Economic evaluation of properties based on consumption data

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Abstract. The building stock is a major factor for achieving climate targets. By improving existing buildings, their efficiency can be significantly increased, thus reducing emissions. The economic evaluation of consumption data is an essential task for operators of properties in order to identify optimization potential. Here, the costs of heat transfer media, electricity and water are essential. The sole evaluation of building-specific consumption data does not fully allow for cross-building comparisons, since other aspects such as their type of use, size and intensity of use have a significant influence. It is necessary to develop a method that allows this comparison and at the same time can be applied with little effort. This paper presents a method for the economic evaluation of buildings taking into account the type of use, size and intensity of use. The innovative method allows the calculation of annuities for certain consumption categories such as electricity. These are combined into an overall performance indicator (PI) for each building. The scale of the PI is generated dynamically depending on the building data under consideration. Thus, a comparison of different buildings is easily and at the same time individually possible in consideration of the real estate portfolio. The results provide an overview of the potential need for optimization of the building as well as the installed plant technology. The effects of potential optimizations on the economic building performance are calculated based on the annuity method and are also included in the revaluation of the respective building. The method was tested in a study of school buildings in a major city in Germany. The method can be used to compare different combinations of measures and determine the optimal option. As a result, decisions regarding possible building optimization measures can be made transparently and scientifically in the future. This enables a more efficient use of resources.

Keywords. Performance Indicator, Annuity, Evaluation of optimizations, Calculation property evaluation.
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1. Introduction

To achieve the climate targets, it is important to plan and construct buildings in an energy-optimized way. However, since the building stock is still responsible for 38% of global energy-related CO2 emissions [1], it should be operated optimally. According to [2], renovating the energy efficiency of buildings has resulted in multiple benefits in terms of energy consumption and environmental impact. To meet this requirement, property operators are regularly faced with economic as well as technical decisions regarding renovation measures of existing properties. Prioritizing which properties to renovate is a challenge. Possible evaluation criteria include, for example, social, moral, economic and other factors [3].

Investments for renovation measures are predominantly made due to economic motivations such as saving energy and repair costs. Less strong motivating factors represent, for example, environmental benefits, efficiency gains, and peer influence. [3]

For this reason, the economic consideration of properties is based on their cost of use. Utilization costs consist of capital, administrative, operating and maintenance costs [4]. The operating costs are the easiest to influence by the operator. According to [5], in residential buildings, energy and water costs account for at least 51%. [6] shows that in the life cycle analysis of various residential buildings, about 44% of the energy consumption is due to the operating phase.

For the reasons mentioned above, it makes sense to consider operating costs when looking at economic optimization measures. However, in order to make recommendations for action on properties to be renovated based on operating costs, reference values or a framework is needed that allows properties to be evaluated economically.

From an energy point of view, the operation of existing residential and non-residential buildings can be assessed, for example, using characteristic values from [7]. However, the use of these characteristic values is hindered by the problem that they represent an outdated building stock from the years 2003 to 2005.

Operator/user-oriented standardized requirements in the building condition and the building technology are not documented there and thus not clearly comprehensible. In [8], energetic factors of building operation are mapped to a specific application. In this example, consumption data is related to supermarket customers.

However, these aforementioned energetic mappings do not allow for an evaluation of possible optimization measures, especially the resulting costs.

Existing tools for deciding on optimization measures so far only consider either the comparison of several optimization measures [9, 10, 11] or the evaluation of buildings [3]. In addition, they include, for example, methods of "machine learning" and can therefore only be used by appropriate experts [9]. Other tools consider the most effective measure under the consideration of different criteria. The focus is on calculating the impact of the different measures rather than making a decision for a property and a measure [10, 11, 12].

The aim of this work is therefore to create a low-threshold and simple tool that can be used to realize a first economic approximation regarding properties worth optimizing. This approximation is based exclusively on data that are reliably available and easy to collect. The evaluation scale is individually adapted to the property portfolio under consideration so that a ranking can be easily identified. The evaluation is carried out with the help of performance indicators, each of which takes into account criteria that are meaningful and individual to the user. The application is based on common spreadsheet programs, which means that investment costs are minimal. In addition to the aforementioned evaluation of the inventory data, an economic evaluation of possible optimization measures with regard to their effects is also planned.

