the museum's profession is able to reach some standards of quality and, therefore, that the funds they receive will be “adequately” used. The approach remains, however, qualitative.
 3. The concept of “evaluation” also appears in the literature based on the economic analysis of museums. This approach –developed by economists– is more quantitative, and tries to show that museums are worth the funds they need. This conception became important at the end of the 1970s. “Only by a systematic economic evaluation of museum programs
-

and activities can efficient decisions be made in terms of which programs to concentrate upon” (Hendon, 1979). Economic impact analyses or new methods of economic evaluation are supposed to improve these decisions.

4. During the 1980s, the effects of what Zolberg (1981) calls the “managers era” starts to spread within the museum community. Research focuses on the planning and management control process. The tools used reflect the general management literature (Griffin, 1987; Lord and Lord, 1991 and 1997). The quantitative approach is stressed, just as for private companies. The last developments of this approach are concerned with the introduction of “*performance indicators*”, supposed to measure the *performance* of institutions.

2. The museum as a single activity centre

2.1 Approaches based on performance indicators

The concept of performance indicators (PIs), is quite common in the “for profit” sector, but also in some parts of the non-profit one. The quantitative performance of libraries, archives or hospitals is scrutinised, but articles dealing with museums appear in the early ‘90s only. Ames (1990) writes what appears to be the first article on the subject. He proposes a list of some 40 ratios dealing with several aspects of the museum, insisting on its administration (finance, fundraising, human resources, and marketing). This first “manifesto”, which states the main benefits and some of the risks of PIs management, is followed by Jackson (1991), who clearly replaces the measure system in the strategic planning process, and insists on its pitfalls. According to Jackson, while PIs are a concise tool that can measure the progress in achieving goals and objectives, they need to be chosen very carefully, since they can distort reality. If misused, they can become an end in itself, they are short-term oriented and obliterate what they cannot measure, especially because the set of indicators cannot become too large. Finally, the information collected needs to be accurate (not consciously distorted), and not subject to any misinterpretation, especially by the government or by the trustees.

This last argument is essentially connected to the concept of museum PIs comparison. Though an increasing number of museum managers tend to accept the idea of indicators, they only agree on their internal use, and do not think that they can lead to meaningful comparisons between museums (Weil, 1995). For this reason, most of the studies on the topic remained limited to some of the largest and (or) most “management advanced” museums (Bud, Cave and Haney, 1991; Museum Professional Group, 1994; Janes, 1995; Museums Association, 1994; Walden, 1991). Of course, PIs can be very useful to compare a museum’s performance over time, or with a set of goals. But this principle of comparison can give a biased part of the information required: a museum can perform less efficiently than most of its peers, but show very stable indicators.⁴

One of the few attempts to measure the performance of a group of museums was undertaken by the British Audit Commission (1991) which proposed a series of PIs for the analysis of museums subsidised by local governments. The selected indicators expressed a vision of the museum, with which the museum profession did not agree.⁵ But the collection and interpretation of PIs appeared to be difficult. After some time, the entire process collapsed. The Commission argued that it was too difficult to establish PIs for the museum sector.

The whole process of comparison is not only difficult because of the specification and gathering of adequate data, but also because of their interpretation. And if the first objection can be tackled by a discussion between museum curators and managers, the second cannot. First, the comparison has to be relative and not absolute: a museum with 200 scientists will obviously undertake more research than an institution with 5 scientists, and ratios provide a possible, but obviously restricted solution. Secondly, a museum has several missions and several goals, and may decide to focus on certain priorities. The system of PIs cannot take this into account, but the principles embodied in efficiency frontiers analysis can.

2.2 Approaches based on efficiency frontiers

⁴ On the other hand, the determination of the appropriate level of PIs by intuition or by experience is another –but also limited– method. See Ames (1990).

The approaches developed in the previous section deal with partial performance indicators associated with specific objectives. To overcome this limitation, one needs to consider a museum as an “economic activity”, which requires inputs or resources and transforms these into outputs or realisations. The transformation process needs therefore to be defined, and one can consider parametric or nonparametric models (see e.g. Fried, Lovell and Schmidt, 1993).

The technique has already been applied to museums (Paulus, 1996; Mairesse, 1997 and 1998, Taalas, 1998). These papers propose a single model reflecting all museum activities and a single evaluation of its performance. The multiplicity of PIs allowed to compare missions but not museums. Efficiency frontier methods produce a single indicator that allows comparisons between museums but not between missions.

3. The museum as a multiple activities oriented centre

3.1. Motivation

As mentioned above, the efficiency frontier approach used in the context of museums has also its limits and makes it only imperfectly applicable for museum managers or public authorities. So far, the models have not offered a really global perspective of the museum concept. If curators can feel partly satisfied (because the museum indicators give information on technical activities), the managers or subsidising authorities are less so (because the indicators may give no information on the public orientation of the museum, or on its economic aspects), and vice versa. Moreover, most of the contributions on the subject were connected to the economic literature, but hardly to the literature on museums, and this can be seen as a serious weakness in the construction of the museum model.

Therefore, to be taken seriously by curators, the efficiency frontier approach should be based on a complete description of the activities of a museum, in connection with existing museum theories. This description does include not only the output or the technical activities, but also the connections between the museum and its community, in order to give a global point of

view that satisfies jointly the curator, the educator, the manager and the public authority. The model should not only be applied to “one shot” analyses (one year), but be used in a long term perspective. We have the feeling that the short term does not fully reflect the activity of a museum. For example a medium or large scale exhibition takes at least two or three years to prepare but the indicator will only reflect the final result. This applies for most of the activities: research, conservation, publications, etc. Consequently, we suggest to work on the basis of three years “windows”⁶, which aggregate data over three years.

3.2. Models

Museums have several missions and functions, which can hardly be ranked by order of importance: research cannot be undertaken without conservation, but the reverse is true also. All the main functions such as acquisitions, research and exhibitions (and all museologists and curators agree on this) are equally important. This does not mean that the activity of a museum cannot be schematised, and different models were suggested. Noble (1970) distinguishes five main activities: collection, conservation, study, interpretation and exhibition. During many years, Noble’s view was the main Anglo-Saxon way of thinking (Alexander, 1993). A new paradigm appears at the end of the 1980’s, the PRC model: Preservation (including acquisition), Research and Communication (interpretation, temporary and permanent exhibitions⁷). Both models focus on the technical aspects of museums, in a curatorial sense, but do not consider “outcomes” such as tourism, economic development, social activities, as suggested by subsidising authorities (Audit Commission, 1991). This last point of view is not really of interest to curators, but a global approach should focus on it as well, because it is sometimes the only viewpoint taken into account to justify subsidies.

