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Benchmarking of industrial park infrastructures in Germany

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Abstract

Purpose – The purpose of this paper is to evaluate the operational performance of industrial park infrastructures in Germany to find first indications for cost saving potentials.
Design/methodology/approach – Between 2006 and 2007, six chemical parks and chemical related industrial parks in Germany participated in a benchmarking study with focus on operation and maintenance of buildings, communication infrastructures and traffic infrastructures. Based on data analysis in combination with workshops, numerous key performance indicators were defined and calculated.
Findings – To compare the different complexities of the analysed infrastructures, the most important key performance indicators were adjusted using correction factors defined and verified during the workshops. This made a discussion based on comparable and comprehensible figures possible which increased the acceptance and applicability of the benchmarking methodology. The benchmarking results showed large differences in performance levels, indicating that there are significant cost saving potentials in some industrial parks.
Research limitations/implications – The comparability may remain limited due to the partly insufficient availability of data from the participants. Other limitations are due to the small number of investigated industrial parks and the focus of the benchmarking study on Germany.
Originality/value – The developed benchmark and best practice methodology is well suited to evaluate best practice in the field of industrial park infrastructures. It is important for industrial parks to understand the individual performance level and to adapt best practice in all areas.

Keywords Performance measurement, Benchmarking, Maintenance, Industrial parks, Chemical parks, Industrial areas

Paper type Research paper

Introduction

Since the 1950s, many communities in the USA have found that turning a local piece of land into an industrial park is an effective method of attracting new companies and thus supporting economic development (Griefen, 1970; Reisdorph, 1991; Peddle, 1993). On a regional and national level, this strategy is applied by policy makers to promote the development of laggard regions or to favour a more decentralised pattern of capacity distribution in a specific sector. In parallel, most industrial and developing countries have allocated considerable resources to industrial and regional policies in order to support key industries, to develop domestic markets and to encourage their foreign trade balance (Markusen, 1996a, b). Depending on the specific alignment and composition of the entities clustered in the location, there are various approaches, like

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science parks on university campuses, technological incubators and industrial parks, that are all policy devices designed to be part of national industrial policy programmes to enhance economic growth (Eliasson, 2000).

Over the last 20 years, Europe has experienced a shift of new investments to destinations outside the continent. As a result, this caused a dissatisfying degree of utilisation of traditional industrial sites and an increasing trend towards industrial parks. This trend is still expected to continue, as chemical companies increasingly pull out as owners of infrastructural activities. Due to the conversion of traditional chemical sites into industrial parks, the whole German industrial park landscape has gone through a long period of restructuring and consolidation (Festel and Bode, 2004). In the course of this restructuring process, there were increasing efforts to realise cost saving potentials. This was accompanied by the stronger focus on core activities and the sale of non-core areas. Simultaneously, there was a call for efficiency through further improvement of organisational structures and business processes by combining with other possibilities, like operational benchmarking and best practice initiatives. Maintaining a competitive cost level of the specific infrastructure is a decisive factor for the success of industrial parks (Festel, 2008; Tian *et al.*, 2012), especially in light of the global competition among industrial locations (Badri *et al.*, 1995; Festel and Würmseher, 2013; Behrendt, 2013).

In the early 20th century, Weber (1909) pioneered the cost-minimising theory of plant location, which had a single focus on costs and remains close to the core of spatial economics (Pace and Shieh, 1988). Today, with facilities oriented costs typically representing between 10 to 20 per cent of a company's total annual expenditure, it is essential to ensure that support services deliver the right performance level, in terms of both affordability and, more importantly, the overall performance of the whole operation (Varcoe, 1993). Generally, facilities management is well suited to conduct benchmarking and performance measurement. But due to deviations in the specific characteristics of the units of analysis, the data comparability is limited in many cases and "benchmarking, in any area, is never as straightforward as it looks" Mainelli (2005).

This research paper was designed as an explanatory investigation of industrial park infrastructures and will present an approach to benchmark operation and maintenance of buildings, communication infrastructures and traffic infrastructures in industrial parks. The following section describes the theoretical background with the review of the relevant literature. After describing the development of industrial parks, this section also provides an overview of performance measurement and the relationship toward benchmarking as well as the underlying metrics. The methodology section presents the scope and approach of the benchmarking and the subsequent discussion of the results gives the basis for the conclusions and recommendations in the last section.

Theoretical background

Development of industrial parks

For several decades, industrial parks have been a tool of economic development policy used by both the public and the private sector to facilitate economic development (Peddle, 1993). As there has been no appropriate definition of industrial parks available so far, Peddle (1990) defined it as "a large tract of land, sub-divided and developed for the use of several firms simultaneously, distinguished by its shareable infrastructure and close proximity of firms". The advantages to companies in a concentrated local cluster flowed from a shared social division of labour that brought together employees with a range of skills needed for various tasks at different stages of the production chain. Skilled workforce from various levels and fields generates personal and corporate benefits and creates a productive atmosphere.

At the same time, this clustering and interaction of skilled people also contributes to an enhanced exchange of tacit knowledge which is a kind of implicit, embodied knowledge that is usually deeply rooted in organisational routines and hard to codify. This can be a decisive success factor for companies, as best practices consist largely of tacit knowledge (von Hippel, 1994; Szulanski, 1996, 2000; Freiling and Huth, 2005). Due to a higher general environmental awareness combined with a call for efficiency, modern research papers are increasingly focusing on industrial parks as eco-systems (Côté and Hall, 1995; Côté and Cohen-Rosenthal, 1998; Geng *et al.*, 2007; Gibbs and Deutz, 2005; Lambert and Boons, 2002; Lowe, 1997; Jung *et al.*, 2013). This trend is based on the idea that the traditional model of industrial activity, in which individual manufacturing processes use raw materials to generate marketable products plus waste, should be transformed into a more integrated model. By integrating and coordinating the consumption of materials and energy of the companies, such an industrial eco-system aims to achieve improved environmental balance as the waste or by-products of one production process might serve as the input for another process (Frosch and Gallopoulos, 1989). In consequence, Tibbs (1992) describes that "industrial ecology involves designing industrial infrastructures as if they were a series of interlocking manmade eco-systems interfacing with the natural global eco-system". Based on this concept of industrial ecology, there is a new type of industrial park, the "eco-industrial park" which is aimed as a district where various companies co-operate with each other and the local community in order to efficiently share resources, leading not just to economic but also environmental improvements (Walcott, 2009). Performance measurement and benchmarking.

As outlined by Brignall and Ballantine (1996), traditional models of performance measurement, largely evolved within major corporations, were initially primarily focusing on the achievement of a limited number of key financial measures, like return on investment or earnings per share. Since the 1990s, there has been an increasing dissatisfaction with these traditional forms of performance measurement, e.g. due to limitations with regard to future performance developments or due to the heavy focus on financial factors, as evidenced by a number of literatures in the areas of management accounting, operations management as well as strategy (Fitzgerald *et al.*, 1991; Brignall *et al.*, 1992; Govindarajan and Gupta, 1985; Gregory, 1993; Kaplan and Norton, 1992; Anderson and McAdam, 2004; Neely *et al.*, 1995; Moffett *et al.*, 2008; Chia *et al.*, 2009; Johnson and Kaplan, 1987; Bourne *et al.*, 2000; Waal and Kourtit, 2013; Franco-Santos *et al.*, 2012).

