Life cycle costs of Dutch school buildings

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Abstract

Purpose – This article aims at providing case-based evidence to support the idea that an integral approach using life cycle costs (LCC) would lead to more in-depth argued adjustments towards sustainable and feasible school buildings. There is a gap between the investment in and the operating costs of public school buildings, caused by the splitting up of responsibility for the financing of the accommodation. Municipalities finance the initial costs of construction, and school boards are responsible for the operating costs. According to architecture-based research on this subject, this split results in higher costs during the lifetime of the buildings. This problem is often referred to as the split-incentive problem.

Design/methodology/approach – The research conducted nine case studies of newly built secondary school buildings. The schools were examined with reference to building characteristics, building costs and operational costs. The sustainable performance of these cases is described with the aid of a Dutch sustainability measurement tool. The core of the research is the LCC analysis and the overall perspective on the ratio between initial costs and operations costs.

Findings – It is often held in the construction sector that investments in sustainability lead to increased expense. However, studies indicate this is not unequivocally true. The authors study, at least, found no clear evidence that schools with investments in specific sustainable solutions have such undesirable higher investment costs. The authors study found some positive effects of sustainable measurements on the LCC of secondary schools.

Originality/value – This study confirms the ratio of Hughes and Ive as defined in office typologies to be true in the school building typology. It is worthwhile for owners and users to keep focus on LCC, as well as for the government as financiers/or funders of school buildings.

Keywords Sustainability, Construction, Life cycle costs, School buildings, Split-incentive problem, Dutch

Paper type Research paper

1. Introduction

Many schools in The Netherlands have inadequate accommodation. Buildings are old and poorly maintained, and most schools also have a poor indoor climate (Arkensteijn *et al.*, 2009; Van der Pol, 2009). Often, the buildings do not conform to contemporary demands for quality education (De Jong, 2011; In 't Veld *et al.*, 2010).

In 1997, the responsibility and budget for accommodation for primary, special and secondary schools were decentralised from central government to the municipalities. Since then, the financing structure for school buildings has been divided into two budgets, one for the initial costs of new buildings (governed by the municipality) and one for maintenance and operation (governed by the school board). Although both

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institutions may supplement the funds, both cash flows come from the national government; one source is provided by the Home Office through a fund for the municipalities, and the other by the Ministry of Education through lump sum financing.

It is strongly suggested that a separation in funding does not lead to the lowest life cycle costs (LCC), even if both municipalities and school boards steer on optimal performance. An integrated management is essential. The idea that a low investment budget will result in higher LCC is commonly accepted. Also, an integrated approach is required to realise sustainable projects (Van Doorn and De Jong, 2012). However, Hughes *et al.* (2004) already revealed the lack of proper data on operating costs. Hence, there is a need to gather data on all different LCC, related to design decisions, to quantify and prove an integral judgement on feasibility during lifetime. It is also difficult to determine the compound cost overruns where the budget is focused on the initial costs, resulting in an as-is approach to the operational budget. In an ideal situation, one should be able to compare initial and operating costs in an LCC model of school buildings to come to an evidence-based conclusion. A first step towards such a comparison is the analysis of the performance of school buildings in the given situation.

This analysis was conducted by Jasper van Langen during his graduation project (2012)[1], based on nine case studies of secondary school buildings which were built between 2005 and 2008. These schools were examined in terms of building characteristics, building costs and operational costs. First, the research method is explained, and as an example, one case, Trinitas College as part of the Johannes Bosco institute, is described in detail. The next element in this paper is the cross-case analysis of the nine cases with detailed conclusions, and the introduction of LCC, after which more generic conclusions are drawn and discussed.

2. Research method

The main question of this study is – how do newly built school buildings for middle-level applied education[2] perform in terms of cost over their entire life cycle?