Confronted with this general vision, we suggest to work with three different models, each one representing a part of the activities. We focus on the results of the final functions of museums (and not the administrative tasks, such as finance, fundraising or marketing), on contacts with “customers”, including both visitors and non-visitors, and “outcomes” (e.g. economic

⁶ This term was first proposed by Chames, Clark, Cooper, and Golany (1985). A discussion on window analysis is proposed in *Talbot and Vanden Eynde (1995)*.

development or tourism). Some “intermediate” indicators, directly connected to museum activities (Bud, Cave and Hanney, 1991), are also taken into consideration. For each model, the input is defined by labour, funds devoted to the activities, and the quality of the infrastructure. The definition of the output is explained in the following paragraphs.

Model 1 Preservation

We assume that, in the context of the PRC model, preservation, although at the same level as other activities, needs special attention. We have noticed that this aspect is sometimes neglected in favour of more visible (visitor oriented) activities. The objective of model 1 is to give a general overview of the realisation of preservation activities. The museum uses labour and capital (the scientific personnel involved in curatorial work, the acquisition and collection management budget) to perform these activities. Selected output indicators should give clear evidence concerning acquisition and disposal, care and (preventive) conservation of collections and storage conditions. A list of indicators concerning these activities has been defined by the Museums Association (see annex 1a).

Model 2 Research and communication

This model deals with the other functions of a museum: documentation of the objects and research on them, scholarly achievements, communication through permanent and temporary exhibitions, education programmes and publications. The list of indicators proposed by the Museums Association is very accurate for this model, and could be completed by the indicators discussed at the Wintergreen conference.⁸ The inputs are roughly the same (the scientific personnel involved in curatorial, educational and communication activities, and the corresponding budgets). The activities differ from those included in the first model, as they are directly connected to the public. But their “public” perspective does not give any information on the reaction of the public: a museum may have very good indicators for all of its activities, but attract no visitor (Weil, 1990).

Model 3 Impact

The objective of this model tends, as Dana (1920) would have said, to define the achievements of “the kind of museum it will profit a city to maintain”. This includes the role and actions of the museum in its community, and not only the number of visitors it attracts. The duration and the frequency of the visits, should also be considered, as well as types of visitors and visiting behaviours, the use made by the local population (and not only tourists), etc. Although the last items have to be measured by visitor surveys, performance indicators can represent most of them. Some of the indicators suggested by the Audit Commission could be included, such as the “outcomes” of the museum (economic development etc, see annex 1b).

The three models will give a simplified view of reality. For technical reasons, the list of indicators has to be limited. It would simply not be possible, for the model (and for managers), to deal with a too large set of indicators.⁹ But what is most important is achieving agreement between curators, managers, and those who provide funds.

⁸ See annex 1a and 1b

Each model corresponds to the point of view of an actor: some curators could consider their main concerns as included in model 1, some others, including those who stress education or exhibitions, would favour model 2, subsidising authorities would recognise themselves in model 3. The points of view are conflicting: educators want to show the collection, while curators would prefer to store it, but everyone will recognise that a museum requires all these dimensions. As mentioned in the introduction, our objective is to stress these specific points of view by analysing the three models individually but also to propose a global interpretation of the three analyses.

3.3 Data

The database includes Belgian museums. Though the territory is small (33,000km²) and its population not very large, it is covered by more than 700 institutions of all sizes and all categories, from international museums such as the “Musées royaux des Beaux-Arts de Belgique”, to locally known (or unknown) institutions (See Ginsburgh and Mairesse, 1997; Mairesse, 1997).

Some of these museums (the largest) have a federal status, and a dozen of them (medium sized) are largely subsidised by the intermediate (French speaking) government. Some 80 museums also receive a small subsidy from the intermediate government. These museums depend on municipal authorities or are run privately as non-profit organisations. We succeeded to obtain information concerning these 80 museums. The data are collected from the annual reports, that were standardised in 1995,¹⁰ and are thus comparable. Only 64 museums completed these annual reports during three consecutive years, and are included in our database. This sample does obviously not reflect the overall situation, but the specific subset of subsidised local museums.

Taalas (1998) and Paulus (1996) make a distinction between the specialisation of the museum (art, science, history,...). These categories, however, do not explain the differences among museum missions (see Ginsburgh and Mairesse, 1997). Technically, the activities carried out

in science or history museums are the same, and it is possible to find indicators reflecting these common activities. Furthermore, by splitting the sample in categories, Taalas (1998) reduces drastically the possibility of comparisons between museums, limiting the interest of the analysis. For these reasons, we decided to make no distinction among museums. The definition of the inputs and outputs, selected from the database, is explained in the following paragraphs.

Model 1 Preservation

The input is the “operational” budget (BUD), or the budget devoted to all activities, (except personnel, heating, electricity, etc). We also include the scientific (PES¹¹) and the technical personnel (PET). The output is the percentage of the collection that has been inventoried (INV), a high priority task which gives a good indication on how collections are managed. A technical indicator (TEC) is also calculated from a set of seven questions addressed to the museums (did it take some conservation measures, did it take care of storage places, etc.¹²). We decided not to add indicators on the acquisition policy, to account for the differences among types of museums and acquisition techniques.

Model 2 Research and communication

The input is the same as for model 1. The output is the number of temporary exhibitions (EXH), the number of publications (PUB), such as catalogues and didactic tools, and the number of communication actions (COM), such as the number of conferences, open-door days, workshops for children, and other events. Because of inconsistencies concerning guided tours, we decided not to include them.

Model 3 Impact

¹¹ This category of personnel is devoted to curatorial, and communication functions.

¹² The indicator is calculated in the same way as self-evaluation accreditation checklists (See American Association of Museums, 1996). A list of seven question (yes/no) were asked to museum: did it renovate some space, invest on equipment or infrastructure, renovate some storage room, participate to international exchange, have some exchange projects, take some conservation measures, take some security measures. The indicator is

The input is the same, with the addition of the security services (PEG). The output is represented by the number of opening hours (VOL¹³), and the number of visitors (VIS).

As can be observed, the three models do not correspond entirely to our wishes. The indicators could certainly be fine-tuned, but the most important objective (underlining the different functions of the museum) is achieved. As we will see in section 3.4, the results are very significant.