In general, research results indicate that organisations using balanced performance measurement systems as the basis for management decisions exhibit superior performance and that measurement plays an important role in the successful implementation of business strategies (Lingle and Schiemann, 1996). Besides this, performance measurement is an essential step to reveal strengths and weaknesses of operations, activities and processes (Zhu, 2009). To achieve this benefit, organisations need to implement an effective performance measurement system that enables well-founded decisions to be made and actions to be taken, because it quantifies the efficiency and effectiveness of past actions. A performance measurement system has a number of constituent steps including acquisition, collection, sorting, combining, analysis, interpretation, and dissemination (Neely, 1998; Kennerley and Neely, 2002). In order to achieve best practice solutions, performance measurement should be linked with benchmarking, as it generates the input data for effective benchmarking (Francis *et al.*, 2002; Camp, 1989; Schmidberger *et al.*, 2009; Mainelli, 2005). Whereas there is no unique and generally accepted definition for benchmarking that can be universally applied to all fields and purposes of benchmarking, most definitions include common features, such as continuity, measurement, improvement, comparison and learning. These features are generally related to the identification and implementation of best practices so as to achieve new, superior performance standards and competitive advantages (Hong *et al.*, 2012; McNair and Leibfried, 1992; Spendolini, 1992; Bhutta and Faizul, 1999; Bogan and Callahan, 2001; Camp, 1995, 1989; Hanman, 1997; Vaziri, 1992; Moffett *et al.*, 2008; Fernandez *et al.*, 2001; Zhu, 2009; Festel and Würmseher, 2013). Based on an analysis of various definitions in literature, Anand and Kodali (2008) described benchmarking as "a continuous analysis of strategies, functions, processes, products or services, performances, etc. compared within or between best-in-class organisations by obtaining information through appropriate data collection method, with the intention of assessing an organisation's current standards and thereby carry out self-improvement by implementing changes to scale or exceed those standards".

As outlined by Alstete (2008), there are differences in perceptions and understanding of the terms benchmarking and performance measurement among practitioners. Due to the widespread use of these terms, the misunderstanding and misuse of the terms is comprehensible. Performance measurement is one of the first steps in process improvement, and involves the choice, designation and use of specific performance indicators to put a number on the effectiveness and success of methods being examined. Organisations typically analyse performance information at a particular point in time and can track their progress and external indicators in subsequent periods. Once a company has implemented a performance measurement system, it can continue its strive for improvement with the benchmarking process by carrying out a comparative analysis with specific performance indicators of its competitors (Fine and Snyder, 1999).

Performance measurement itself has an internal focus and does not contain a comparison to best practice leaders outside the company to obtain knowledge for performance improvement (Gillen, 2001). Therefore, only using a performance measurement system (e.g. in form of a balanced scorecard) cannot provide information about the company's position compared to competitors (Neely *et al.*, 1995). Performance measures can be considered as the information base for strategies to meet improving productivity, customer needs and enhancing corporate competitiveness. So performance indicators (or measures) constitute the basic building blocks as the source for the subsequent evolution and provide the fundamental inputs to the analytical process by which the enablers are identified (Gillen, 2001; Schmidberger *et al.*, 2009; Gunasekaran *et al.*, 2001).

It is important to differentiate between performance measures and benchmarks (as the metrics or target points) on the one hand, and performance measurement and benchmarking (as the related processes) on the other. But there is also a clear difference between a performance measure and a benchmark, mainly due to its focus either on a period of time or a date. Generally, a performance measure provides a continuing measure of cost efficiency, productivity, operating excellence or level of quality and service delivery during a certain period. On the contrary, a benchmark is a point of reference or target that can refer to a core functional area (such as production), a support area (finance), sub-function (billing), business process (product design) or even to a specific task (receipt recording). So once a benchmark has been specified, the performance measure evaluates progress in achieving it (Gillen, 2001). To achieve their overall aims, the performance measures should be specifically determined based on a clear purpose and linked to the company's strategy and business objectives (Varcoe, 1993; Loosemore and Hsin, 2001). Therefore, choosing appropriate performance measures is a basic condition and the characteristics that are required can be summarised as follows (Al-Turki and Duffuaa, 2003):

(1) Relevance. Include data that are essential to provide a basis for understanding the accomplishments of goals and objectives of the company.

(2) Interpretability. Communicate in a readily understandable manner that is concise, yet comprehensive.

(3) Timeliness. Report in a timely manner so that the information will be available to users before it loses its value in making decisions.

(4) Reliability. Report consistency from period to period.

(5) Validity. The measure should determine the intended quality indicator.

With regard to the fifth characteristic, an indicator generally describes a product of several metrics or measures. A performance indicator, in contrast, is a measure capable of generating a quantified value to indicate the level of performance taking into account single or multiple aspects (Parida and Kumar, 2006).

Kaplan and other authors (Cooper and Kaplan, 1988; Kaplan, 1984a, b; Johnson and Kaplan, 1987; Neely *et al.*, 1995) note that for performance measurement and benchmarking purposes, financial data from accounting systems need careful scrutiny and an examination as to whether and which adjustments are deemed necessary. In many cases, these data arise from outdated standard costing systems which are primarily designed to satisfy external financial reporting purposes, such as GAAP, auditing and tax requirements, and the interests of the shareholders, rather than the needs of continuous improvement of operational performance (Varcoe, 1993). This is an important point as sub-optimal decisions based on distorted costs could adversely affect the company's profitability (Frey and Gordon, 1999).

Management accounting literature suggests that for decision making purposes one should consider the relevant influenceable costs (Theeuwes and Adriaansen, 1994), as management is only able to influence these costs by their decisions in the short term. Here the term "influenceable costs" means all costs that can be influenced by choosing one alternative and that can be measured with satisfying accuracy (Nykamp *et al.*, 2012; Belz and Mertens, 1996). By using this cost category for the performance measurement analysis, cost reduction potentials for the company can be better identified.

Methodology

Research scope

A benchmarking study with six chemical parks and chemical related industrial parks in Germany took place between 2006 and 2007. The term "industrial parks" is used in this paper as there are only few chemical industry specific aspects within this study. The size of the industrial parks was between 30 and 230 hectare (ha) and the organisational structures ranged from an infrastructure division, still integrated in the parent company, over an infrastructure division of a company as own legal entity to an independent infrastructure company (participants P1 to P6 in Figure 1). As the study covered a broad spectrum of size and organisational structures, the analysed industrial parks are representative for the industrial park landscape in Germany. The main focus of this study was on operation and maintenance of buildings, communication infrastructures (data and telecommunication networks) and traffic infrastructures (roads including street lighting). Building and construction activities outside normal maintenance (e.g. the build-up of new infrastructures including capacity extensions) were not part of the analysis. Aim of the benchmarking was the evaluation of the performance to obtain an overview regarding the operational competitiveness of the participants and to find first indications for cost saving potentials.

In respect of methodological choices, benchmarking and the related performance measurement process are associated with an action research methodology in a number of studies (Neely *et al.*, 2000; Moss *et al.*, 2007; Kaplan, 2001; Schmidberger *et al.*, 2009; Najmi *et al.*, 2005). This is mainly due to the developmental nature of both processes, and action research combines practical needs for developing performance and the collective intentional learning involved in it. As it contributes to an advanced understanding of the interplay between scientific and practical knowledge, action research can be used at the same time for both practical developmental work and scientific studies (Kyrö, 2004, 2006). The action research methodology simultaneously strives to achieve useful outcomes for the benefit of the participants from practice and new forms of theoretical understanding. Due to interdependencies between both components, reflection is decisive for practical and scientific advancement (Reason and Bradbury, 2008; Coughlan and Coghlan, 2002; Gummesson, 2000; Coghlan and Brannick, 2010). So action research is a continuous and iterative process which can be described as a spiral of cycles, each consisting of four components:

(1) research and development;

(2) intellectual inquiry and practical improvement;

(3) reflection; and

(4) action (Altrichter *et al.*, 2002).