All the cases selected were the same type for homogeneous data collection. This type is characterised by practical training and classroom learning under similar conditions (as defined by official requirements and financial limitations). For this reason, as well as for logistical reasons, cases were chosen from schools built between 2005 and 2008 and all part of the consulting portfolio of a specialised project management organisation[3]. The cases are not selected on specific sustainable performance but represent the population of this typology built during this period.

For each case, the collected data were:

1. general data about the school;
2. drawings, as supplied for the building permit;
3. energy performance calculations (EPC: energy performance coefficient) also as supplied for this permit;
4. investment calculations, source municipality/governing body of the school; and
5. operating costs for two years, source governing body of the school:
   - Energy use;
   - cleaning; and
   - maintenance (preventive) and service.

Drawings and energy calculations are used to conduct the Green Performance on Real estate (GPR) Building calculations. Based on the cost data, the LCC calculations are elaborated on a 40-year basis[4]. For a comparison between cases, all costs are recalculated to costs per square metre gross floor area (GFA).

2.1 Rationale for the selection of sustainability tools

This research is focussed on LCC and how to contribute to a better sustainable approach, not about evaluating sustainable measurements or tools. However, it is assumed that the sustainable performance will heavily influence the LCC. Therefore, the sustainable performance of the cases has to be labelled.

The starting point was an all-encompassing evaluation (Van Langen, 2012) of several theories on sustainable building, such as Trias Energetica (Van den Dobbelsteen, 2008), Cradle to Cradle (McDonough and Braungart, 2002) and The Need for Flexibility as a Sustainable Concept (Remøy *et al.*, 2011), and comparison of measurement tools including BREEAM.nl[5], LEED[6], GreenCalc+[7], Eco cost value ratio (EVR)[8] (De Jonge, 2005), EPC and GPR Building. The last two tools were selected, partly due to the fit with available data and their earlier application in the process. EPC stands for energy performance coefficient, which includes an in-depth calculation method; a calculation in which, based on standardised consumption, the energy demand is elaborated, resulting in a numeral. The Dutch building code has defined the limit for this value per function. In 2011, the EPC for newly built houses was refined from 0.8 to 0.6. In 2009, the EPC for utility buildings was already refined by an average of 20 per cent.

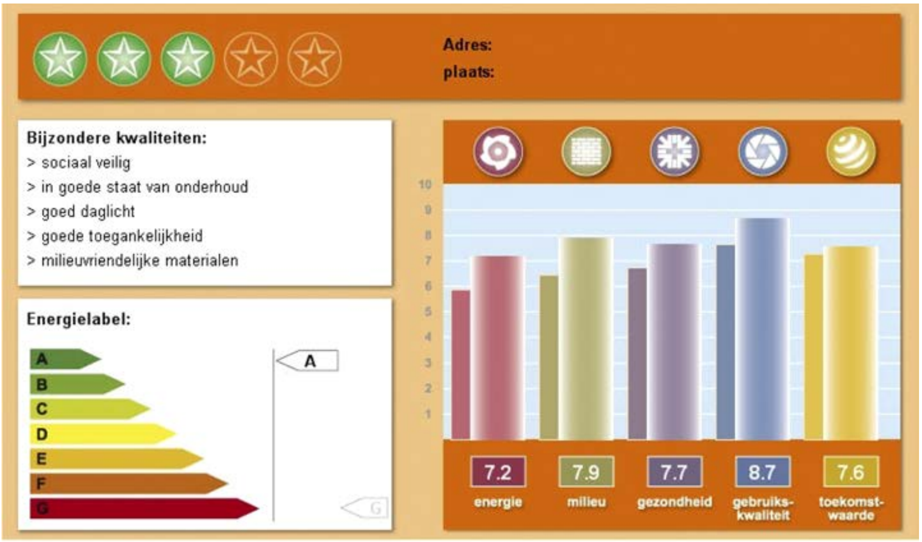
GPR Building is an assessment tool for comparative ranking of sustainable performance. In the GPR, division is made according to five themes: energy, environment, health, user quality and future value. As a compulsory standard, the EPC is the main component of the energy theme (Figure 1).