Except for the opening hours volume (VOL), indicators fluctuate over the three years. Tables 3.1 and 3.2 give a short statistical description of the input and output variables.¹⁴ Although the museums are not particularly different, the standard deviation is very large. This variation is, of course, very normal in the museum world. The selection of variables is different from those used in previous studies, where all the activities of a museum are evaluated jointly¹⁵.

Table 3.1 Statistical description of the inputs

Year	Statistics	BUD	PER	PES	PET	PEG
	<i>Models</i>	<i>1,2,3</i>	<i>Not used</i>	<i>1,2,3</i>	<i>1,2,3</i>	<i>3</i>
1995	Minimum	1.00	0.50	0.01	0.01	0.01
	Maximum	6025.00	53.00	15.00	8.00	30.00
	Average	678.19	6.37	1.73	1.71	2.94
	St.	912.69	7.55	2.07	1.69	4.82
1996	Minimum	29.00	0.50	0.01	0.01	0.01
	Maximum	14313.00	53.00	15.00	21.00	30.00
	Average	941.39	6.47	1.83	2.03	2.61
	St.	2004.16	7.36	2.15	2.81	4.41
1997	Minimum	24.00	0.40	0.01	0.01	0.01
	Maximum	9387.00	53.00	15.00	21.00	30.00
	Average	950.08	6.85	1.93	2.09	2.83
	St.	1548.27	7.38	2.16	2.89	4.36

Note: BUD: Operational budget (in thousands BEF), PER: Total personnel (in Full Time Equivalents: FTE), PES: Scientific personnel (in FTE), PET: Technical personnel (in FTE), PEG: Guardians (in FTE)

Table 3.2 Statistical description of the output.

		INV	TEC	PUB	EXH	COM	VOL	VIS
--	--	-----	-----	-----	-----	-----	-----	-----

¹³ This indicator is calculated from data provided by the “*Guide des Musées Wallonie Bruxelles*” (1997).

¹⁴ The complete dataset is presented in Annex 2. We adjusted all zero values and converted them to 0.01 in order to avoid technical difficulties. This change does not have any impact on the result.

¹⁵ Paulus (1996) selected the number of employees and other operating expenses as inputs. The outputs represent a part of our three activities. An indicator is selected for preservation activity. Three indicators illustrate the research and communication process: the number of exhibitions during the last five years, the number of research workers welcomed and the number of children taking part in a special program. Finally, for the impact activity, the number of visitors was selected. Mairesse (1997 and 1998) used the same database as here and the variables are the same with two important exceptions: the categories of personnel are not used, nor is the volume indicator. Taalas (1998) used the budget as input. For the output, the preservation activity is represented by the acquisition of items and documents. The same indicator is used for the communication and outcome activities.

	<i>Model</i>	<i>1</i>		<i>2</i>			<i>3</i>	
1995	Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Maximum	100.00	6.00	6.00	12.00	383.00	2730.00	52600.00
	Average	37.57	3.08	1.49	2.22	20.59	1286.65	11057.52
	St.	42.23	1.64	1.66	2.89	50.31	744.98	13231.32
1996	Minimum	0.01	0.01	0.01	0.01	0.01	0.01	286.00
	Maximum	100.00	7.00	7.00	15.00	331.00	2730.00	63899.00
	Average	43.28	3.39	1.29	2.38	26.45	1286.65	10447.02
	St.	43.54	1.82	1.52	2.69	47.64	744.98	12606.01
1997	Minimum	0.01	0.01	0.01	0.01	0.01	0.01	756.00
	Maximum	100.00	7.00	9.00	16.00	309.00	2730.00	52000.00
	Average	51.71	3.52	1.41	2.50	25.66	1286.65	11294.61
	St.	44.24	1.80	1.78	2.80	45.80	744.98	11675.06

Note: INV: percentage of inventoried collections, TEC: technical ratio estimating preservation job, PUB: Number of publications, EXP: Number of exhibitions, COM: Number of communication actions, VOL: Number of opening hours, VIS: Number of visitors.

4. The methodology

In this section we define more formally the concepts used in our analysis, including the new concept of restricted scale. We also briefly discuss computational aspects, and conclude with a way of classifying the results in order to facilitate their interpretation.

4.1 Production technologies and radial efficiency

A production technology is based on k observations using a vector of inputs $x \in \mathfrak{R}_+^n$ to produce a vector of outputs $y \in \mathfrak{R}_+^m$. Technology is represented by its production possibility or transformation set $GR = \{(x, y): x \text{ can produce } y\}$, i.e., the set of all feasible input-output vectors. An alternative representation of a technology is the input requirement set: $L(y) = \{x: (x, y) \in GR\}$.

Following Farrell (1957), efficiency is measured in a radial or equiproportional way. The radial input efficiency measure $DF_i(x, y)$ is:

$$DF_i(x, y) = \min \left\{ \lambda \mid \lambda \geq 0, \lambda x \in L(y) \right\},$$

where λ indicates the maximum amount by which inputs can be decreased while still producing a given vector of outputs. $DF_i(x, y)$ is bounded above by one, with efficient production on the

isoquant of $L(y)$ represented by unity. This efficiency measure can be used relative to different production models.

The first model that we define is the traditional Free Disposal Hull (FDH) technology, initially proposed by Deprins, Simar and Tulkens (1984), that imposes strong disposability assumptions, and no specific returns to scale hypothesis:

$$GR^{FDH} = \{(x, y): M'z \geq y, N'z \leq x, I'_k z = 1, z_i \in \{0,1\}\}.$$

This model is related to the well known Data Envelopment Analysis (DEA) technology.¹⁶ The difference between DEA and FDH relies on the assumption of convexity, that is imposed for DEA and not for FDH.

4.2 Returns to scale for a technology

We may impose conditions on returns to scale for a given technology. Several returns to scale assumptions have been defined for FDH (see Kerstens and Vanden Eeckaut 1998a, 1998b). A FDH technology with constant returns to scale (FDH-CRS) is defined as:

$$GR^{FDH-CRS} = \{(x, y): M'w \geq y, N'w \leq x, I'_k z = 1, z_i \in \{0,1\}, w_i = \delta z_i, \delta \geq 0\}.$$

In contrast with the definition of FDH in section 4.1, there is now one activity vector z operating subject to a non-convexity constraint and one rescaled activity vector w allowing for any scaling of the observations spanning the frontier. The scaling parameter δ is free because of the CRS assumption. The classical FDH technology results thus from the FDH-CRS technology as a special case by fixing the scaling parameter δ at 1.