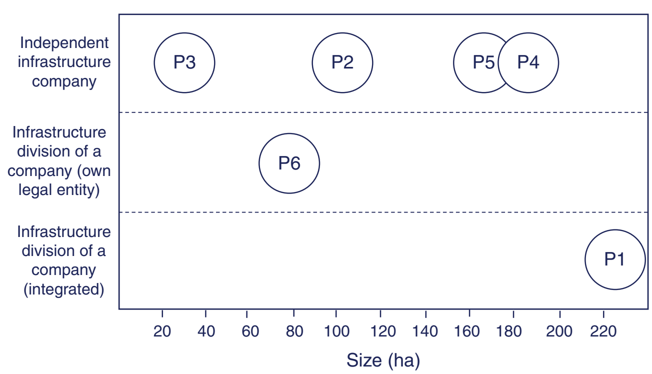

Figure 1.
Participants P1 to P9 of the benchmarking study

Research approach

The research work was performed in a five-phase approach (Figure 2). In a first phase between December 2006 and February 2007, the performance measurement study was initialised through telephone interviews with experts from all participating industrial parks. These interviews aimed to define the areas for the analysis, the objectives of the study for each area and to ensure the understanding of the specific aspects of each analysed infrastructure. Based on these interviews, the consolidated information was presented and discussed with all experts in a first workshop arranged in February 2007 within phase 2. At this workshop, the key performance indicators for all areas covered in this research study were defined according to the needs of all participants. Following up on this event, standardised excel survey templates were prepared and distributed, in order to compile and process the input data in a structured and comparable manner.

In a second workshop held in March 2007 within phase 3, the research methodology, including excel templates and related data set up, was adjusted. In this context, an important feature was to take into account the specific aspects in the layout and age/history of the infrastructures by appropriate correction factors for all key performance indicators. This was aimed at enabling a standardised and reasonable comparison of the different infrastructures of the participants. The definition and detailed specification of the correction factors was based on expert opinions and consensus among the participants of this workshop. In April and May 2007, the data were collected from all participants using the excel templates, and the key performance indicators were calculated.

For the examination, a fitted linear regression line is plotted for each key performance indicator to illustrate the correlation between the independent and dependent variables. Furthermore, the regression function y (incl. correlation coefficient) and the coefficient of determination R^2 are stated in the figures for each fitted linear regression line. As indicated by the slope of the regression line and the small correlation coefficients, the dependent variables are relatively unaffected by marginal changes of the independent variables (e.g. resulting from measurement errors). Tests for the normality of the distribution were omitted due to small sample size. However, to evaluate the impact of one observation on the results obtained by this model, a sensitivity test was performed by omitting one observation. Particularly the omission of one observation with a higher distance to the regression line (which, in this study, often occurs at the lower end of the abscissa) may cause considerable changes to the results. Furthermore, based on the Dixon type test (Dean and Dixon, 1951) some outliers could be detected using a 95 per cent confidence level, particularly for observations in context with total costs. But this was to be expected, due to the small sample size, and the consequences are acceptable for the purposes of this exploratory study on an innovative benchmarking approach.

The key performance indicators were discussed and the cost saving potentials evaluated as follows: in a diagram, for each participant, the correction factor was plotted on the horizontal axis and the key performance indicator on the vertical axis; a fitted linear regression line was calculated based on data points based on correction factor and value of the key performance indicator for all participants, which is considered to be best practice; the distance between each individual data point and the regression line illustrates the cost saving potential for a particular participant. Positive cost saving potentials are shown, if the value of the key performance indicator of this data point is higher than the correlating value (i.e. the same value of the correction

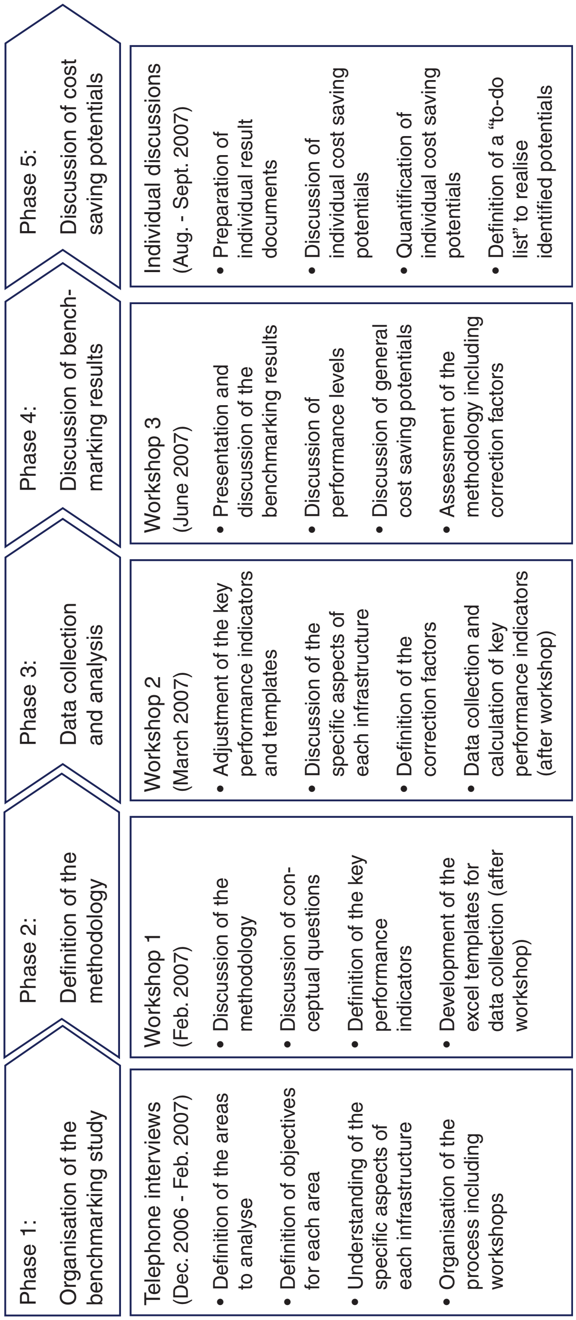

Figure 2.
Phases and time schedule of the benchmarking study

factor) of the regression line. Values below the regression line means that the key performance indicator is below best practice showing "negative" cost saving potentials.

The calculation and illustration of the results were discussed with all participants during a final workshop held in June 2007 within phase 4. In the final phase 5, an individual set of documents containing opportunities for improvement was prepared and delivered to each participant. In order to further specify these individual results, final discussions regarding the identified cost saving potentials and other improvements were conducted with each participant in August and September 2007.

Data basis

The study is based on two kinds of measures: influenceable and total costs. In this context it is very important to clearly define the two categories of costs and determine the relevant costs therein. Here the key performance indicators based on influenceable costs are defined to comprise own labour costs (including fringe benefits), external labour/service costs, and material costs (e.g. spare parts). The key performance indicators based on total costs, as the more comprehensive category, additionally contains management and other overhead costs (e.g. administration, marketing and sales), and capital costs. It is important to note that operational costs and costs for new infrastructure and infrastructure extensions, including planning, are generally not considered in this study.

With respect to the comparability, some issues arose related to insufficient data quality, as some participants were unable to retrieve the required data for both cost categories from their management accounting system, i.e. some of the participants could only give figures for total costs and not for influenceable costs. During the second workshop, held in March 2007, these issues were discussed and it was jointly decided to use the available total cost data and carry out specific adjustments based on expert opinions – as far as possible. There was a broad consensus that these data limitations would only have a minor impact on the results of this analysis.

Results and discussion

The presentation and discussion of the results is structured along the different investigated areas: buildings, communication infrastructures with data networks and telecommunication networks as well as traffic infrastructures with roads, including street lighting.

Buildings (maintenance costs and rates)

Evaluation scope was on operation and maintenance of buildings in the industrial parks. Important was a differentiated view according to the type of building (administration buildings, industrial buildings, warehouses) and the consideration of specific aspects, like average age of the buildings, technical equipment of the buildings and usage of the buildings (type and intensity of usage). In order to benchmark absolute cost performance (e.g. euros per m^2), the building costs need to be normalised to account for these factors (Migliaccio *et al.*, 2011; Dai *et al.*, 2012). This could be covered by using normalised building costs which allow the assessment of each building regarding type and usage, age and technical standard. In Germany, these normalised building costs are listed in the "Wertermittlungsrichtlinie" published by the German Federal Ministry of Transport, Building and Urban Development

(BMVBS, 2006). The standardisation of maintenance costs for buildings on the basis of normalised building costs, and not only based on replacement value, made the customer specific allocation of maintenance costs possible.