The selection of tools is not a disqualification of the other tools that were evaluated, but the selected tools provide the best match with tools used by the municipality, which eases comparison.

3. Life cycle costs

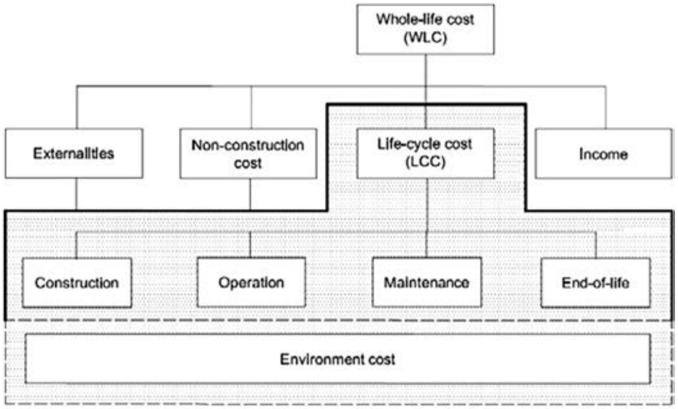
The LCC are calculated according to the European standard (NEN-ISO, 2008; Figure 2). Environmental costs are not taken into account within this study. An exit value is applied as an alternative. Although environmental costs do take a prominent place in the overview of whole-life cost (WLC) and LCC elements (NEN-ISO, 2008, p. 6), the examples in this standard allow exclusion (NEN-ISO, 2008, p. 7). For an advanced approach including these environment costs, other methods such as the EVR could have been used. Without any pressure, figures on these environmental costs are not supplied by facility management nor used by commercial partners.

The period of analysis is 40 years, after which a residual value is calculated, assuming that the actual operating costs continue to be the same for the remainder of the lifespan. Such an approach suggests an afterlife following this period of use in the designated function, meaning that the final end-of-life costs for demolition are not considered.



Notes: On the left some significant qualities (in this case socially safe, good state of maintenance, sufficient daylight, accessibility and environment-friendly materials). On the lower left is the energy label, and on the right the performance on the five themes: energy, environment, health, user quality and future value

Figure 1. Presentation of GPR results



Source: NEN-ISO (2008)

Figure 2. Graphical representation of costs

4. Case: Trinitas College, Johannes Bosco

The case of the Johannes Bosco is detailed here as an example of a representative case. The building Johannes Bosco, together with the Han Fortmann College, belongs to the Trinitas College. Both colleges were procured at the same time (Plate 1 and Table I).

Plate 1.
View of courtyard

Table I.
Trinitas College, Johannes Bosco

General data	Trinitas College, Johannes Bosco building
Location	Heerhugowaard, The Netherlands
Number of students (in 2010)	1,200 at Johannes Bosco, of a total of 2,300 at Trinitas College
Year completed	2007
Architect	De Jong Gortemaker Algra
Investment costs	€ 14,900,000 ex. VAT
(Price index 2012)	€ 1,150/m^2 GFA
Design attributes	
Gross floor area (GFA)	12,942 m^2
Usable area (UA)	11,867 m^2
Façade	6,035 m^2
Roof	5,161 m^2
Traffic area	2,594 m^2
Shape factors (Gerritse, 2007)	
Stacking	2.50
Compactness	0.47 Façade/GFA
Efficiency	69.00 per cent UA/GFA
GFA/student	10.40 m^2
Average room size	47.50 m^2

The Johannes Bosco building contains two building blocks. The upper part mainly accommodates classrooms, while the lower part contains sports centres and rooms for technical education. The two blocks are linked with a footbridge on the first floor. The building blocks use different installation systems. The "theory" block uses heat storage in combination with floor heating. The ceilings are half open with mechanical balance ventilation and heat recovery. The block for practical education uses a standard concept with high efficiency boilers and radiators. The calculated energy label is "A" for both blocks. The GPR-scores are 7.1 for energy, 7.4 for environment, 7.7 for health, 8.9 for user quality and 7.7 for future value.