In the following, therefore, section 2 describes the generally applicable calculation method. Section 3 explains the practical implementation of the method on the basis of an application example. Section 4 evaluates the method in terms of its usefulness and discusses its application limits. Finally, section 5 offers concluding remark.

2. Research Methods

In the following section, the method of economic evaluation of properties and suitable optimization measures is considered on the basis of the input parameters, the calculation formulas and the output parameters. In the first step of the method, a current property performance is determined. This is followed in the second step by a comparison of the economic effects of different optimization measures for one of the properties. The choice of the property to be considered is up to the user. It is recommended to investigate optimization possibilities for one of the properties that has a bad economic rating, since the potential for improvement is greater here.

2.1. Input parameters for property evaluation

The input parameters for the calculation are provided by the user. The input is done in list form line by line in given columns.

Object designation: For the identification of the considered objects of the property portfolio, a unique designation for the different objects has to be entered.

Comparison parameters: When creating the data set, care must be taken to ensure that the objects match in certain parameters and are thus comparable with each other in terms of consumption data. One column is provided for each parameter. This enables filtering the list.

Medium e: The following key figures each refer to a medium for which consumption data is available. Examples are water, fuels, or other consumption media.

Price medium p_e: The prices of the medium should be adjusted according to the energy supplier and location. For different energy suppliers and locations, other taxes and charges should be included in the price. Alternatively, an average price depending on the city can be used.

Consumption medium c_e: The consumption of the media heating energy, electricity and water should be stated in kWh/a or l/a. If the properties are located in different climatic zones, the consumption of the heating energy medium must be adjusted with regard to the weather. This can be done, for example, according to [7].

Reference parameter r_d: The key performance indicator can refer to various reference parameters. These reference parameters should reflect the use of the property in the best possible way. Examples of reference parameters include net floor area, number of users, usage times and revenues generated by the property. At least one reference parameter must be specified.

2.2. Calculation of property evaluation

The first step of the calculation includes the calculation of the annuity of the demand-related costs $A_{N,V}$. The calculation is performed per object according to the following formula:

$$A_{N,V,i} = \frac{\sum_{e=1}^{n} p_e * c_e}{\prod_{d=1}^{n} r_d} \quad (1)$$

$A_{N,V,i}$	*Annuity of the demand-related costs*
p_e	*Unit price per medium*
c_e	*Consumption per medium*
r_d	*Reference parameters*
i	*Index per property*

In order to generate a dynamic evaluation of all properties considered, the annuity $A_{N,V}$ of the individual properties is projected onto a performance indicator $PI_{ECO,tot}$. Here, the scale range is defined between the property with the highest annuity ($A_{N,V,max}$) and the property with the lowest annuity ($A_{N,V,min}$) and mapped to a scale from 1 (worst) to 10 (best).

$$PI_{ECO,tot,i} = 1 + \left(\frac{10-1}{(A_{N,V,min} - A_{N,V,max})}\right) * (A_{N,V,i} - A_{N,V,max}) \quad (2)$$

$PI_{ECO,tot,i}$	*Performance indicator economic*
$A_{N,V,i}$	*Annuity of the demand-related costs*
$A_{N,V,min}$	*minimum value of $A_{N,V,i}$*
$A_{N,V,max}$	*maximum value of $A_{N,V,i}$*
i	*Index per property*

2.3. Output of property evaluation

Performance indicator economic: The result represents a listing of all objects. Objects in particular need of optimization can be identified on the basis of $PI_{ECO,tot}$.

2.4. Input parameter for measure evaluation

In order to be able to compare different optimization measures for a specific property, information must be provided on the investments and savings that these measures entail. These optimization measures should be developed and quantified by a specialist planner in terms of their investment costs and consumption savings, depending on the property and the system technology used. In the case of an entry of optimization measures, the previously mentioned parameters of the calculation are adopted for the respective property. The object designation is supplemented by a designation of the respective optimization measure in order to enable a differentiation of the lines. The original object remains in the calculation.

Investment-linked annuity of the optimization measure (according to [13]): The optimization measures of a property are to be calculated on a matching observation period to maintain comparability.