It is also possible to define two additional technologies based on FDH assuming non increasing returns to scale (FDH-NIRS) and non decreasing returns to scale (FDH-NDRS). This simply requires modifying the scaling parameter included in the $GR^{FDH-CRS}$ technology to be smaller than or equal to unity ($\delta \leq 1$) or larger than or equal to unity ($\delta \geq 1$).

This definition of constant returns to scale implies that a unit may be scaled upwards and downwards with no restriction. We may consider this assumption as realistic for the long term but certainly not for the medium or short term. In this paper, we propose to introduce a more restrictive concept of returns to scale (RRS) based on the definition of an interval where an observation can be scaled¹⁷. This definition is particularly adapted to the example of museums, as the size of these institutions cannot be radically transformed, except in the very long term.

A FDH-RRS technology is represented by:

$$GR_{(\alpha, \beta)}^{FDH-RRS} = \{(x, y): M'w \geq y, N'w \leq x, I'_k z = 1, z_i \in \{0, 1\}, w_i = \bar{a} z_i, \hat{a} \leq \bar{a} \leq \hat{a}, \alpha \geq 0, \beta \geq 1\}.$$

Again, the classical FDH model results from the FDH-RRS model as a special case by setting $\delta = 1, \alpha = 0, \beta = \infty$.

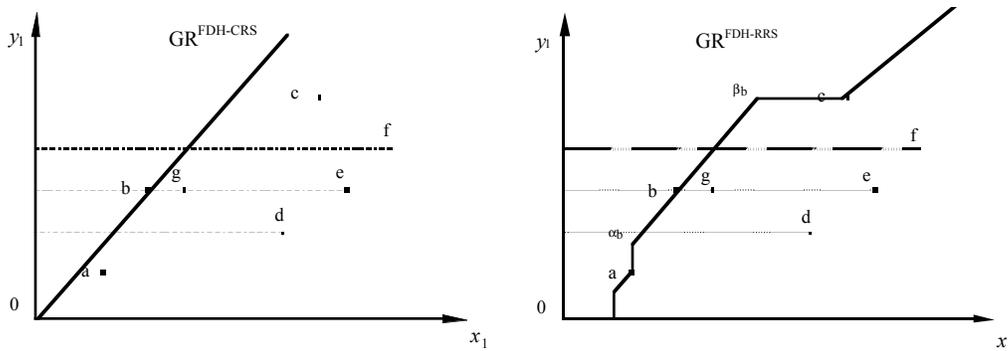


Figure 4.1 FDH-CRS and FDH-RRS technologies

The difference between the two models is illustrated in figure 4.1., where unit b is scale restricted downward by a factor $\alpha < 1$ and upward by a factor $\beta > 1$. This scaling is applied to all observations in the set. In our case, this restricted scaling enables a and c to be efficient, while they were not under the CRS assumption. By definition, the frontier is nested into the CRS frontier.

4.3 Decomposition of scale and technical efficiency

Informally defined, technical efficiency (TE) requires production on the boundary of the production possibility set. If production occurs in the interior of the set, then a producer is technically inefficient. This is a private goal defined in terms of the best interest of the producer. Technical efficiency is usually measured relative to a technology endowed with the least restrictive returns to scale assumption. A producer is scale efficient (SCE) if his production corresponds to a longrun zero profit competitive equilibrium configuration; he is scale inefficient otherwise. This social goal relates to a possible divergence between the actual and ideal configuration of inputs and outputs, the latter requiring production with constant returns to scale (CRS). Efficiency measurement relative to the latter technology thus conflates scale and technical efficiencies.

Extensive decompositions between technical and scale components of the efficiency measures have been developed for convex nonparametric deterministic reference technologies. The first operational procedure to measure technical efficiency is described in Farrell (1957). Färe, Grosskopf and Lovell (1983, 1985, 1994) offer a more elaborate taxonomy of efficiency concepts. Efficiency decompositions based on non convex nonparametric deterministic reference technologies have been proposed by Vanden Eeckaut (1997) and further developed and contrasted with DEA decomposition in Kerstens and Vanden Eeckaut (1998b).

Traditionally, scale efficiency is defined as the ratio of two efficiency measures: one calculated on a CRS technology ($DF_i(x, y | CRS)$), and one computed on a variable returns to scale technology ($DF_i(x, y | VRS)$).¹⁸ Formally, an input oriented scale efficiency measure ($SCE_i(x, y)$) is defined as:

$$SCE_i(x, y) = DF_i(x, y | CRS) / DF_i(x, y | VRS).$$

This ratio gives the lowest possible input combination able to produce the same output in the long run as a technically efficient combination situated on the VRS technology. Since $DF_i(x, y | CRS) \leq DF_i(x, y | VRS)$, evidently $0 < SCE_i(x, y) \leq 1$.

¹⁸ The VRS technology stands for variable returns to scale. In our case, this corresponds with the classical FDH

If we apply our concept of restricted constant returns to scale, then scale efficiency could be decomposed into two components. The first component SM-SCE represents the medium term inefficiency due to scale and the second term, ML-SCE, represents the difference between medium and long term scale efficiency. Formally we define :

$$SM-SCE_i(x, y) = DF_i(x, y | RRS) / DF_i(x, y | VRS).$$

$$ML-SCE_i(x, y) = DF_i(x, y | CRS) / DF_i(x, y | RRS).$$

The usual concept of scale inefficiency is simply defined as the product of these two terms:

$$SCE_i(x, y) = SM-SCE_i(x, y) \cdot ML-SCE_i(x, y)$$

The radial measurement yields a multiplicative decomposition (see Färe, Grosskopf and Lovell, 1985). Overall technical efficiency (OTE) differs from technical efficiency (TE) in that it is always measured relative to a strongly disposable CRS technology. This yields the identity:

$$OTE = TE \cdot SCE, \text{ or: } DF_i(x, y | CRS) = DF_i(x, y | VRS) \cdot SCE_i(x, y).$$

Technology exhibits CRS at the observation under evaluation or at its input-oriented projection point when $SCE_i(x, y) = 1$. If $SCE_i(x, y) < 1$, then the evaluated observation is not located or projected on a piecewise linear segment where CRS prevail. For these observations, it is possible to determine the exact nature of returns to scale at its bounding hyperplane. Several methods exist to obtain this qualitative information regarding local scale economies¹⁹.