The Johannes Bosco is a so-called IFD (industrial flexible and demountable) building. There are no load-bearing inner walls. Due to the grid system, the building is very flexible, and this explains the high score on future value. By integration of networks for audio, video, building control, security, phone and Information and communication technology (ICT) based on Ethernet with glass fibre and a duct system, materials are reduced and are fully demountable and recyclable (Plate 2–4).

This school has a multiple year maintenance schedule for 40 years, accounting for replacement (Table II).

The calculation of the LCC, using the figures stated earlier, also depends on the exit value. Most municipalities use an exit value of 0 after 40 years. This approach is used for comparison to make a cross-case analysis, even though it is disputable, given the fact that the overall stock of school buildings shows a longer actual lifetime. The initial

Plate 2.
Sport centre

Plate 3.
Hallway in theory building

construction costs are treated using an accounting approach, also practised by the municipalities, delivering a net present value of depreciation and interest.

5. Cross-case analysis

The first results of the cross-case analysis are the average compound building-related operating costs of €46/m^2 GFA. These costs, energy, cleaning and maintenance form 92 per cent of the total operating costs, resulting in an average of €50/m^2 GFA. This building-related average is based on the benchmark of HEVO (◇) and the cases of Van Langen (◇).

The spread shown in Figure 3 suggests that there is still a lot to improve. A more detailed case-based explanation is needed to understand why a single school can score almost four times higher in operating costs compared to the lowest score (and how they can tackle these costs). The dataset consists of schools for applied education as well as theoretical education. The operating costs per square metre GFA of the theoretical education schools are slightly higher (€51/m^2 GFA) compared to applied education (€42-43/m^2 GFA). This may seem remarkable, as applied education requires more maintenance, but applied education is also more voluminous, causing a better score per square metre GFA: (theoretical education has 9.4/m^2 GFA per student and applied education has 13.3/m^2 GFA).

Hereafter, the research will focus on the nine cases that are scrutinised in-depth (◇). The weighted average initial costs of these nine newly built schools for middle-level

Plate 4.
Auditorium

Operating costs	2009 (€)	2010 (€)	Average per m^2 GFA (€)
Energy	102 982	100 357	8.10
Cleaning	156 751	125 522	11.00
Replacement	259 011	282 130	20.90
Maintenance	64 852	74 752	5.40
Total	602 446	514 210	36.00

Table II.
Operating costs Johannes
Bosco

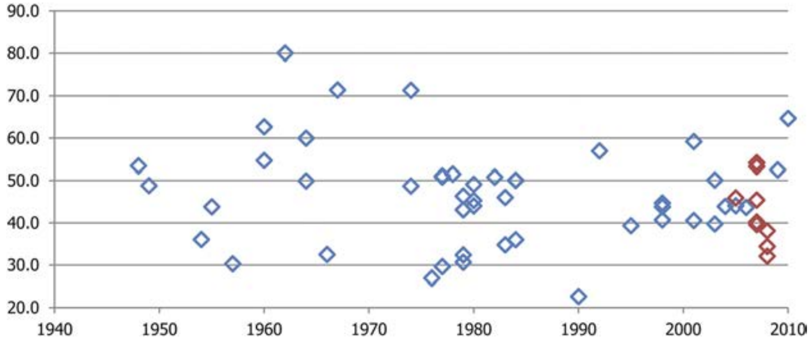


Figure 3.
Operating costs related to
year of construction

applied education is €1,340/m^2 GFA (price level 2010). A weighted average is used to reduce the impact of project size. The cases follow the normal trend in which smaller buildings have higher building costs. The GFA varies from 4,742 to 23,742 m^2, and the building costs vary from €1,242 to €1,539/m^2 GFA. All cases are analysed with regard to building characteristics such as efficiency, shape, stacking and compactness, not resulting in any arguments for excluding cases such as outliers. Efficiency varies from 69 per cent to 79 per cent (usable floor space/GFA), which is normal for this typology (Figures 4–8).