Consumption savings of the optimization measure: This is to be subtracted from the consumption of the respective medium in the original unit.

2.5. Calculation of measure evaluation

The calculation of the effects of the individual optimization measures is analogous to the calculations described above. In addition to the annuity of the demand-related costs, the annuity of the capital-related costs (= investment) is also taken into account. The annuity of the operation-related costs is not included here.

$$A_{N,j} = A_{N,V,j} + A_{N,K,j} \quad (3)$$

$A_{N,j}$	*Total annuity optimization measure*
$A_{N,V,j}$	*Annuity of the demand-related costs*
$A_{N,K,j}$	*Annuity of capital-linked costs*
j	*Index per optimization measure*

The following parameters of [13] must be chosen sensibly according to the market situation and individual approach.

Tab. 1 - Parameters of the annuity method

variable	meaning
a	Annuity factor
b_i	Present value factors per cost type
r	Price change factor
T	Number of years of the period under review
T_N	Number of years of calculated useful life
q	Interest factor

The new performance indicator of profitability is calculated analogously to the formula of the calculation of the property comparison according to the formula:

$$PI_{ECO,tot,i} = 1 + \left(\frac{10-1}{A_{N,min} - A_{N,max}}\right) * \left(A_{N,i} - A_{N,max}\right) \quad (4)$$

$PI_{ECO,tot}$	*Performance indicator economic*
$A_{N,i}$	*Total annuity*
$A_{N,min}$	*minimum value of $A_{N,i}$*
$A_{N,max}$	*maximum value of $A_{N,i}$*
i	*Index per property*

2.6. Output of measure evaluation

Performance indicator economic: The included optimization measures for a property in the calculation tool usually lead to an adjusted scale with a new scale range. Measures are economically meaningful if their $PI_{ECO,tot}$ is better than that of the property in its original state. The greater the deviation, the more worthwhile the measure. If $PI_{ECO,tot}$ is lower than that of the property in its original condition, the measure is not recommended from an economic point of view. However, social and ecological aspects can speak for the implementation of this measure.

3. Application example

The method presented in the Research Methods was tested for its effectiveness on the basis of a concrete application.

The basis of the examination is the characteristic data of 220 educational facilities of a municipal real estate operator, who strives for an optimized operational behavior of his real estate.

The focus is on a property selected by the operator. This property was first evaluated for its economic efficiency using the method presented here. After the property evaluation, predefined and elaborated optimization measures were prioritized. The example is based on data of the year 2018.

3.1. Input parameters for property evaluation

Object designation: Each educational institution is given a short designation. The property under consideration within the educational facilities is a vocational college and is designated "BK1".

Comparison parameters: The comparison parameters school type and time of use, ensure the comparability of the selected data.

Through these comparison parameters, the selection of 220 real estate objects was filtered to 14 different vocational colleges.

Media: The media electricity and water heat are considered. The medium heat is divided in the property portfolio into gas, district heating and heat supply by electrical energy. BK1 is supplied by gas as the heat energy carrier.

Price medium p_e (Tab. 2): The unit prices of the media are based on the assumption according to [14] and are shown in Tab. 2.

Consumption medium c_e (Tab. 2): The consumption values of the individual media were recorded by an energy monitoring of the property operator and subjected to a weather and area adjustment. The unit of these values is $\left[\frac{kWh}{m^2}\right]$.

Reference parameters r_d (Tab. 2): The reference parameter net floor area is already integrated in the available data.

The number of students was added as a reference parameter to best represent the use of the property. This results in the following unit:

$$\left[\frac{kWh}{m^2 * a}\right] * \left[\frac{1}{students}\right] = \left[\frac{kWh}{m^2 * students}\right]$$

Tab. 2 - Input parameters for demand-related annuity

variable	meaning	value	unit
p_{gas}	Unit price: gas	0.044	$\frac{€}{kWh * a}$
p_{elec}	Unit price: electricity	0.20	$\frac{€}{kWh * a}$
$p_{wat.}$	Unit price: water	3.9	$\frac{€}{m^3 * a}$
$r_{students}$	Number of students BK1	3,011	-
$c_{gas,BK1}$	Consumption BK1: gas	63	$\frac{kWh}{m^2 * a}$
$c_{elec,BK1}$	Consumption BK1: electricity	8	$\frac{kWh}{m^2 * a}$
$c_{wat,BK1}$	Consumption BK1: water	0.35	$\frac{m^3}{m^2 * a}$