Some participants were unable to deliver all data. P2 has no warehouse buildings in their cost accounting system as these are considered under industrial buildings. P3 was unable to split-the data for buildings into the different types of buildings and delivered only the total value for all the types of buildings. In general, P5's data availability was poor compared to the other participants (e.g. it was not possible to evaluate non-influenceable costs, so that the maintenance rates for influenceable costs and total costs are the same).

Key performance indicators for administration buildings are the maintenance rates based on the gross floor area as well as in relation to the normalised building costs and the replacement value (Table I). The maintenance rates for administration buildings, based on the gross floor area, are between 7.59 (P5) and 34.74 (P1) euros per m^2 for influenceable costs and between 7.59 (P5) and 44.75 (P2) euros per m^2 for total costs. Based on normalised building costs, the maintenance rates are between 0.64 (P5) and 2.31 (P1) per cent for influenceable costs and between 0.64 (P5) and 4.51 (P2) per cent for total costs. The maintenance rates based on replacement value are between 0.52 (P2) and 2.13 (P4) per cent for influenceable costs and between 0.71 (P5) and 3.70 (P4) per cent for total costs.

For industrial buildings, the gross building volume is used instead of the gross floor area. The maintenance rates for industry buildings based on the gross building volume are between 0.23 (P5) and 1.84 (P6) euros per m^3 for influenceable costs and between 0.23 (P5) and 2.34 (P6) euros per m^3 for total costs. Based on normalised building costs, the maintenance rates are between 0.14 (P5) and 1.47 (P6) per cent for influenceable costs and between 0.14 (P5) and 1.86 (P6) per cent for total costs. The maintenance rates based on replacement value are between 0.12 (P5) and 1.76 (P4) per cent for influenceable costs and between 0.12 (P5) and 3.05 (P4) per cent for total costs. P2 has remarkably large differences between influenceable and total costs for administration and industrial buildings, which were caused by the fact that most costs were allocated as overhead costs and were not further specified in the cost accounting system. Thus making more cost transparency necessary in the future.

For warehouse buildings, the gross building volume is used, as in the case of industrial buildings. The maintenance rates for warehouse buildings based on the gross building volume are between 0.07 (P4) and 1.79 (P6) euros per m^3 for influenceable costs and are between 0.33 (P5) and 2.27 (P6) euros per m^3 for total costs. Based on normalised building costs, the maintenance rates are between 0.06 (P4) and 1.33 (P6) per cent for influenceable costs and between 0.23 (P5) and 1.69 (P6) per cent for total costs. The maintenance rates based on replacement value are between 0.05 (P4) and 1.49 (P6) per cent for influenceable costs and between 0.23 (P5) and 1.89 (P6) per cent for total costs.

The maintenance rates for all types of buildings are calculated as weighted average of the different types of buildings. Based on normalised building costs, the maintenance rates are between 0.29 (P5) and 1.53 (P1) per cent for influenceable costs and between 0.29 (P5) and 1.84 (P6) per cent for total costs. The maintenance rates based on replacement value are between 0.29 (P5) and 1.59 (P1) per cent for influenceable costs and between 0.29 (P5) and 2.79 (P2) per cent for total costs.

Table I.
Key performance indicators for buildings

		P1	P2	P3	P4	P5	P6
Administration buildings							
Maintenance costs							
Influenceable costs	(mn euro)	0.76	0.05	na	0.39	0.08	1.94
Total costs	(mn euro)	0.93	0.24	na	0.68	0.08	2.47
Maintenance rates (gross floor area)							
Influenceable costs	(euro/m^2)	34.74	8.74	na	20.40	7.59	18.32
Total costs	(euro/m^2)	42.52	44.75	na	35.45	7.59	23.23
Maintenance rates (normalised building costs)							
Influenceable costs	(%)	2.31	0.88	na	2.08	0.64	1.51
Total costs	(%)	2.83	4.51	na	3.62	0.64	1.91
Maintenance rates (replacement value)							
Influenceable costs	(%)	1.98	0.52	na	2.13	0.71	1.53
Total costs	(%)	2.43	2.64	na	3.70	0.71	1.04
Indus try buildings							
Maintenance costs							
Influenceable costs	(mn uro)	0.10	0.22	na	0.88	0.02	2.65
Total costs	(mn euro)	0.10	0.66	na	1.52	0.02	3.36
Maintenance rates (gross building volume)							
Influenceable costs	(euro/m^3)	0.67	0.49	na	1.06	0.23	1.84
Total costs	(euro/m^3)	0.67	1.51	na	1.84	0.23	2.34
Maintenance rates (normalised building costs)							
Influenceable costs	(%)	0.60	0.38	na	0.83	0.14	1.47
Total costs	(%)	0.60	1.17	na	1.44	0.14	1.86
Maintenance rates (replacement value)							
Influenceable costs	(%)	1.13	0.93	na	1.76	0.12	1.53
Total costs	(%)	1.13	2.85	na	3.05	0.12	1.94
Warehause buildings							
Maintenance costs							
Influenceable costs	(mn euro)	0.03	na	na	0.01	0.10	1.30
Total costs	(mn euro)	0.03	na	na	0.37	0.10	1.64

(*continued*)

		P1	P2	P3	P4	P5	P6
Maintenance rates (gross building volume)							
Influenceable costs	(euro/m^3)	0.28	na	na	0.07	0.33	1.79
Total costs	(euro/m^3)	0.28	na	na	1.84	0.33	2.27
Maintenance rates (normalised building costs)							
Influenceable costs	(%)	0.33	na	na	0.06	0.23	1.33
Total costs	(%)	0.33	na	na	1.58	0.23	1.69
Maintenance rates (replacement value)							
Influenceable costs	(%)	0.33	na	na	0.05	0.23	1.49
Total costs	(%)	0.33	na	na	1.20	0.23	1.89
All types of buildings							
Number of buildings		12	9	26	80	4	143
Normalised building costs	(mn euro)	58.11	61.67	71.55	148.48	65.73	407.05
Replacement value	(mn euro)	55.90	32.20	80.00	100.23	65.11	387.00
Maintenance costs							
Influenceable costs	(mn euro)	0.89	0.26	0.56	1.28	0.19	5.89
Total costs	(mn euro)	1.06	0.90	0.75	2.57	0.19	7.47
Maintenance rates (normalised building costs)							
Influenceable costs	(%)	1.53	0.43	0.78	0.86	0.29	1.45
Total costs	(%)	1.82	1.46	1.05	1.74	0.29	1.84
Maintenance rates (replacement value)							
Influenceable costs	(%)	1.59	0.82	0.70	1.28	0.29	1.52
Total costs	(%)	1.89	2.79	0.94	2.58	0.29	1.93
Cost s aving potential (normalis ed building costs)							
Influenceable cos ts	(%)	0.80	(0.27)	(0.02)	(0.18)	(0.4)	0.07
Total costs	(%)	0.65	0.29	(0.2)	0.16	(0.82)	(0.17)
Cos t s aving potential (normalis ed building costs)							
Influenceable costs	(Teuro)	465	(167)	(14)	(267)	(263)	285
Total costs	(Teuro)	378	179	(143)	238	(539)	(692)

(*continued*)

Table I.

Table I.