5.1 The vertical axis shows the initial costs per square metre GFA; the different GPR-scores are given on the horizontal axis (a higher score indicates better performance)

The range in the GPR-score is narrow in most graphs, causing questions concerning the use of trend lines. In general, a declining trend line would be significant, suggesting increased building costs do not lead to improved performance. Given the number of

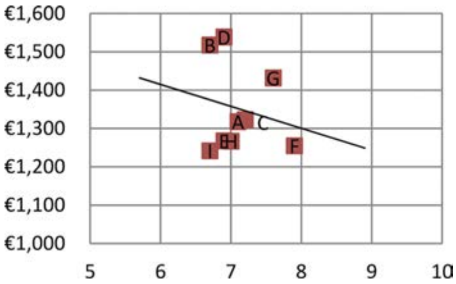


Figure 4.
GPR-score on energy

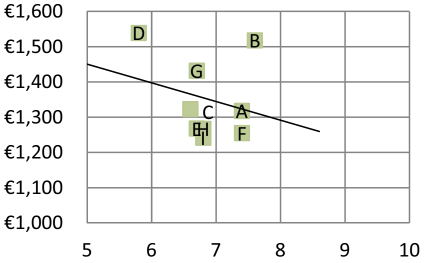


Figure 5.
GPR-score on environment

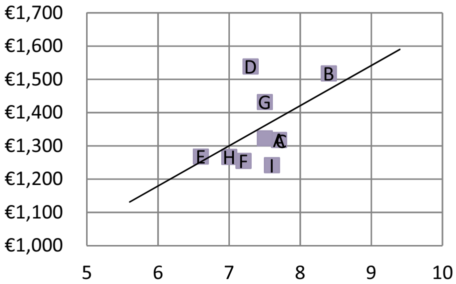


Figure 6.
GPR-score on health

cases and their variety, the trend line in these graphs should be seen as an indicator for the need for further research, instead of a conclusive statement (see also the conclusion).

Comparable graphs (Van Langen, 2012, p. 91) in which the EPC, the theoretical performance, is related to the actual costs of energy, show that those buildings that are expected to be more energy efficient do not always perform as expected. In the majority of these nine cases, the reverse relation is identified, leading to a negative trend line. This is not conclusive, however, because during the research it appeared that several schools had problems with an optimal regulation of their installations.

The best performing schools on energy costs have floor heating and use low water temperatures to heat the building. The bandwidth of the gas/heating costs for buildings with floor heating is between €1.80-€5.50/m^2 GFA, and for buildings that are heated by radiators €4.00-€8.10/m^2 GFA. Also, optimum energy costs can be achieved when buildings have floor heating and low temperature heating, often in combination with soil storage. This result does not imply that these systems are the best possible solutions. As stated before, these schools are not designed for optimal sustainable performance, and the number of cases does not allow statistical qualification of this random selection of systems used. This is, however, typical of data with which one is confronted when searching for operational data for LCC calculations on a building level.

5.2 From initial cost to LCC

Where the previous graphs show performance according to GPR against initial cost identifiers (building cost), a better focus comes with LCC, necessary to improve future performances to attain more sustainable solutions.

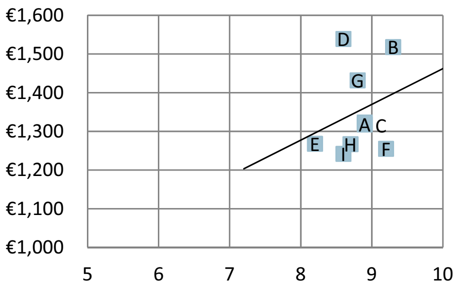


Figure 7.
GPR-score on user quality

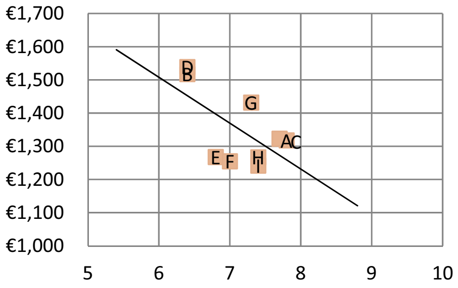


Figure 8.
GPR-score on future value

In the LCC calculations, the following parameters are applied:

- standard inflation 2.1 per cent: even though current inflation (December 2013) is once more below this standard, long-term inflation tends towards the level of 2.1 per cent;
- energy inflation 6.8 per cent: based on a comparison between standard allowance for schools and energy prices over the last decade (2012), but decreasing at the moment;
- discount rate of 4 per cent: applied in the calculation of discounted cash flows, selected for similarity with calculations used by the municipality; and
- interest rate 3 per cent: applied in the calculation of initial costs with the same argument.

The outcome of LCC calculations is strongly influenced by the selection of these figures. To what extent should the current situation be taken into account? It is expected the sharp edges of the crisis will flatten out in time, e.g. a more long-term average interest rate is used. Energy inflation is decreasing at the moment, but depending on the sources, will stabilise (optimistic scenario/industry) or increase International Energy Agency (IEA). The increase could be severe, according to many scientists concerned with the depletion of resources.

The maintenance costs are responsible for 16 per cent of the LCC. These costs are difficult to compare, because the maintenance strategy and the long-term maintenance planning period have a major impact on the actual and accounted costs incurred for maintenance.

Cleaning costs take a share of 15 per cent of LCC. The data in this study show that outsourcing to a cleaning company saves on cleaning delivery. The bandwidth of the cleaning of schools where the cleaning is performed in-house is between €11.50-€22.70/m^2 GFA and schools where it is outsourced between €8.00-€11.00/m^2 GFA. An optimization of the cleaning costs must therefore be mainly sought in the organization. The selection of materials of the building also has a limited influence.

The resulting LCC per case are given in the table below. Due to differing circumstances, the LCC vary considerably, e.g. in cases A, C and H, cleaning is outsourced, with an average of cleaning at €9.2/m^2 GFA, while the others take care of cleaning themselves, with an average of €16.4/m^2 GFA (Table III).

Case H, the comprehensive school where Di is doing well, thanks to:

- low initial costs of €1,267/m^2 GFA;
- very low cleaning costs of €8,50/m^2 GFA;
- average maintenance costs of €14,70/m^2 GFA; and
- low energy costs of €12,10/m^2 GFA.

Case F, the Insula College, is not doing well, thanks to:

- low initial costs of €1,255/m^2 GFA;
- high cleaning costs of €20/m^2 GFA;
- low maintenance costs of €11,60/m^2 GFA; and
- very high energy costs of €22,60/m^2 GFA.

Table III. LCC cases (no exit value)

Case	Name	LCC per m^2 (€)
A	Johannes Bosco	2932
B	Niekée	3201
C	Sevenwolden	2915
D	Connect College	3240
E	Casparus College	3167
F	Insula College	3539
G	Lek en Linge	2719
H	Were Di	2627
I	Westerpoort College	2822

The good news for this school is the provisional situation. They have had many problems with temperature control, for which even mobile air conditioning units are deployed. It took a long time to regulate all systems.

As stated before, LCC calculations are highly conditional on the economic parameters, for which different scenarios are applied. The ratio between initial capital costs and operating costs varies in these scenarios from 1.15 to 1.59 while for the standard (or most expected) scenario the result is 1.37 (Figure 9).

6. Conclusions and recommendations

Within the design process, the focus should be on optimisation of LCC: both initial costs and operating costs. This should be the emphasis of those with a long-term stake in the building, including the owners, users and financiers as well as the architect and other advisors. This article adds case-based evidence to support the idea that an integral approach expressed in LCC will lead to more in-depth argued adjustments of school buildings.