4.4 Computational aspects

For non-convex technologies, mixed integer programming is required. Input efficiency is computed relative to $GR^{FDH-CRS}$, GR^{FDH} , $GR^{FDH-NIRS}$, $GR^{FDH-NDRS}$ and $GR^{FDH-RRS}$ by solving for each observation (x^o, y^o) the following binary mixed integer, non-linear programming problem:

$$\begin{aligned}
DF_i(x, y) &= \text{Min}_{\lambda, z, \delta} \lambda \\
\text{subject to } & \sum_{k=1}^K y_{km} \delta z_k \geq y_{km}^0, \quad m = 1, \dots, M, \\
& \sum_{k=1}^K x_{kn} \delta z_k \leq \lambda x_{kn}^0, \quad n = 1, \dots, N, \\
& \sum_{k=1}^K z_k = 1, \\
& z_k \in \{0, 1\}, \\
& \delta \in \Gamma(s), \\
& \lambda \geq 0, z_k \geq 0, \quad k = 1, \dots, K,
\end{aligned}$$

where

- (i) $\Gamma(s) = \{\delta : 0 < \delta\}$ for $s = \text{FDH - CRS}$;
- (ii) $\Gamma(s) = \{\delta : \delta = 1\}$ for $s = \text{FDH}$;
- (iii) $\Gamma(s) = \{\delta : 0 < \delta \leq 1\}$ for $s = \text{FDH - NIRS}$;
- (iv) $\Gamma(s) = \{\delta : 1 \leq \delta\}$ for $s = \text{FDH - NDRS}$;
- (v) $\Gamma(s) = \{\delta : \alpha \leq \delta \leq \beta\}$ for $s = \text{FDH - RRS}$;

In this formulation the constraint on the sum of z , together with the integer constraint on z represent the non-convexity. This problem is non-linear and furthermore contains (0,1) integer restrictions. Therefore, it is solved using an implicit enumeration algorithm based on a simple vector comparison procedure introduced by Kerstens and Vanden Eeckaut (1998a). This procedure can be easily adapted to take into account technologies with restricted returns to scale.

4.5 Classification

The linear program presented in section 4.4 calculates an efficiency score for each unit. This provides us with a first classification under the form of a ranked list. This information is often difficult to manage due to the value given to the efficiency score (we work in a deterministic world and measurement errors are not taken into account). The enumeration algorithm mentioned in section 4.4 also provides information on dominance. It appears more robust to classify observations on this basis. For this, we need to introduce the concept of dominated and dominating unit:

Dominated unit

A unit x is dominated by one or more other units, if:

- (a) These units have all their input indicators smaller than or equal to those of unit x ,
and
- (b) These units have all their output indicators larger than or equal to those of unit x .²⁰

Dominating unit

A unit x is dominating one or more other units, if:

- (a) These units have all their input indicators larger than or equal to those of unit x ,
and
- (b) These units have all their output indicators smaller than or equal to unit those of x .²¹

This leads to the following mutually exclusive classification :

- (a) A unit is *inefficient* if it is dominated by one or more other units,
- (b) A unit is *efficient* if it is undominated and dominates at least one unit.
- (c) A unit is *efficient by default* if it is undominated and undominating.

This classification will be intensively used in the presentation of the results in the section which follows.

²⁰ With at least one inequality.

5. Results

We first discuss the results obtained by using the classical FDH technology approach. Incidentally, we show that annual results are very unstable so that our suggestion to base the results on several years (window) seems reasonable. Second we present results regarding scale efficiency. Finally, we propose a method for interpreting the three models together.

5.1. FDH results: temporal analysis

Table 5.1. summarises the results of a classical FDH analysis for the three models.²² Average efficiency is increasing over time. The number of efficient museums is higher in the second and third models than in the first one, reflecting the general opinion that internal tasks (preservation,...) are less rewarding and therefore less efficiently performed than external ones. Between brackets, we give the numbers of inefficient observations with a score of one but a status of dominated observation.²³ We observe that the number of such museums is much smaller when we aggregate over time (from 13 to 1 in model 1, from 10 to 1 in model 2 and from 8 to 3 in model 3 if we compare year 3 and the three years together). The power of the models to discriminate is thus also improved.

Table 5.1 Yearly vs. aggregated results: Descriptive statistics on FDH efficiency scores and status

	1995	1996	1997	1995-97
MODEL 1 Preservation				
Average Efficiency	0.706	0.702	0.834	0.796
Number of museums	64	64	64	64
Efficient	18	20	19	21
Efficient by default	3	4	10	15
Inefficient	43 (10)	40 (5)	35 (13)	28 (1)
MODEL 2 Research and Communication				
Average Efficiency	0.795	0.839	0.880	0.888
Number of museums	64	64	64	64
Efficient	16	31	23	22
Efficient by default	16	6	14	22
Inefficient	32 (10)	27 (3)	27 (10)	20 (1)
MODEL 3 Impact				
Average Efficiency	0.881	0.942	0.951	0.943
Number of museums	64	64	64	64

²² The complete results are given in Annex 3.

²³ In one dimension it is still possible to reduce the input but not for all dimensions. This is the well-known

Efficient	18	15	15	11
Efficient by default	22	33	33	38
Inefficient	24 (7)	16 (6)	16 (8)	15 (3)

Table 5.2 provides an alternative perspective, by distinguishing between inefficient and not-inefficient (i.e. efficient and efficient by default) observations, for museums whose status has not changed over time. We observe whether the status is moving or not among these models for each of the three years. The results vary. For model 1, only 7 observations are not-inefficient during the three years. According to model 3, half of the museum remains not inefficient.²⁴

Table 5.2: Number of museums with an identical status for the three years

	MODEL 1 <i>Preservation</i>	MODEL 2 <i>Research and Communication</i>	MODEL 3 <i>Impact</i>
Not Inefficient	7	21	33
Inefficient	21	15	7
Total	28	36	40

This analysis leads to two conclusions. First, inefficiency is more present in model 1 than in models 2 and 3. Secondly, the number of museums that are efficient by default is important. This is clearly a shortcoming of our analysis or of our database.

5.2 Museums and scale efficiency

We now turn to the results related to scale. Unfortunately the analysis is restricted to model 2, since variables such as INV (% of collection in inventory) used in the first model and VOL (Number of opening hours) used in the third model are bounded above. Therefore, it is not possible to scale these variables in a non restrictive way and frontiers with constant or increasing returns to scale cannot be computed.