3.2. Calculation of property evaluation

In the following section, the property evaluation described in the methods section is calculated for BK1 as an example. In the first step, the demand-related annuity $A_{N,V,BK1}$ is determined based on formula (1):

$$A_{N,V,BK1} = \frac{\sum_{e=1}^{n} p_e * c_e}{\prod_{d=1}^{n} r_d}$$

$$= 9.206 * 10^{-3} \left[\frac{€}{m^2 * students * a}\right]$$

Using the extrema, the $PI_{ECO,tot}$ for the BK1 is calculated based on formula (2) (shown in Fig. 1).

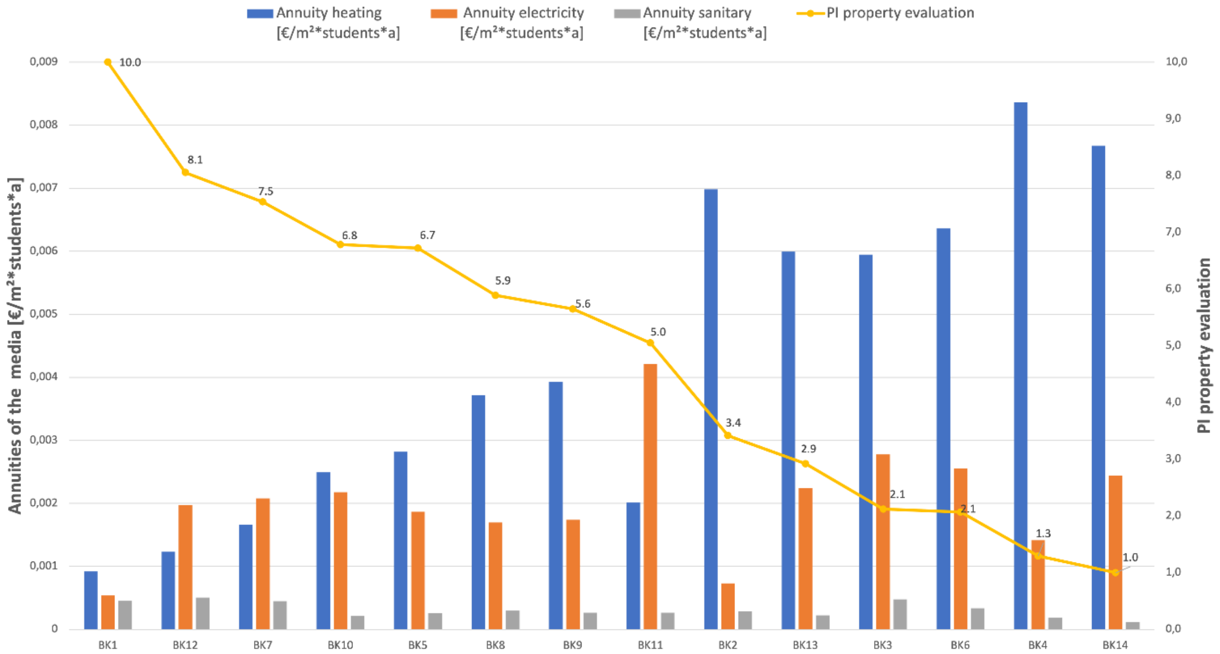

Fig. 1 - Annuities of heating, electricity and sanitary as well as the PI property evaluation for each property

3.3. Output of property evaluation

Performance indicator economic: The calculation of the demand-related annuity is carried out according to formula (1) for all 14 professional colleges considered. By looking at the maximum and minimum annuities, a mapping can be made to a scale of 1-10**.**

The analysis and the resulting $PI_{ECO,tot,BK1} = 10$ show that BK1 is the most economical vocational college out of all the participating vocational colleges in terms of demand-based efficiency.