6.1 Ratio between initial costs and operating costs

With regard to the on-going discussion on ratios between initial costs and operating costs, the overestimation of the impact of operating costs (1:5:200) in the publication of Evans *et al.* (1998) is seen as a setback. Research by Hughes *et al.* (2004) and Ive (2007) lowered these ratios to a more recognisable bandwidth of 1:0.4–1.5:12–15, still depending on the applied discount rate and the building type under consideration. The

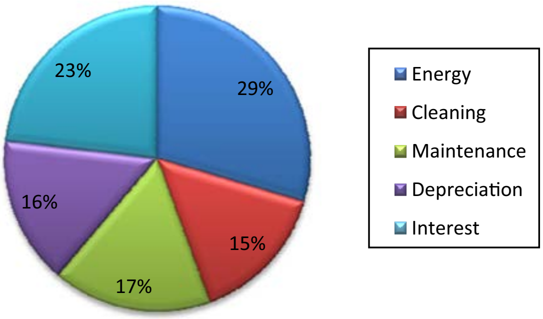


Figure 9. Division of LCC in the standard scenario

results of our study, concerning school buildings rather than the offices of Hughes and Ive, fit within this bandwidth, with a ratio of 1:1.15–1.59 for the initial costs versus the operating costs (discounted with 4 per cent compared to 7 per cent by Ive). This reduced ratio does not mean that operating costs are not significant. The possible gains will not be as impressive as they would be with the previous figure of 1:5, but the operating costs exceed the initial costs. Further improvement of buildings leading to better optimization for sustainability and low LCC than the cases researched here, may even bring the operating costs down below the initial costs, leading to a better overall result. The ratio is a tool to direct the focus in the right direction, while the real target will be revealed with more absolute yearly costs.

The cases do not deal with the corporate operating costs, the last factor in Evans' ratio. However, in the educational sector, 79 per cent off all costs are personnel costs. In this perspective, the contribution of accommodation-related costs is modest. Cost cutting on building costs, and therefore on initial costs, will only have a small positive impact on the total organisational performance. At the same time, such cost cutting may have a distinctly negative impact on staff performance. Steering towards quality may have negative financial consequences in some cases with regard to the initial costs, but have a more positive impact on LCC and user satisfaction and productivity.

The trend lines in Figures 4–8 are pointing at a weakness in this study. As shown before in the research of Hughes and Ive, it is very difficult to get proper data on such cost parameters. A detailed study on the energy cost of a single building will reveal peaks and troughs in performance depending on renewal of installations, tuning, wear and educating users. The given performance in this study is only a snapshot in time on a very limited number of cases. The results on this performance can be seen as an indication. However, for further elaboration of these trend lines and more grounded data, more in-depth and long-term research is recommended.

6.2 Design figures versus operating costs

Tools such as GPR and BREEAM deal with a similar problem as that which is observed in the ratios, lacking the dynamics of a holistic integral evaluation. A division in categories is made beforehand, e.g. energy versus other elements, where an element is awarded a certain weight. Optimising on a certain element, however, should have impact on the weight of that element in relation to the other elements. For example, working on a zero energy building increases the impact of energy in the justification, where in some tools better performance leads to a lesser impact. In hindsight, the cases are showing the effort of the starting process of buildings is underestimated; it took some time for some of the buildings to perform according to design expectations, while in most cases the theoretical energy performance (EPC) is never reached.

6.3 Investment in sustainability does not lead to higher investment costs

It can be concluded that there is a general acknowledgement within the construction sector in The Netherlands that sustainability involves higher costs. This is a common fallacy, even though studies clearly indicate that it is not a universal truth. An elaborated study by Davis Langdon reveals within a given spread of building costs an equal spread of certified buildings (Morris and Matthiessen, 2007). Our study supports this finding and found (at least) no clear indication that those schools with some sustainable adjustments had higher building costs. In our cases, the less expensive buildings perform slightly better on GPR performance. We recommend an increase of the number of cases as a next step towards provide statistically justifiable evidence.