		P1	P2	P3	P4	P5	P6
Cost saving potential (replacement value)							
Influenceable costs	(%)	0.74	(0.04)	(0.23)	0.07	(0.55)	(0.04)
Total costs	(%)	0.34	1.22	(0.72)	0.68	(1.27)	(0.34)
Cost saving potential (replacement value)							
Influenceable costs	(Teuro)	414	(13)	(184)	70	(358)	(155)
Total costs	(Teuro)	190	393	(576)	682	(827)	(1,316)
Number of facility managers		2.50	1.25	1.00	2.00	0.36	6.00
Building management costs	(Teuro)	175	71	60	130	22	421
Specific building management costs (replacemente/value)	(%)	0.31	0.22	0.08	0.13	0.03	0.11
Cost saving potential (replacement value total costs)	(euro)	26,250	199	(1,200)	(9,100)	(440)	(21,050)

Note: The numbers in brackets are “negative” cost saving potentials

Buildings (cost saving potentials)
The number of buildings was chosen as correction factor, i.e. as measure for the complexity of maintenance. Figure 3 shows the maintenance rates for all types of buildings based on normalised building costs with the number of buildings as vertical axis. The linear regression line increases slightly with the correction factor, which is expected as increasing maintenance rates should correlate with increasing complexity. Despite P1 and P6 having the same maintenance rate, the complexity correction shows that the values for P1 are unusually high compared to the other participants. P6, P3 and P4 represent best practice, as the data points are near the regression line. Figure 4, with the maintenance rates for buildings based on replacement value, shows almost the same

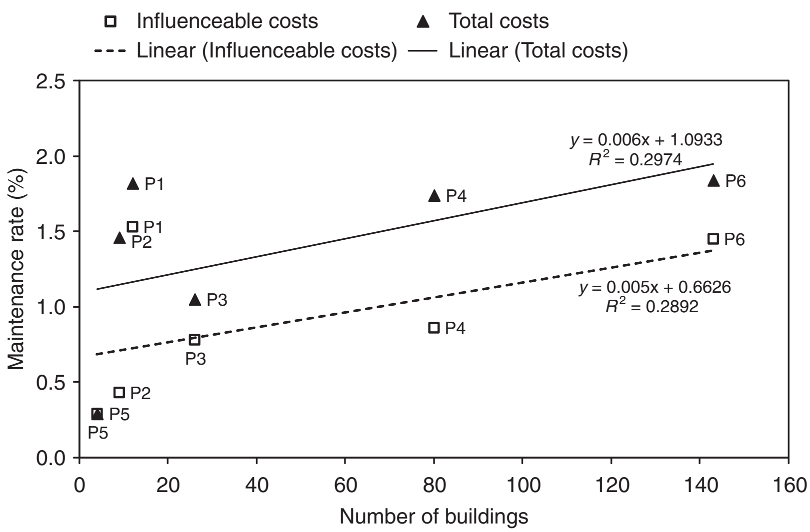

Figure 3.
Maintenance rates for all types of buildings based on normalised building costs with number of buildings as correction factor

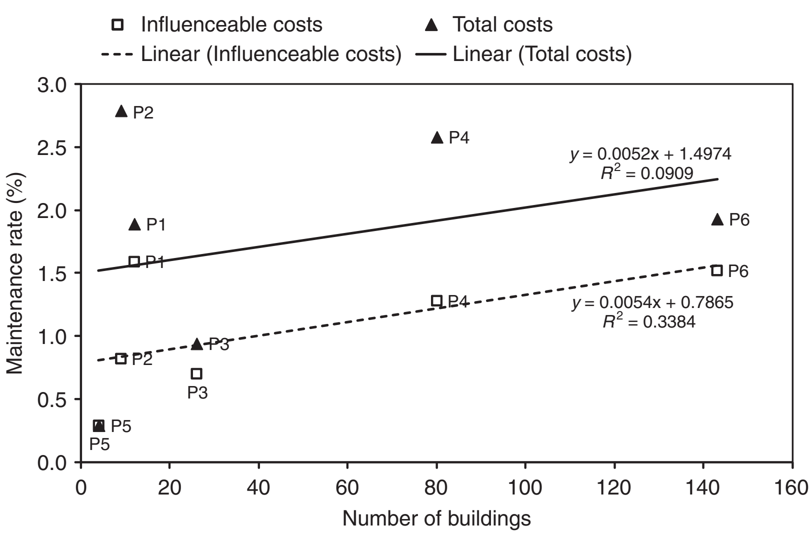

Figure 4.
Maintenance rates for all types of buildings based on replacement value with number of buildings as correction factor

result with the difference that P2 and P4 instead of P1 have unusually high maintenance rates after complexity correction. P3 and P4 are best practice and P5 below best practice.

The cost saving potentials are calculated in different ways: based on influenceable costs and total costs as well as maintenance rates for buildings based on normalised building costs and on replacement value (Table I). The cost saving potentials based on normalised building costs are for influenceable costs between 285 (P6) and 465 (P1) thousand euros per year and based on total costs between 179 (P2) and 378 (P1) thousand euros per year. Values below the regression line, as in the case of P2, are in brackets and mean that the maintenance rates are below best practice (i.e. "negative" cost saving potentials) which could be an indication that maintenance is not sufficient in the long term. The cost saving potentials based on replacement values are for influenceable costs between 70 (P4) and 414 (P1) thousand euros per year and based on total costs between 393 (P2) and 682 (P4) thousand euros per year. Comparing the cost saving potentials based on normalised building costs with the potentials based on replacement values shows some differences, but the same tendency and the clear message that P1, P2 and P4 can achieve significant cost reductions without quality loss within their maintenance activities.

Besides maintenance, the building management costs, i.e. costs for the technical facility management, are the second largest cost factor within the category buildings. They are between 60 (P3) and 421 (P6) thousand euros per year. The specific building management costs are the building management costs in correlation to the replacement value to consider the value of the buildings. They are between 0.03 per cent (P5) and 0.31 per cent (P1). The specific building management costs based on replacement value with the number of buildings as correction factor could not be used to evaluate the cost savings potential, as the regression line declined with an increase in the number of buildings, indicating the need for a more appropriate correction factor (Figure 5). Using instead the maintenance rate, based on the replacement value and total costs as correction factor gave better results (Figure 6). P2, P3 and P5 represent best practice and the value of P1 is double as high than expected, which could be explained by organisational inefficiencies. On the other hand, the below best practice values of P4

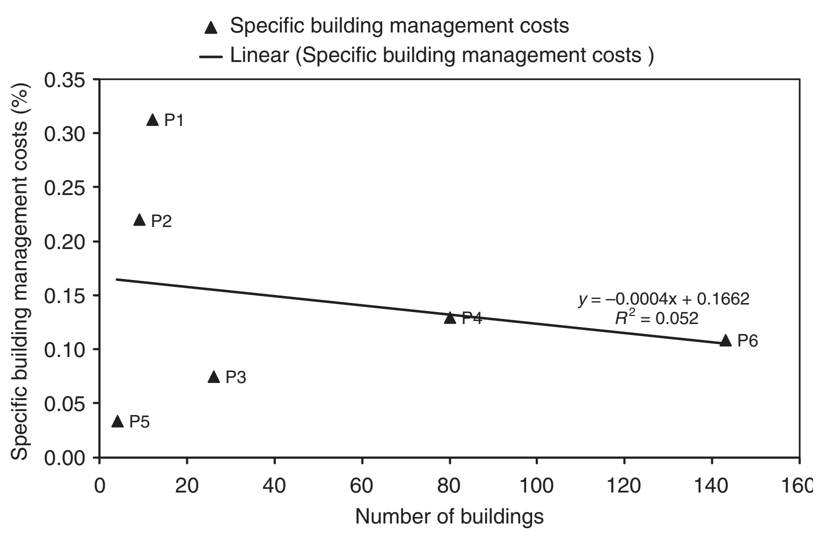

Figure 5.
Specific building management costs for all types of buildings based on replacement value with number of buildings as correction factor

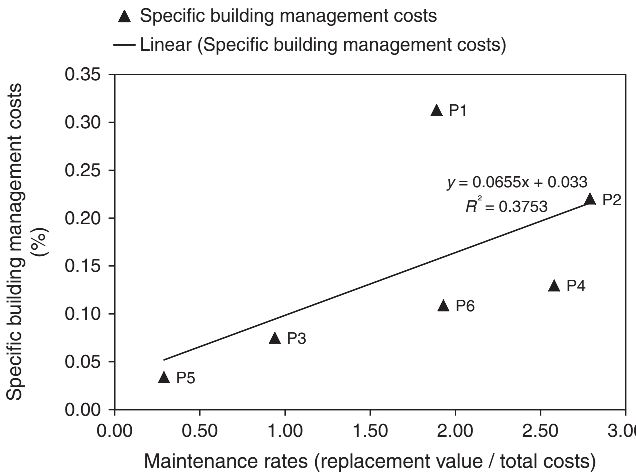

Figure 6. Specific building management costs for all types of buildings based on replacement value with maintenance rates (replacement value/total costs) as correction factor

and P6 are also due to efficiency increase in the organisation (e.g. bundling of the technical facility management for buildings and streets). The cost saving potential, as a result of the specific building management costs in correlation to the maintenance rates, as correction factor, is from 199 (P2) and 26,250 (P1) euros per year.