To identify scale at the individual level, we use a method proposed by Kerstens and Vanden Eeckaut (1998a), where one computes a frontier with various returns to scale assumptions (constant, non-increasing and non-decreasing). The frontier which maximises the score is considered as giving the best fit.

²⁴ We note that the number of efficient by default is higher in Taalas (1998) than in our sample. This may be

The results given in table 5.3 imply that increasing returns to scale (19 cases) are more frequent than decreasing returns to scale (14 cases).²⁵ The results do not conflict with previous ones. Paulus (1996) finds increasing returns in 52 out of 64 cases, using a DEA approach. A classical regression analysis based on a translog cost function also confirms the presence of increasing returns (Jackson, 1988).

Table 5.3: Individual returns to scale for the model 2

	Number of museums
Increasing returns to scale	19
Constant returns to scale	31
Decreasing returns to scale	14

We now decompose the overall technical efficiency score into two components: a component for technical efficiency and a component for scale efficiency. Scale efficiency will be decomposed again in order to obtain the short-medium term part and the medium-long term part (see section 4). Our choice for the parameters α and β is 0.5 and 2 which means that the size of a museum may be reduced or multiplied by 2. This range seems reasonable for short and medium term changes.

The decomposition of efficiency proposed in table 5.4 is of special interest to see the potential gain from a change in size. With a classical approach, we observe that the gain in efficiency is important (more than 30% if the observations were scale efficient). If we look at the decomposition of the scale change, we observe that short and medium term possibilities are rather limited (10%). This information illustrates that scale efficiency is often overestimated. In Paulus (1996), mean scale efficiency is 60%. Based on our results, there is strong evidence that in this sample the size of museums is clearly smaller than what would be optimal. However, these results overestimate the possible change in size for a museum. This bias is due to the use of DEA and the assumption of unrestricted constant returns to scale. We should also be aware that the identification of returns to scale is heavily dependant on the sample of museums used.

Table 5.4 Technical and scale efficiencies decomposition

	Geometrical ²⁶ Avg. Efficiency Score	Number of efficient units
Technical Efficiency	0,857	45
Scale	0,698	31
Short-Medium	0,901	43
Medium-Long	0,775	42
Overall technical efficiency	0,599	30

5.3 The museum: a global approach

We now consider jointly the results of the three models. We define a new classification, propose a way to implement this newly defined classification, and discuss some examples of how to interpret the results within this classification.

A museum is defined as efficient (EFF), efficient by default (EBD) or inefficient (INE). For each museum, we define a triplet which represents its status (EFF,EBD or INE) for each of the three models. We assume that (a) all the three models have the same weight in the evaluation; (b) efficiency is weakly preferred to efficiency by default and efficiency by default is preferred to inefficiency. By transitivity, efficiency is strongly preferred to inefficiency.

To implement the classification, we attribute values +1, +1/2 and -1 to efficient, efficient by default and inefficient observations. We define for each museum a global status (GS) which is the sum of the three values. GS takes values between +3 (all activities are efficient) and -3 (all the activities are inefficient). The resulting classification is presented in table 5.5. Class 0 includes museums that are never inefficient (this class is subdivided into four categories). Class 1 contains museums with one inefficient activity. Museums with two and three inefficient activities are in Classes 2 and 3.

Table 5.5 Global classification

Classes		GS	Status		
Class 0 (27 units)	a	3	{EFF, EFF, EFF} (M19,M26,M34,M55)		
	b	2.5	{EBD, EFF, EFF} (M01)	{EFF, EBD, EFF} (M42)	{EFF, EFF, EBD} (M06,M07,M37,M43, M48,M58,M64)
	c	2	{EBD, EBD, EFF} (M32,M35,M54)	{EFF, EBD, EBD} (M22,M36)	{EBD, EFF, EBD} (M27,M47)

	d	1.5	{EBD, EBD, EBD} (M08,M28,M39,M41,M46,M57,M60)		
Class 1 (15 units)	a	1	{INE, EFF, EFF} (ϕ)	{EFF, INE, EFF} (ϕ)	{EFF, EFF, INE} (M14,M49,M59)
	b	0.5	{INE, EBD, EFF} (ϕ) {INE, EFF, EBD} (M17,M23)	{EBD, INE, EFF} (ϕ) {EFF, INE, EBD} (M24)	{EBD, EFF, INE} (M15) {EFF, EBD, INE} (M30,M33)
	c	0	{INE, EBD, EBD} (M11,M21,M44,M50,M51)	{EBD, INE, EBD} (M03)	{EBD, EBD, INE} (ϕ)
Class 2 (19 units)	a	-1	{INE, INE, EFF} (M52,M61)	{EFF, INE, INE} (M13)	{INE, EFF, INE} (M62,M63)
	b	-1.5	{INE, INE, EBD} (M04,M09,M10,M16,M18 ,M20,M31,M38,M40,M53,M56)	{EBD, INE, INE} (ϕ)	{INE, EBD, INE} (M2,M5)
Class 3 (4 units)	a	-3	{INE, INE, INE} (M12,M25,M29,M45)		

Use of the global classification

Due to the size of the sample, several cells are empty. If only 4 museums are totally inefficient, only 4 others are totally efficient; the remaining ones (56) have a mixed status. A few selected examples will illustrate the use of this classification.

Museum M55 (Class 0, GS= +3) is a very small museum which exhibits local crafts for tourists. Born through a local initiative, its activity level indicators are not very high, and the quality of the exhibits is not very good either, but the budget and the personnel are so small that the return output/input is very high. Many museums, with larger budgets, do not have more activities than this one, and are dominated by it. However, it is very different from M8 (GS= +1.5), a very dynamic and innovative art history museum with nation-wide reputation, one of the finest of the region. M8's budget (and personnel) are larger than average. Its indicators are among the highest. Large inputs and high outputs give to this museum a very specific status: it is efficient, but does not dominate any other institution.

Museum M11 (Class 1, GS= 0) is a small war museum devoted to the history of a famous battle. Managed by a historical society, it mainly attracts amateurs and tourists visiting the battle field. Being partly run by non professionals, it carries no inventory, and its technical level is not particularly high (it is for instance dominated by M55). Its communication activities are mainly devoted to the needs of the historical society (conferences etc.), but the

number of visitors is important, given its location. M11 is considered as efficient by the two last models, but it does not dominate any other institution, and could therefore not be considered as an example of a well-run institution.