This study has been conducted on the basis of a lifetime of 40 years. We recommend more in-depth research of this aspect, with more realistic lifetimes of up to 80 years, taking all the attendant effects into account.

Increasing the number of cases would allow for a clear distinction between buildings with standard design solutions versus buildings optimised for sustainability, and between buildings with the lowest initial costs and buildings designed for low LCC.

Notes

1. The student was guided by both authors.
2. Middle-level applied education takes up to four years. Those who complete their training can enter the workplace or may go on to another form of (professional) education. It prepares students for a wide range of occupations.
3. www.hevo.nl
4. A debatable choice: another study of 70 schools for primary education and day-care in The Netherlands, partly conducted by the authors, revealed an average age of 67 years, but also gave evidence of numerous conversions during this period.
5. BRE Environmental Assessment Method, see www.breeam.nl
6. LEED, or Leadership in Energy & Environmental Design of the US Green Building Council, see www.usgbc.org/leed
7. www.greencalc.com/
8. Eco cost value ratio, see www.ecocostsvalue.com/

References

Arkensteijn, M., Steijns, Y. and de Vries, J. (2009), "Het schoolgebouw central", *Over normkosten en kwaliteit bij nieuwbouw van scholen in het primair onderwijs*, TU Delft, Delft.

De Jong, P. (2011), "Investeren in een veranderlijke markt", in van Dam, S., Komossa, S. and Spoormans, L. (Eds), *De transformatie van het schoolgebouw*, Uitgeverij Thoth, Bussum.

De Jonge, T. (2005), "Cost effectiveness of sustainable housing investments", Doctoral dissertation, Delft University Press, Delft.

Evans, R., Haryott, R., Haste, N. and Jones, A. (1998), *The Long Term Costs of Owning and Using Buildings*, The Royal Academy of Engineering, London.

Hughes, W., Ancell, D., Gruneberg, S. and Hirst, L. (2004), "Exposing the myth of the 1:5:200 ratio relating initial cost, maintenance and staffing costs of office buildings", paper presented at the 20th Annual ARCOM Conference, Heriot Watt University, Currie.

In 't Veld, J., Hamdan, Y. and Barendregt, E. (2010), *Een fris alternatief voor de huisvesting van kinderen*, PO Raad, the Hague.

Ive, G. (2007), "Re-examining the costs and value ratios of owning and occupying buildings", *Building Research & Information*, Vol. 34 No. 3, pp. 230-245.

McDonough, W. and Braungart, M. (2002), *Cradle to Cradle Remaking the Way We Make Things*, North Point Press, New York, NY.

Morris, P. and Matthiessen, L.F. (2007), *Cost of Green Revisited*, Davis Langdon, London.

NEN-ISO (2008), “Buildings and constructed assets – service-life planning – Part 5”, Life-cycle costing, ISO 15686-5:2008, IDT.

Remøy, H., de Jong, P. and Schenk, W. (2011), “Adaptable office buildings”, *Property Management*, Vol. 29 No. 5, p. 11.

Van den Dobbelsteen, A. (2008), “Towards closed cycles – new strategy steps inspired by the cradle to cradle approach”, paper presented at the PLEA 2008, Dublin.

Van der Pol, L. (2009), *Gezond en goed, scholenbouw in topconditie*, Den Haag.

Van Doorn, A. and De Jong, P. (2012), “Kosten en baten van een duurzaam project”, in van Doorn, A. and van Bueren, E. (Eds), *Het duurzame ontwerp project*, SUN, Amsterdam, p. 195.

Van Langen, J. (2012), “Hoe presteren schoolgebouwen op levensduurkosten?”, MSc dissertation, Delft University of Technology, Delft, available at: http://repository.tudelft.nl/view/ir/uuid%3A18f81cef-711e-4d9a-9501-6041d53bd3d2/

Further reading

Gerritse, C. (2007), *Controlling Costs and Quality in the Early Phases of the Accommodation Process*, VSSD, Delft.

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