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Decision support tools for energy efficient and healthy school buildings

Ad Straub*, Kevin Frankena

Highlights

Decision support tools provide school boards more insight in the technical, financial and organizational opportunities of the renovation of their school buildings. By raising problem awareness about indoor environmental quality (IEQ) effects, the flowchart and accompanying sustainable measures packages are also expected to contribute to improved IEQ in renovated school buildings, improving the balance between People, Planet & Profit.

Abstract

Property owners are being forced to increase the energy efficiency of their buildings. Besides energy efficiency the indoor environmental quality (IEQ) of a larger part of Dutch primary school buildings is insufficient. This affects the performance, productivity and health of students and staff, and additionally has monetary consequences for school boards. The inability to achieve healthy, energy efficient buildings is largely explained by a lack of knowledge and experience in building renovation by school boards. The objective of the study is to provide school boards of primary schools with decision support tools to provide more insight in the technical, financial and organizational opportunities of renovation of school buildings. It is expected that this will lead to better balanced school buildings in terms of People (Indoor Environmental Quality), Planet (energy efficiency), and Profit (costs) and will contribute to a better work and learning environment for staff and students. Applied research methods are a literature review, semi-structured interviews, desk research, expert meetings, a focus group and design. Expert meetings were organized to get input for the design ofa decision flow chart. Both were tested by members of school boards. It was found that the tools provides more insight in the renovation decision-making process and opportunities to renovate the school buildings. By raising problem awareness about the indoor environment, the decision support tools are also expected to contribute to an improved IEQ in renovated school buildings. . The research was the basis for the development of a web tool for school boards: “Decision tree sustainable renovation primary and secondary school buildings”, published by Netherlands Enterprise Agency (RVO), design and consultancy firm Arcadis and the ‘Green Deal Scholen’.

Keywords

School buildings, Sustainability, Indoor Environmental Quality (IEQ), Energy Efficiency, Decision Flowchart, Renovation

1. STATE OF ART AND PAPER AIM

International attention towards energy improvement is growing, pressuring property owners to increase the energy efficiency of their buildings. School boards also have to imply energy efficiency solutions in their school buildings. Besides energy efficiency, the indoor environmental quality (IEQ) of Dutch

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primary school buildings is insufficient. This affects the performance, productivity and health of students and staff, and has monetary consequences for school boards. The inability to achieve healthy, energy efficient buildings is largely explained by a lack of knowledge and experience in building renovation by school boards. They are in need of simple decision support tools that provide insight in the technical, financial as well as organisational opportunities of renovation.

Ma et al. [1] propose a systematic approach for sustainable building retrofits that could be used for retrofitting any type of buildings requiring minor modifications. The overall retrofit strategy consists of two parts: a strategic planning including models and tools selection and retrofit activities in the whole building retrofit process. There are many other decision-making tools available, most of them targeting specific buildings and their specific stakeholders. Examples of these are TOBUS, a decision-making tool for selecting office building upgrade [2] and RENO-EVALUE [3]. RENO-EVALUE is a tool for a holistic assessment of sustainability in building renovation projects considering stakeholders, environment, economy and project organisation. Granados and Gamez [4] discuss how Spanish head teachers, acting as school principals, can achieve sustainable performances by following triple bottom line approaches, as defined by Elkington [5]. They emphasise the need for adequate resources and managerial tools. However, tools especially addressing the needs of school boards retrofitting primary school buildings do not exist.

The purpose of the study is to provide school boards with decision support tools to provide more insight in the technical, financial and organisational opportunities of renovation of schools buildings. It is expected that more knowledge and insight by school boards and other stakeholders in technical, organizational and financial opportunities for renovation of school buildings will lead to better decision-making of renovation projects. Consequently this will lead to more financial space and attention towards the indoor environmental climate and energy efficiency of renovated buildings. Following the introduction, the paper has been structured as follows: the following section provides a literature review on sustainability, the characteristics of Dutch school buildings, energy and indoor climate issues and financial responsibilities for renovation. Section 3 explains the reseach methodology. Section 4 presents the designs of sustainable measures packages and the decision flowchart. This is followed by the testing of the tools and the needed adaptations to make them into final valuable instruments in sections 5 and 6. The discussion in section 7 highlights the added value and limitations of the

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decision support tools. Section 8 gives the main conclusions of the study and addresses further research needs.

2. LITERATURE REVIEW

EU member states have committed themselves to the so-called '20-20-20 targets', which includes the reduction of greenhouse gas emissions by 20%, increase of renewable energy to 20%, and increase of energy efficiency by 20% relative to 1990 [6]. Of these targets, the energy efficiency target is furthest from being achieved. Prospects are that only half of the 20% reduction will be achieved, forcing member states to act [7].