Communication infrastructures

The data networks were evaluated up to the port and there were five participants, as P3 was not able to deliver data. The analysed data networks has very different sizes: the number of connected buildings ranges from 12 (P2) to 75 (P6), the number of active ports from 500 (P2) to 3,000 (P6) and the number of users from 200 (P2) to 3,500 (P6) (Table II). The operation and maintenance costs are between 90 (P2) and 676 (P6) thousand euros (influenceable costs) and 98 (P2) and 792 (P6) thousand euros (total costs). The specific costs for the data networks per active port are between 159 (P1) and 268 (P4) euros and per user between 94 (P5) and 489 (P2) euros.

Important for cost saving potentials was the consideration of specific aspects, like number of connected buildings and the number of active ports or users. Figure 7 shows the specific costs for data networks per active port and per user with the number of connected buildings as correction factor. Only the determination of cost saving potentials per active port makes sense, as the regression line per user is declining. An explanation for this is the extremely high value of costs per user of P2, due to the downsizing of the site (two large industrial companies left this site) without a consequent reduction of the infrastructure or correlated costs. The cost saving potentials for data networks per active port are 14.4 (P2) and 43.2 (P4) euro per year. Within this analysis, the cost reduction potential of P2 is far too low, due to the fact that many active ports are not used. This is a good example of the impact on the outcome of such a benchmarking that the definition of key performance indicator and correction factor has.

The telecommunication networks were evaluated up to the connector socket. As P5 and P6 could not provide data, only P1 to P4 were analysed. The number of connected buildings ranges from 12 (P2) to 80 (P4), the number of devices from 280 (P3) to 3,300 (P4) and the number of users from 180 (P3) to 3,300 (P4) (Table II). The number of devices includes fax machines and digital enhanced cordless telecommunications (DECT) telephones. The specific cost for telecommunication networks per device is 57

Table II. Key performance indicators for communication infrastructure

		P1	P2	P3	P4	P5	P6
Data networks							
Basic data							
Number of connected buildings		60	12	na	60	45	75
Number of active ports		1,800	500	na	2,800	1,200	3,000
Number of users		3,000	200	na	2,000	2,500	3,500
Operation/maintenance costs				na			
Influenceable costs	(Teuro)	282	90	na	540	215	676
Total costs	(Teuro)	286	98	na	750	235	792
Specific costs				na			
Per active port	(euro)	159	196	na	268	196	264
Per user	(euro)	95	489	na	375	94	226
Cost saving potentials				na			
Peractive port	(euro)	(64.8)	14.4	na	43.2	16.8	28.8
Telecommunication networks							
Network structure							
Number of connected buildings		60	12	40	80	na	na
Number of devices		2,400	700	280	3,300	na	na
Number of users		3,000	700	180	3,300	na	na
Operation/maintenance costs							
Influenceable costs	(Teuro)	228	35	21	700	na	na
Total costs	(Teuro)	324	40	21	850	na	na
Specific costs							
Per device	(euro)	135	57	73	258	na	na
Per user	(euro)	108	57	114	258	na	na
Cost saving potentials							
Per device	(euro)	(30)	28.8	(33.6)	36.0	na	na
Per user	(euro)	(57.6)	14.4	(1.2)	40.8	na	na

Note: The numbers in brackets are "negative" cost saving potentials

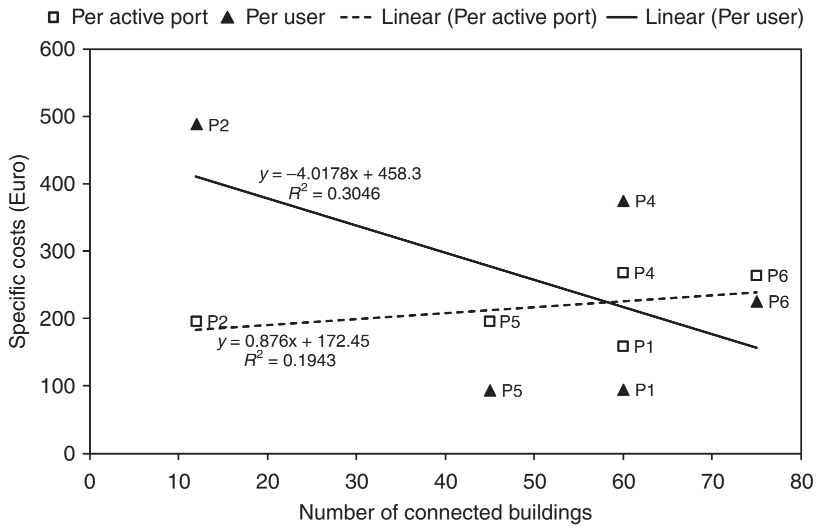

Figure 7.
Specific costs for data networks per active port and user with number of connected buildings as correction factor

(P2) and 258 (P4) euro as well as per user 57 (P2) and 258 (P4) euro. P4 has high specific costs per device and per user due to high DECT coverage.

In the case of telecommunication networks, the specific costs for telecommunication networks per device and per user are correlated with the number of connected buildings as correction factor (Figure 8). The two regression lines per device and user are very similar, so that both are used to calculate cost saving potentials. In contrast to Figure 7, this example shows a high consistency of the two different key performance indicators, because almost all the devices are used. The yearly cost saving potentials for telecommunication networks per device are 28.8 (P2) and 36.0 (P4) euro as well as per user 14.4 (P2) and 40.8 (P4) euro.

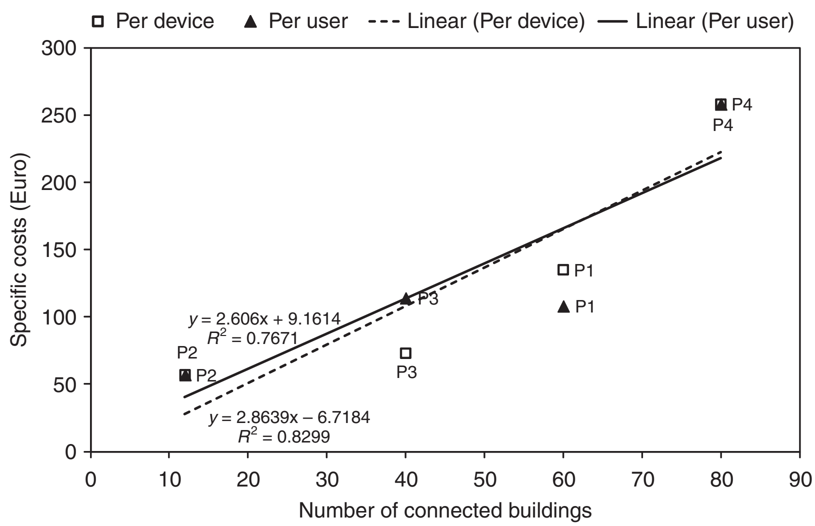

Figure 8.
Specific costs for telecommunication networks per device and user with number of connected buildings as correction factor

Traffic infrastructures

The traffic infrastructures, roads including street lighting, were evaluated (Table III). The length of the roads is between 4 (P2) and 27 (P1) km covering an area between 48,000 (P2) and 256,600 (P1) m^2. Important was the consideration of specific aspects, like the number of road categories in the sense of construction classes to cover the complexity of the road system. The determination of the age of roads and the traffic frequency (especially heavy vehicle traffic) was not possible. The replacement values are between 4.8 (P2) and 36.6 (P1) million euros. The total maintenance costs are between 30 (P5) and 740 (P4) thousand euros.