Fig. 1 shows the state before the optimization measures were implied. The yellow line in the graph shows the course of the economic demand-based performance indicators of the economic efficiency of all 14 considered professional colleges. In addition, the medium-dependent absolute demand-based annuities are shown as columns. BK11 is striking here, as it has very high electricity costs. The reason for this is unclear due to the lack of detailed information on the installed systems.

The calculation of the medium-dependent annuities enables a detailed consideration and analysis of the demand-related costs, so that comparatively high medium-dependent annuities can be used as a reference point for extended investigations into optimization measures, but are not necessarily indicative of poor economic efficiency.

If the vocational college to be analyzed had been BK14, it would be appropriate to analyze the heating costs because it has a $PI_{ECO,tot,BK14}$ of 1 and a demand-based annuity for the medium heat of approx. 9.206*10^{-4} $\left[\frac{€}{m^2 * students * a}\right]$, which is one of the highest.

This technical analysis of why medium-dependent demand-based annuities are high or low requires a technical understanding and therefore must be performed by a professional planner.

The evaluation result presented here shows the actual condition of the properties. Due to the dynamic scaling, the evaluation only applies exactly to the 14 vocational colleges analyzed here.

3.4. Input parameters for measure evaluation

Consumption savings of the optimization measure: The optimization measures were developed in advance and took technical aspects into account. On the one hand they arose from the analysis of the property described, and on the other hand from the wishes of the client. These wishes may have been influenced by aspects related to the social or ecological optimization of the property.

Investment-bound annuity of the optimization measure (according to [13]): In order to be able to keep the measures comparable, the period under consideration as well as the calculated useful life of the measure must be set equal. In addition to the new demand-related costs, the capital-related costs are also included in the calculation of the annuity.

The new annuity is made up of the following parameters:

- Period under review
- Service life
- Investment costs
- Medium-dependent consumption savings

The period under consideration was set at 10 years in order to keep the measures comparable with each other. The remaining calculation parameters are listet in Tab. 3.

Tab. 3 - Parameters for calculating annuities of optimization measures

variable	value	unit
a	0.11	-
b_i	10.25	-
r	3	%
T	10	years
T_N	10	years
q	2	%

Using the parameters and the following investment costs and savings in different media (Tab. 4) the new annuities for choosen measures are calculated. The optimization measures include implementation of daylight control (M1), refactoring of heating curve (M2), optimization of supply air control for comfort (M3), expansion of energy supply through photovoltaics (M4) and hydraulic balancing of heating system (M5).

Tab. 4 - Investments and savings for choosen measures

measure	media	investment [€]	savings [kWh/m²*a]
M1	elec	2500	1,22
M2	gas	230	3,15
M3	-	2560	-
M4	elec	10000	5,39
M5	gas	870	2,05

Fig. 2 shows the converted annuities of the measures, which were multiplied by the area and the number of students. This results in the total costs or savings that the operator can expect from the respective measures in the period under consideration. The presentation of the total costs is intended to make the selected examples appear more comprehensible. In the end, they represent the calculated annuities.

The newly calculated annuity in each case results in the $PI_{ECO,tot,BK1}$.

The measure with the lowest annuity represents the new $PI_{ECO,tot,BK1}$ of ten. The measure with the highest has a $PI_{ECO,tot,BK1}$ of 9.7. The data for the property in its original state remains in the assessment to make the benefits of each measure visible.

In the case of this vocational college, the highest scoring measure is the adjustment of the heating curve (M2) in Fig. 2. The savings are 772€.

3.5. *Output of measure evaluation*

Performance indicator economic: The $PI_{ECO,tot}$ of the best measure causes the graph to shift. The school in the as-is state becomes a 9.96 from the original ten.

Thus, even though the client already has the best school in comparison, it is shown to the client that there is potential for optimization.

Since only economic considerations are dealt with here, the requirement of this elaboration is to give a reference point whether the investment is economically worthwhile or not. The other advantages of an optimization are not included in the evaluation here. The savings of an optimization measure can be identified by a better PI compared to the original property. In this application example, it follows that any measure that has a higher $PI_{ECO,tot}$ than 9.96 provides savings within the period under consideration. On the one hand, this allows ranking within the measures and relating the measures to other existing properties. On the other hand, it shows in an easily understandable way whether money is saved or not.