The Dutch government composed strategies to comply with these binding EU targets. They are divided into sector specific strategies. In the 'Plan van Aanpak Energiebesparing Gebouwde Omgeving', the Dutch Ministry of the Interior and Kingdom Relations [8] presents instruments as well as organizational and financial measures that stimulate energy savings. Part of the energy efficiency improvement must be achieved in Dutch school buildings. The core issues identified in the Dutch educational building sector are:

- pressure to increase energy efficiency of school buildings;
- poor indoor climate in school buildings;
- a complex financing system and related decision-making process;
- lack of knowledge and experience by school boards in managing renovation projects.

Dutch primary education building stock

The Dutch non-residential building stock consists of approximately 600 million m2 GFA of which 80% is used for the services sector [9]. Primary education is estimated to account for 3% of the total number of buildings in the services sector (14,4 million m2 GFA). Key figures on the size of Dutch primary education are shown in Table 1.

Total number of schools	6.985
Average floor area	1.300 m^2
Total number of students	1.546.000
Average number of students per school	224
Total number of school boards	1.085
School boards with <10 schools	75%
School boards with >10 schools	25%
Average number of schools per school board	6,4

Table 1. Key figures primary school buildings in the Netherlands [10].

At present, a maximum of 150 new school buildings are built every year [11]. The average lifespan of Dutch school buildings is estimated at 69 years [12]. With the current construction rate, the average age of school buildings will increase further [13]. The demand for primary education will decline in the period 2020, depending on location [14]. Growth areas will experience less decline than shrinking regions. After 2020, the demand for primary education increases slightly. Influencing the building production and renovation. Currently, one-third of the building production counted in m^2 GFA consists of renovation projects. In the period till 2020, this will grow to half of the yearly building production, and will remain so after 2020. The growth in renovation is explained by the expected reduction in demand.

In 2011 Dutch primary school buildings in 2011 used on average 12.900 m^3 gas and 22.600 kWh electricity per year [15]. The total gas use by the primary education sector in 2008 was estimated at 105,9 million m^3 and the total electricity use at 284,3 million kWh. The total gas use was 4 Petajoule (PJ), which accounts for 2% of the total energy use by all non-residential buildings. The total electricity use by primary schools was 1 PJ, which is 0,6% of the total energy use by all non-residential buildings. The total expenditures for gas add up to €72,7 million and electricity adds up to €53,2 million in total in 2008 [15]. On average, each school building thus spent almost €10.000 on gas and €8.000 on electricity in 2008.
Inferior housing and budget overruns are the main problems in the building task of school boards (Arkesteijn et al., 2009). With new budget cuts in prospect, these problems could grow worse. One of the first things that suffers from budget cuts in education is the indoor climate [17], for example leading due to the use of cheap materials in newly built school buildings or neglecting indoor climate measures [18]. Bad indoor climate affects the health, performance and productivity of occupants [19].

		% all school buildings
Insulation	Single glazing	31%
	Roof not/poorly insulated	44%
	Façade: not/poorly insulated	41%
	Floor: not/poorly insulated	58%
Installations	Ventilation without heat recovery	89%
	Conventional boiler	11%
	Lighting – Conventional fluorescent lighting	61%
	Lighting – Lightbulbs	2%
Indoor environment	CO2-concentration > 1200 ppm	80%
	Temperature summer > 25 °C	45%
	Too high dust concentration	35%

Table 2. State of primary school buildings in the Netherlands (20).

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According to a survey by the Netherlands Enterprise Agency RVO [20] over 80% of school boards apply sustainability measures to school buildings to reduce energy costs or to improve the indoor climate. Yet the state of primary school buildings remains poor. In 2015 RVO reported the situation of Dutch primary school buildings The results are presented in Table 2.

Indoor environmental quality

The indoor environmental quality of school buildings can affect health and performance of its occupants. Many researchers have presented evidence of the effect of the IEQ on occupant health and performance, e.g. the effect of the indoor temperature on performance [21, 22], the effect of the CO_2 concentration on performance [23], 24], the effect of the ventilation rate on performance [22] and the relation between CO_2 concentration and health [23]. Studies indicate that health problems in schools are similar to the symptoms of the Sick Building Syndrome, a group of mucosal, skin, and general symptoms that are temporally related to working in particular buildings [24, 25, 26]. In offices, increased sick leave results from lower levels of outdoor air supply and IEQ complaints [27]. An increased relative risk of 1.5-5 for respiratory illnesses and 1.1-6 for symptoms of the Sick Building Syndrome are estimated for low ventilation rates compared to high ventilation rates [28]. This indicates the urgency to improve the educational building stock not only in terms of energy performance, but also in terms of IEQ. In 2015 RVO introduced the 'Programme of Requirements Healthy School Buildings' to raise awareness in the educational field for IEQ [29].