Museums M52 (GS= -1) and M53 (GS= -1,5) belong to Class 2 and are both located in a touristic region. M52 is devoted to the history of the medieval past of the city where it is located; M53 is a very large open-air museum situated in a forest; it collects examples of traditional regional architecture. Both are considered as inefficient by the first model, but the inefficiency is more apparent for M53, which is dominated by eleven museums (even by M52). M52's inventory is complete, while M53's is not; the technical ratio remains more or less equal –and low– for both, but the large size of M52 drives it to be dominated by a lot of other smaller ones. Both are also considered as inefficient in the communication model. While M52 is dominated by three museums, the performance of M53 is better, but one smaller institution succeeds to do as well. The last model shows the nature of both museums, or their visitor oriented attitude, in which both appear to be efficient. Models 2 and 3, together, suggest that their popularity is not only due to their communication actions, but also to their location.

Museum M45 (Class 3, GS= -3) is considered as inefficient by all three models. This medium size institution, devoted to the study of the global environment of a specific countryside region, has an outstanding scientific output, which is unfortunately not fully captured by the indicators. It is dominated by three museums, one of which (M64) has exactly the same missions and tasks, has better indicators with a smaller budget and less personnel, but the quality of its scientific output is lower. Museum M64 dominates M45 in the second model also. In the third model, M45, which is more locally oriented, is dominated by the tourist oriented M52 (already described) and M42 museums.

Table 5.5 presents the advantage of summarising the data and also identifying clearly a subset of museums which share the same characteristics. The examples presented above illustrate the

differences among classes. But this table is only a starting point for a more thorough discussion of the implementation of our methods in the real world.

6. CONCLUSIONS

In this paper, we have offered a new approach for a global assessment of museums. The efficiency frontier analysis of the museum sector is not new, but so far it has only been transposed in a straightforward way from other fields with no adaptation to the museum particularities and with no possible use for curators or museum managers.

We have shown that, museum comparisons are possible, but not unconditionally. The main condition is to be able to set up a model which encompasses the complexity of museum activities. This model should enable us to single out the activities where a museum is not performing optimally. After this identification, peer museums should be provided in order to ascertain the quality of the evaluation and to uncover a path for improvement. Our three steps museum model, as well as FDH technology, emerge as a solid pretender for these requirements.

Given the results of our application, we can observe that the same museum can react in very different ways, being efficient in one model and not in the other. The classification proposed reflects this reality and allows us to fine-tune the research on the causes explaining the results. Regarding scale efficiency, the classical findings of improvements with a change in size are overestimated. In our sample, only one third of the possible improvement with a change in scale appear to be realistic. In consequence, scale inefficiency is no longer the main source of inefficiency in the context of overall technical efficiency focusing on the short and the medium term.

The use of a three year window appears to improve the quality and the robustness of the results. However, due to the size of our sample we could only offer a static point of view. This limitation needs to be alleviated by using a wider database. We are well aware that the number of museums taken into account is small and that working with a small number of observations is always a limitation with nonparametric techniques. A larger database would undoubtedly reduce the number of efficient by default museums. In the same context, the first

example analysed in section 5.3 (M55) warns us that small museums might (due to the selection of the indicator) be favoured.

New questions arise. First, if the size of a museum is of importance, should we consider possible collaborations or even merging? Non parametric techniques could easily be adapted to cope with the detection of efficient reorganisations. Secondly, the variables that we need to consider are offering us tricky challenges. We are confronted with the important number of variables and the problem of aggregation. Most of the variables are not classical performance indicators, but qualitative assessments and visitor surveys. This last problem which is intrinsically linked to museum assessment has often been neglected in the theoretical literature.

We hope that this study will trigger the curiosity of cultural managers and be followed by real discussions and applications of our method. As stated by Dana “A museum is good only in so far as it is of use”: a sentence which everyone should also apply to efficiency measurement.

REFERENCES

- ALEXANDER, E. P. (1983). *Museums in Motion. An Introduction to the History of Museums*, Nashville, American Association for State and Local History (2nd ed.).
- AMBROSE, T. and PAINE, C. (1993). *Museum Basics*, London, Routledge.
- AMERICAN ASSOCIATION OF MUSEUMS (1996). *Accreditation Self-Study*, Washington, American Association of Museums, s.d.
- AMES, P.J. (1990). Breaking New Grounds. Measuring Museums' Merits, *Museum Management and Curatorship*, 9, 137-147.
- APPA, G., YUE, M (1999) On Setting Scale Efficient Targets in DEA, *Journal of the Operational Research Society*, 50(1), 60-69.
- AUDIT COMMISSION (1991). *The Road to Wigan Pier ? Managing Local Authority Museums and Art Galleries*, London, HMSO.
- BANKER, R., CHANG, H. and COOPER, W. (1996). Equivalence and Implementation of Alternative Methods for Determining Returns to Scale in Data Envelopment Analysis, *European Journal of Operational Research*, 89, 473-481.
- BESSENT, A, BESSSENT, W., ELAM, J., and CLARK, T. (1988). Efficiency Frontier Determination by Constrained Facet Analysis, *Operations Research*, 36, 765-796.
- BOGETOFT, P. (1996). DEA on Relaxed Convexity Assumptions, *Management Science*, 42, 457-465.
- BUD, R., CAVE, M. and HANNEY, S. (1991). Measuring a Museum's Output, *Museums Journal*, January, 29-31.
- BURCAW, G.E. (1998). *Introduction to Museum Work*, Nashville, American Association for State and Local History (3rd ed.).
- CHARNES, A., CLARK, C.T., COOPER, W.W. and GOLANY, B. (1985). A Developmental Study of Data Envelopment Analysis in Measuring the Efficiency of Maintenance Units in the US Air Forces, *Annals of Operation Research*, N°2, 95-112.
- DANA, J.C. (1920). *A Plan for a New Museum - The Kind of Museum it Will Profit a City to Maintain*, Woodstock, Elm Tree Press.
- DEPRINS, D. and SIMAR, L. (1983). On Farrell Measures of Technical Efficiency, *Recherches Economiques de Louvain*, 49, 123-137.
- DEPRINS, D., SIMAR, L. and TULKENS, H. (1984). Measuring Labor-Efficiency in Post Offices, in: Marchand, M., Pestieau, P. and Tulkens, H. (eds) *The Performance of Public Enterprises: Concepts and Measurement*, Amsterdam, Elsevier, 243-267.
- DESVALLEES, A. (1989). Le défi muséologique, in Rivière, G.H., *La Muséologie selon Georges Henri Rivière*, Paris, Dunod, 345-367.
- DI MAGGIO, P. (1985). When the Profit is Quality. Cultural Institutions in the Marketplace, *Museum News*, June, 28-35.
- FÄRE, R., GROSSKOPF, S. and LOVELL, C.A.K. (1983). The Structure of Technical Efficiency, *Scandinavian Journal of Economics*, 85, 181-190.