Various key performance figures for roads were defined, like maintenance rates based on the size of area (not the length) of the roads and in relation to the replacement value. The maintenance rates for roads based on size of area are between 0.36 (P5) and 4.16 (P4) euro/m^2 for influenceable costs and between 0.38 (P5) and 5.13 (P4) euro/m^2 for total costs. The maintenance rates for roads based on replacement values are between 0.01 per cent (P1 and P5) and 0.07 per cent (P4) for influenceable costs and between 0.01 (P1 and P5) and 0.08 (P4) euro/m^2 for total costs.

It was tried to analyse the cost improvement potentials using the maintenance rates for roads based on size of area with number of road categories as correction factor (Figure 9) and the maintenance rates for roads based on replacement value with number of road categories as correction factor (Figure 10). In both cases the linear regression line does not represent the data points showing a negative slope which makes no sense, as it should be positive representing increasing complexity. Due to limitations of data availability, the application of other correction factors was not possible. This is an example that the evaluation of best practice and cost reduction potentials is not always possible using the described correction factor methodology.

The road management costs, i.e. costs mainly for the road managers to observe the road conditions and to manage maintenance activities, are between 6.0 (P5) and 37.4 (P4) thousand euros. The specific management costs as key performance indicator for roads based on size of area are between 0.01 (P5) and 0.28 (P1) euro/m^2. The best practice analysis with the number of road categories as correction factor is shown in Figure 11. P1 and P2 are worse than best practice and show cost saving potentials between 0.06 (P1) and 0.08 (P2) euro/m^2 or in absolute numbers 3,800 (P2) and 15,400 euros per year.

The number of street lights are between 304 (P2) and 813 (P1) and the maintenance costs both for influenceable costs and total cost between 7.2 (P2) and 80.0 (P1) thousand euros. Due to data availability, it was not possible for most of the participants to split the costs into influenceable costs and total costs. For street lighting, the maintenance rates, based on the number of lights and the size of road area, were defined as key performance indicators. The values for maintenance rates based on the number of lights are between 23.81 (P2) and 98.5 (P1) euro and the maintenance rates based on the size of road between 0.15 (P2) and 0.42 (P4) euro. The maintenance rates for street lighting, based on the number of street lights with size of area as correction factor are shown in Figure 12 with only P4 slightly above the best practice regression line. Additionally, the electricity consumption and electricity costs per light and per size of area were determined. The electricity consumption per light is between 313 (P4) and 914 (P5) KWh and per size of area between 1.56 (P4) and 4.10 (P5) KWh/m^2. The electricity costs per light are between 37.5 (P4) and 109.7 (P5) euro and per size of area between 0.19 (P4) and 0.49 (P5) euro/m^2.

		P1	P2	P3	P4	P5	P6
Roads							
Basic data							
Length	(km)	27.0	4.0	na	13.3	9.2	na
Area	(Tm^2)	256.6	48.0	na	144.3	80.5	na
Number of road categories		5	1	3	3	3	3
Replacement value	(mn euro)	36.6	4.8	na	9.9	5.6	na
Maintenance costs							
Influenceable costs	(Teuro)	456	140	na	600	29	na
Total costs	(Teuro)	529	140	na	740	30	na
Maintenance rates (size of area)							
Influenceable costs	(euro/m^2)	1.78	2.92	na	4.16	0.36	na
Total costs	(euro/m^2)	2.06	2.92	1.25	5.13	0.38	4
Maintenance rates (replacement value)							
Influenceable costs	(%)	0.01	0.03	na	0.07	0.01	na
Total costs	(%)	0.01	0.03	0.02	0.08	0.01	0.04
Cost saving potential (size of area)							
Influenceable costs	(euro/m^2)	(0.05)	0.05	na	1.93	(1.93)	na
Total costs	(euro/m^2)	(0.09)	(0.18)	(1.38)	2.48	(2,210)	1.29
Cost saving potential (size of area)							
Influenceable costs	(Teuro)	(12.8)	2,4	na	278.5	(155.4)	na
Total costs	(Teuro)	(23.1)	(8.6)	na	357.9	(177.9)	na
Road management							
Number of road managers		1.0	0.3	na	0.6	0.1	na
Road manager costs	(Teuro)	7.2	12.6	na	37.4	6.0	na
Specific management costs (size of area)	(Euro/m^2)	0.28	0.07	na	0.10	0.01	na
Cost saving potential (road management)							
Road management costs	(euro/m^2)	0.060	0.080	na	(0.017)	(0.103)	na
Road management costs	(Teuro)	15.4	3.8	na	(2.4)	(8.3)	na
Street lighting							
Basic data							

(*continued*)

Table III. Key performance indicators for traffic infrastructure

Table III.

		P1	P2	P3	P4	P5	P6
Number of street lights		813	304	na	720	361	na
Maintenance costs							
Influenceable costs	(Teuro)	80.0	7.2	na	61.0	14.6	na
Total costs	(Teuro)	80.0	7.2	na	61.0	15.3	na
Maintenance rates (number of street lights)							
Influenceable costs	(Euro)	98.5	23.81	na	84.72	40.32	na
Total costs	(euro)	98.5	23.81	na	84.72	42.33	na
Maintenance rates (size of area)							
Influenceable costs	(euro/m^2)	0.31	0.15	na	0.42	0.18	na
Total costs	(euro/m^2)	0.31	0.15	na	0.42	0.19	na
Cost saving potential (per street light)							
Influenceable costs	(euro)	(7.0)	(7.8)	na	8.0	(3.1)	na
Total costs	(euro)	(7.0)	(8.5)	na	8.0	(0.8)	na
Electric energy consumption							
Per light	(KWh)	554	362	na	313	914	na
Per size of area	(KWh/m^2)	1.75	2.29	na	1.56	4.10	na
Electric energy costs							
Per light	(euro)	66.4	43.4	na	37.5	109.7	na
Per size of area	(euro/m^2)	0.21	0.28	na	0.19	0.49	na

Note: The numbers in brackets are "negative" cost saving potentials

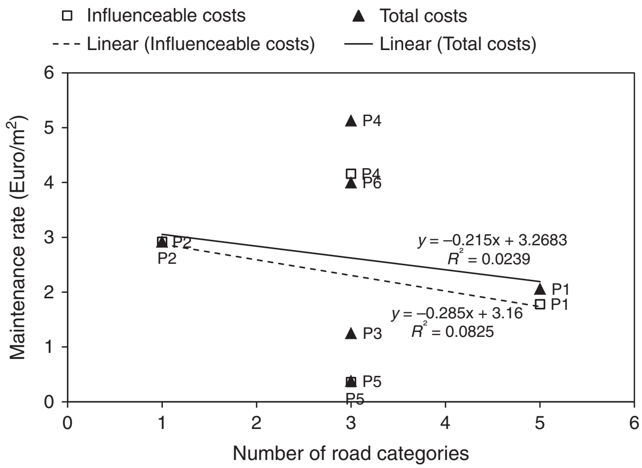

Figure 9.
Maintenance rates for roads based on size of area with number of road categories as correction factor

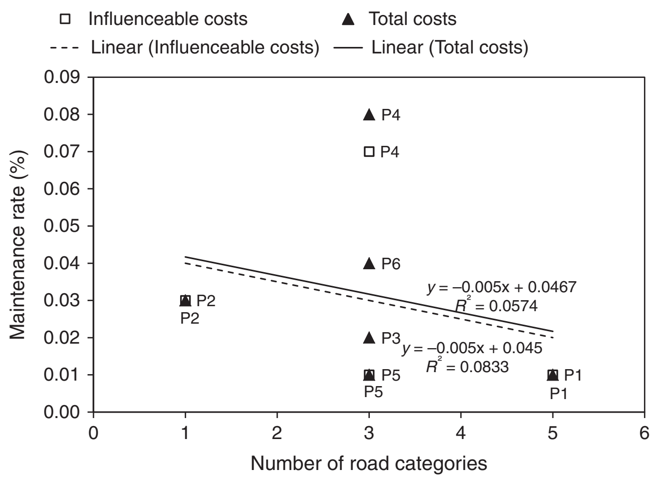

Figure 10.
Maintenance rates for roads based on replacement value with number of road categories as correction factor

Conclusions and recommendations

Assessment of the research methodology

The developed benchmark methodology using the correction factors made a discussion based on comparable and comprehensible figures possible. It is well suited to evaluate best practice in the field of industrial park infrastructures. The usage of the correction factors enabled the comparison of infrastructures with different complexity. The experience from the workshop showed that the correction factors increase the acceptance of the benchmarking methodology in practice, especially if they are individually identified by the participants. The correction factors in this study worked well in most cases and could be applied in other studies or used at least as starting point to customise them more to the special needs of other studies.