Renovation of school buildings

In the Netherlands municipalities are responsible for the new construction of primary school buildings. They assign a portion of their budget to this purpose. After construction, municipalities remain the economic owner of school buildings and school boards become the legal owner [14]. Exploitation of the buildings is the responsibility of school boards, for which they receive a lump sum budget from the Ministry of Education, Culture & Science [30]. They assign a portion of the budget for the maintenance and small improvements of the building. In the case of renovation, responsibilities are often unclear. Neither of the parties are responsible in juridical or financial terms [31]. The core business of school boards is to provide high quality education, not the construction or renovation of school buildings. Generally, school boards set up a program of requirements for renovation. Depending on the arrangements, this task can be transferred to the municipality. Repeatedly, indoor

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environmental quality is neglected in this program of requirements [17]. This could lead to suboptimal sustainability solutions with too little emphasis on the People dimension. School boards have insufficient insight in sustainable solutions for their buildings, accompanied by insufficient knowledge about financial opportunities and suspicion towards market parties. Besides the lack in building experience in general, sustainability is still a relatively new development concept, experiencing rapid new developments. Larger school boards are expected to have more knowledge of renovation than small school boards.

According to knowledge centre Ruimte-OK & Klimaatverbond Nederland [32] there are school boards that do not act because they describe themselves as 'unconsciously incompetent', which does injustice to the renovation potential.

Both school boards and municipalities indicate financing of renovation projects as the major barrier to start renovation projects [32]. Yet, there are plenty financing opportunities to facilitate school building renovation [30, 33]. Ruimte-OK & Klimaatverbond Nederland [32] questioned 135 school boards, of which 73% indicates that they do not possess sufficient knowledge of different financing forms. There is a large pool of knowledge regarding renovation opportunities, yet this knowledge is scattered and poorly coupled [17]. De Jong and Arkesteijn [34] found no clear evidence of schools that investment in specific sustainable solutions have higher investment costs. They found, based on nine case studies of newly built secondary school buildings, some positive effects of applying sustainable measurements on the life-cycle costs.

3. RESEARCH METHODOLOGY

This research follows the triple bottom line theory by Elkington [5] that indicates that sustainability is determined by the balance between 3 P's: People, Planet, Profit. The People dimension in the research refers to the Indoor Environmental Quality (IEQ) of primary school buildings, which influences health and performance of its occupants. The Planet dimension refers to the thermal energy performance of school buildings, and indirectly the damage inflicted on the Planet. The Profit dimension refers to the investment costs or Total Cost of Ownership of making school buildings sustainable. Sustainability is the ultimate balance between these 3 P's, where the goals are to keep IEQ as high as possible, investment costs and energy demand as low as possible.

Applied research methods are explorative semi-structured interviews, desk research, expert meetings, a focus group and design. Expert meetings were

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organised to get input for the initial design of a decision flowchart. Desk research involved analysing existing lists of energy efficient renovation solutions for primary school building analysed to determine useful aspects that could be combined in new sustainable measures packages. The focus of the existing lists is primarily on energy efficiency. The developed sustainable measures packages reflect on these measure packages by improving the attention towards indoor environmental quality (IEQ), and reflecting the measures against Dutch school building types. Insights are provided in the effects of the measures on energy efficiency, IEQ, investment costs and payback period.

According to Fryman [36], a decision flowchart is 'a graphical representation of the specific steps, or activities, of a process'. By presenting the considerations that need to be made in primary school building renovation in the form of decision flowcharts, school boards are guided through the decision-making process, eventually leading to technical, financing and organizational opportunities. All the while, the effects of indoor environmental quality are addressed. With this design, sufficient information should be provided to support school boards in organizing and financing renovation, and trigger them to consider indoor environmental quality improvements.

Fryman describes the following steps for constructing a flowchart [36]:

1. determine the process to be flowcharted;
2. determine the level of detail;
3. determine the process boundaries;
4. list the beginning activity;
5. list the sequential activities;
6. list the ending activity.

Although not in this exact sequence, these steps were taken in the development of the decision flowchart. The results from those steps are presented in the sections on design and testing.