- FÄRE, R., GROSSKOPF, S. and LOVELL, C.A.K. (1985). *The Measurement of Efficiency of Production*, Boston, Kluwer.
- FÄRE, R., GROSSKOPF S., and LOVELL, C.A.K. (1994). *Production Frontiers*, Cambridge, Cambridge Univ. Press.
- FARRELL, M. (1957). The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society Series A: General*, 120, 253-281.
- GINSBURGH, V. and MAIRESSE, F. (1997). Defining a Museum : Suggestions for an Alternative Approach, *Museum Management and Curatorship*, 16, 15-33.
- GOODALL, E. (1994). Quality control, *Museums Journal*, January, 22-25.
- GRIFFIN, D.J.G. (1987). Managing in the Museum Organisation -I. Leadership and Communication, *The International Journal of Museum Management and Curatorship*, 6, 387-398.
- GRIFFIN, D.J.G. (1988), Managing in the Mseum Organisation II. Conflicts, Tsks and Rsponsibilities, *The International Journal of Museum Management and Curatorship*, 7, 11-23.
- HENDON, W.S. (1979). *Analysing an Art Museum*, New York, Praeger.
- JACKSON, J.M. (1991). Performance Idicators: Pomises and Ptfalls, in Pearce, S. (ed.), *Museum Economics and the Community*, London, Athlone Press, 156-172.
- JACKSON, R. (1988). A Museum Cost Function, *Journal of Cultural Economics*, 12, 41-51
- JANES, R.R. (1995). *Museums and the Paradox of Change. A Case Study in Urgent Adaptation*, Calgary, Glenbow Museum.
- KERSTENS, K. and VANDEN EECKAUT, P. (1998a). Estimating Returns to Scale Using Nonparametric Deterministic Technologies: A New Method Based on Goodness-of-Fit, *European Journal of Operational Research*, 113, 210-218.
- KERSTENS, K. and VANDEN EECKAUT, P. (1998b). Distinguishing Technical and Scale Efficiency on Non-Convex and Convex Technologies: Theoretical Analysis and Empirical Illustrations, *CORE Discussion Paper*, N°9855, June 1998.
- LAWRENCE, G. (1991). Rats, Street Gangs and Culture : Evaluation in Museum, in Kavanagh, G., *Museum Language : Objects and Texts*, Leicester, Leicester University Press, 11-32.
- LORD, B. and LORD, G.D. (1997). *The Manual of Museum Management*, London, Stationery Office.
- LORD, G.D. and LORD, B. (1991), *The Manual of Museum Planning*, London, HMSO.
- LOVELL, C.A.K. (1993). Production Frontiers and Productive Efficiency, in: Fried, H., Lovell, C.A.K. and Schmidt, S. (eds) *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford, Oxford Univ. Press, 3-67.
- MAIRESSE, F. (1997). Les limites de l'analyse d'efficacité dans le secteur des musées, in *International Association for the Management of Arts and Culture, 4th Biennial Conference, Proceedings*, San Francisco, Golden Gate University, 401-412.
- MAIRESSE, F. (1998). *Le Vouloir et le Valoir - Pour une Evaluation Globale du Projet Muséal*, PhD Dissertation, Université Libre de Bruxelles.
- MAROEVIC, I.(1998). *Introduction to Museology - the European Approach*, Munich, Verlag Dr. Müller-Straten.
- MENSCH, P. van (1989). *Professionalising the Muses*. Amsterdam, AHA Books.

- MUSEUM PROFESSIONAL GROUP. (1994). *Measuring the Immeasurable: Performance Measurement in Museums*, Edinburg, Scottish Museum Council.
- MUSEUMS ASSOCIATION (1991). Guidelines on Performance Measurement, *Museums Association Yearbook*, London, MA, 409-412.
- NOBLE, J.V. (1970). Museum Manifesto, *Museum News*, April, 27-32.
- PAULUS, O. (1993). Approche des Coûts des Musées, AIMAC conférence, Jouy en Josas, France.
- PAULUS, O. (1996). Museum Efficiency, paper presented in the Fourth European Workshop on Efficiency and Productivity Analysis, CORE, Université Catholique de Louvain.
- PETERSEN, N. (1990). Data Envelopment Analysis on a Relaxed Set of Assumptions, *Management Science*, 36, 305-314.
- SAMSON, D. and SCHIELE, B. (1989). *L'évaluation muséale, publics et expositions. Bibliographie raisonnée*. Paris, Expo-Media.
- TAALAS, M. (1998). Efficiency of Finnish Museums - Free Disposal Hull Method to Measure Cost Efficiency, Paper read at the Conference on Cultural Economics, Barcelona.
- TULKENS, H. (1993). On FDH Efficiency Analysis: Some Methodological Issues and Applications to Retail Banking, Courts, and Urban Transit, *Journal of Productivity Analysis*, 4, 183-210.
- TULKENS, H. and VANDEN EECKAUT, P. (1995) Non-parametric Efficiency, Progress and Regress Measures for Panel Data: Methodological Aspects, *European Journal of Operational Research*, 80(3), 474-499.
- VANDEN EECKAUT, P. (1997). *Free Disposal Hull and Measurement of Efficiency: Theory, Applications and Software.*, PhD dissertation, CIACO, Louvain-la-Neuve, Faculté des Sciences Economiques, Sociale et Politiques, Nouvelle Série nr 299.
- VANDEN EECKAUT, P., TULKENS, H. and JAMAR, M. (1993). Cost Efficiency in Belgian Municipalities, in Fried, H., Lovell, C.A.K. and Schmidt, S. (eds). *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford, Oxford University Press, 300-334.
- WALDEN, K. (1991). Qualities and Quantities, *Museums Journal*, January, 27-28.
- WEIL, S. (1990). *Rethinking the Museum and other Meditations*, Washington, Smithsonian Institution.
- WEIL, S. (1995). Progress report from the field: the Wintergreen conference on performance indicators for museums, in *A Cabinet of Curiosities. Inquiries into Museums and their Prospects*, Washington D.C., Smithsonian, 19-31.
- ZOLBERG, V. (1981). Conflicting visions in American art museums, in *Theory and Society*, 103-126.