Fig. 2 shows the five measures selected. The columns indicate the annuities, the line in the graph the $PI_{ECO,tot,BK1}$. The results of the measure evaluation provide operators, on the one hand, with a benchmark of where their object stands economically and what potential is in it. On the other hand, it specifies which measures make economic sense and which do not. By projecting the annuities onto the performance indicators, no technical understanding of the individual measures is necessary.

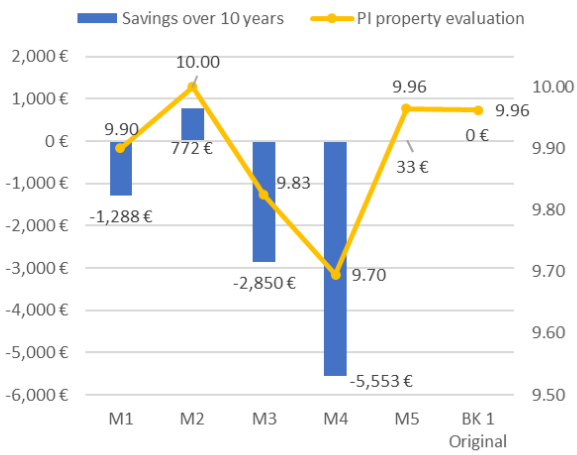

Fig. 2 – Savings and new PI for each measure

4. Discussion

The method presented enables the operator of a real estate portfolio to perform an economic performance analysis for each of its properties.

It is divided into a property evaluation and a measure evaluation. In the property evaluation, the properties are ranked by their annuity (formula (2)) on a dynamic scale. The basis for a comparability of the annuities is formed by the choice of reasonable comparison parameters.

This dynamic scale, which assigns each property a value on a scale from 1 - 10, means that reference values from standards, laws or empirical values are no longer necessary for the analysis of the building performance. Thus, in a real estate portfolio in which all properties already have a good economic performance, there will still be one property that represents the worst with a 1 on the scale created for this purpose. The purpose of this is to provide operators with a customized performance analysis within their property. The urgency of buildings in need of optimization becomes apparent through the ranking.

A high relevance in the real estate evaluation has also the data acquisition. Here, as in section 2.2, care must be taken to ensure that the various data are comparable with each other. Thus, the same boundary conditions must always apply (data quality, weather adjustment, meaningful reference parameters, observation period). The more reliable the data quality and boundary conditions are, the more accurate and meaningful the method is. Nevertheless, the method is only an approximation, which may also be subject to errors. It is based on consumption data only without taking into account further details like the HVAC-system installed.

If the operators have capital available, the evaluation can produce a suggestion as to which property can benefit most from optimization. Consequently, there will consistently be optimization potential within their property, which implies that the operators are constantly incentivized to optimize their facilities economically. The selection of the property to be optimized lies individually with the operator, despite the fact that the property has been evaluated.

The optimization proposals for the property should be prepared by persons with expertise in the respective trades, so that the measure evaluation can then be carried out according to section 2.5. The optimization proposals should only ever be compared with each other for one property. An improvement of the performance indicator always implies a cost saving, which makes the measure economically recommendable. The method then also enables a comparison of the optimization approaches. The performance indicator that generates the largest difference compared to the existing performance is then also the most economical.

This method only considers economic efficiency throughout. In the above example, saving economic resources always implies saving ecological resources. If an interdisciplinary evaluation (economic, ecological and social) of the optimization measures is to take place, a social as well as ecological analysis must be carried out in addition to the evaluation described.

5. Conclusion

In conclusion, this method provides the operator with a tool to evaluate the properties with regard to their economic performance and to identify properties worthy of optimization on the basis of this evaluation. Furthermore, the proposed optimizations for the property can be compared with each other, whereby the economically optimal measure can be filtered out. The property evaluation as well as the measure evaluation should also be understandable for laymen. This is achieved by the dynamic scale from one to ten. The operator does not need a deeper technical understanding for his decision making.

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Data Statement

The datasets generated during and/or analysed during the current study are not available because they are partially the property of third parties and may not be published but the authors will make every reasonable effort to publish them in near future.