The linear regression line in the graphs with the correction factor as horizontal axis and the key performance indicator as vertical axis was in most cases suitable for the definition of best practice. This regression line has to increase with increasing

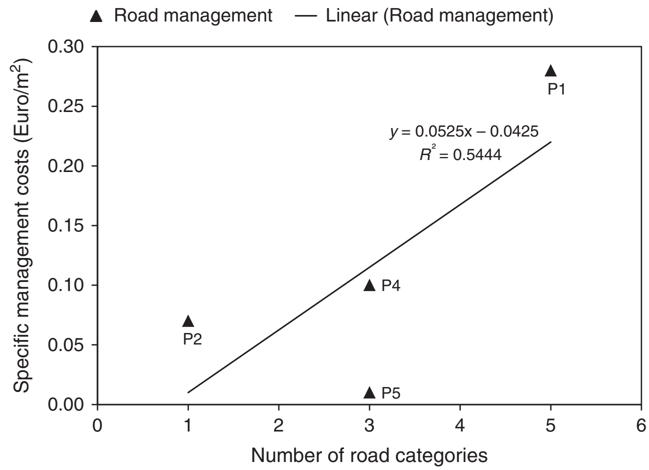

Figure 11.
Specific management costs for roads based on size of area with number of road categories as correction factor

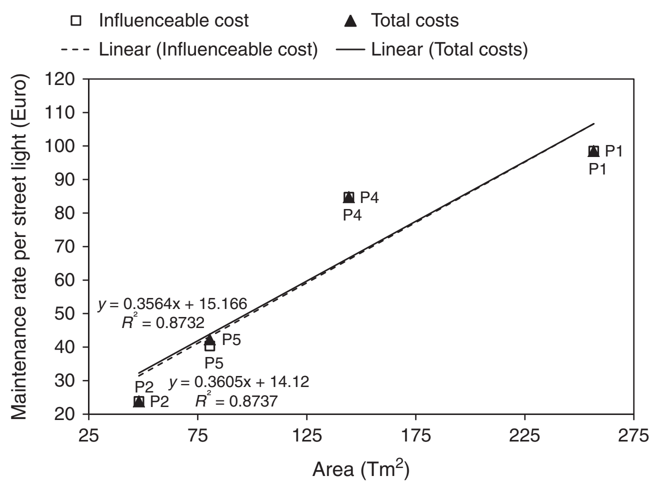

Figure 12.
Maintenance rates for street lighting based on number of street lights with size of area as correction factor

correction factor, i.e. increasing complexity. The quantification of cost saving potentials by measuring the difference between an individual data point and the regression line, if the value of the key performance indicator of this data point is higher than the correlating value of the regression line, gave values which were judged as realistic and attainable by the participants. Important is that it is possible to explain the deviation from best practice. Using both influenceable and total cost categories helped to check these costs for consistency especially in the case of limited data availability as some of the participants could only give figures for total costs and not for influenceable costs. Looking from different angles and combining the benchmarking with the qualitative analysis of infrastructure activities can provide a realistic picture. Identification of cost saving potentials.

Generally, the benchmarking showed large differences in performance levels, indicating that there are still significant cost saving potentials in some industrial parks. The identified cost saving potentials for all investigated areas are summarised in Table IV. The cost saving potentials calculated on influenceable costs for maintenance of all types of buildings based on normalised building costs are roughly between 285,000 and 465,000 euros per year. Based on replacement values, the cost saving potentials for maintenance are roughly between 70,000 and 414,000 euros per year. The correlated values calculated based on total costs confirm these significant potentials which can improve the competitiveness dramatically. The cost saving potential for building management with up to nearly 27,000 euros per year are much lower compared to those in the area of maintenance. The cost saving potentials within the area of communication infrastructure are much lower and more heterogeneous ranging from roughly 7,000 to 121,000 euros for all active ports within data networks, 20,000 to 119,000 euros for all devices within telecommunication networks and 10,000 to 135,000 euros for all telecommunication network users. Compared to building maintenance also the cost saving potentials for road maintenance and management costs are much lower with 2,000 to 275,000 euros for road maintenance based on size of area, 4,000 to 15,000 euros for road management costs and 6,000 euros for the maintenance of street lights.

		P1	P2	P3	P4	P5	P6
All types of buildings							
Maintenance rates (normalised building costs)							
Influenceable costs	(Teuro)	465	(167)	(14)	(267)	(263)	285
Total costs	(Teuro)	378	179	(143)	238	(539)	(692)
Maintenance rates (replacement value)							
Influenceable costs	(Teuro)	414	(13)	(184)	70	(358)	(155)
Total costs	(Teuro)	190	393	(576)	682	(827)	(1,316)
Building management costs							
Data networks	(euro)	26,250	199	(1,200)	(9,100)	(440)	(21,050)
Per active port	(euro)	(64.8)	14.4	na	43.2	16.8	28.8
For all active ports	(euro)	(116,640)	7,200	na	120,960	20,160	86,400
Telecommunication networks							
Per device	(euro)	(30)	28.8	(33.6)	36.0	na	na
For all devices	(euro)	(72,000)	20,160	(9,408)	118,800	na	na
Per user	(euro)	(57.6)	14.4	(1.2)	40.8	na	na
For all users	(euro)	(172,800)	10,080	(216)	134,640	na	na
Roads							
Maintenance rates based on size of area							
Influenceable costs	(Teuro)	(12.8)	2,4	na	278.5	(155.4)	na
Total costs	(Teuro)	(23.1)	(8.6)	na	357.9	(177.9)	na
Road management costs	(Teuro)	15.4	3.8	na	(2.4)	(8.3)	na
Street lighting							
Maintenance rates per street light							
Influenceable costs	(euro)	(7.0)	(7.8)	na	8.0	(3.1)	na
Total costs	(euro)	(7.0)	(8.5)	na	8.0	(0.8)	na
Maintenance rates for all street lights							
Influenceable costs	(euro)	(2,226)	(2,371)	na	5,760	(1,119)	na
Total costs	(euro)	(2,226)	(2,584)	na	5,760	(289)	na

Note: The numbers in brackets are "negative" cost saving potentials

Table IV. Cost saving potentials for the analysed areas

Values of key performance indicators below the regression line indicate that the key performance indicator is below best practice. These "negative" cost saving potentials can be a signal that the maintenance level is too low with negative consequences for the long-term competitiveness of the infrastructure. Not the lowest maintenance level but rather the optimal maintenance level should be the aim of best practice and performance improvement initiatives. Sometimes this insight is lost, especially within top management, which leads to unrealistic and long-term, even counter-productive, cost saving targets. For example, P5 was in almost all evaluations lower than best practice, indicating that the maintenance is not sufficient in the long-term. This was confirmed by a detailed analysis of the maintenance activities over the last years.

Limitations and implications for further research

The results of this exploratory study are not without limitations. The comparability between some industrial parks in the scope of this study may remain limited due to insufficient quality of performance data of the investigated areas. For example, for some of the analysed entities only total costs and not influenceable costs were available. This study is based on a small number of participating industrial parks and further researchers are invited to conduct quantitative research studies on larger data bases including uncertainty analyses. Whether the findings could be generalised outside of Germany warrants further research on an international level. While this study is focusing on a cross comparison of industrial parks, the development of infrastructure costs over time should be examined by longitudinal studies. Whereas there are a large number of research studies focusing on various topics around eco-industrial parks, there are relatively few studies investigating the need to control particular infrastructure costs in industrial parks in general. In the case that there is a need for a corresponding cost monitoring, further studies should also focus on the specification of a related cost control system.

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