Three expert meetings with six experts were organized to gain further knowledge from practice as input for the initial design of the flowchart. The six experts are key players in the Dutch primary educational housing sector, working for the Netherlands Enterprise Agency RVO, knowledge centre Ruimte-OK, a contracting and procurement department of a law firm, design and consultancy firm Arcadis, and a building contractor. Their expertise was used to gain insights in opportunities for school building renovation and to determine what considerations are or should be made by school boards in the decision-making process, which could be used in the development of the

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decision flowchart. To gather the necessary information from these meetings, documents were prepared beforehand: a draft version of the flowchart based on literatue and desk research and a list of themes to cover in the decision flowchart. This enabled the attendees to focus their comments towards a final product.

In a focus group setting four experts were asked to test the workability and comprehensiveness of the initial design of the flowchart and the sustainable measures packages. A focus group enables the attendees to directly respond to each other's comments. Discussion among the attendees can instigate innovative ideas about the design and provide new opportunities.

Two experts were selected based on their involvement and expertise in especially financing school building renovation. Also, two peoples from the expert meetings attended. The initial design was also tested in qualitative and semi-structured interviews with two members of school boards. Ultimately, the final design was tested in qualitative and semi-structured interviews with another member of a school board and an employee of a municipality.

4. DESIGNS

Following the identified barriers and opportunities, sustainable measure packages and a decision flowchart were developed.

Sustainable measures packages

Derived from existing lists of technical measures sustainable measures packages were set up. To do this, lists of sustainability measures for existing non-residential buildings formulated by the Netherlands Enterprise Agency (RVO), Energy research Centre of the Netherlands (ECN), design and consultancy firm Arcadis and the statutory regulations according to the 'Activiteitenregeling Milieubeheer' of the Dutch Ministry of Infrastructure and Water Management [36] were analysed.

The packages differ between three building periods: built before 1975, built between 1975 and 1992, and built after 1992. For each building period, three packages are being presented classified according the payback periods of the measures:

1. *Basic package (in Table 3 called Minimum Building Code)*

   Based on measures that are paid back within 5 years, comprising of the acknowledged measures according to the statutory regulations [36]. In case of the oldest buildings, it is not always possible to comply with the Building Code.
2. *Energy & Cost efficient package (in Table 3 called Energy Certificate C*

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& Healthy Schools B/C)

This package includes measures that are paid back within 15 years, including the measures of the basic package and others: façade insulation instead of cavity wall insulation, floor insulation, draught proofing, HR++ glazing, insulation of ventilation ducts, balanced ventilation with heat recovery, outdoor shading; and the HR107 boiler is replaced by air based heat pumps.

3. *Energy neutral package (in Table 3 called Energy Certificate B & Healthy Schools B/C)*

   This package includes measures that are paid back within 25 years, and is similar to the Energy & Cost efficient package, with the following additions: roof insulation, the air based heat pump is replaced by heat pumps combined with heat cold storage, mechanical in- and outlet ventilation, and PV-panels.

   For school buildings built after 1975 some measures are left out, because school buildings dating from these period are expected being equipped with these measures since construction. See Table 3.

All measures were assessed for their effect on energy use and indoor environmental quality: air quality, thermal comfort, light and acoustical comfort. The costs of the measures and the payback period were calculated based upon data provided by consultancy firm Arcadis. The costs are expressed in two items: investment costs per m2 gross floor area and additional investment

	1.1 Minimun Building Code	1.2 Energy Certificate C Healthy Scho B/C	1.3 Energy Certificate B Healthy Scho B/C	2.1 Minimun Building Code	2.2 Energy Certificate C Healthy Scho B/C	2.3 Energy Certificate B Healthy Scho B/C	3.1 Minimun Building Code	3.2 Energy Certificate C Healthy Scho B/C	3.3 Energy Certificate B Healthy Scho B/C	Energy	Air quality	Temperatu
Cavity wall* (Rc = 4,5)	1									+		+
Outdoor wall (Rc = 4,5)		1	1		1	1		1	1	+		+
Roof (Rc = 6)			1			1			1	+		+
Floor (Rc = 3,5)		1	1		1	1		1	1	+		+
Weather proofing		1	1		1	1		1	1	+		+
HR++ glazing (U-value = 1,2)		1	1		1	1		1	1	+		
Insulation ventilation pipes		1	1		1	1		1	1	+		
Insulation heating pipes*	1	1	1	1	1	1	1	1	1	+	+	
Timer ventilation*	1	1	1	1	1	1	1	1	1	+	+	
Cascade control ventilation	1	1	1	1	1	1	1	1	1	+	+	
Heat recovery ventilation*							1	1	1	+	+	+
Weather-dependent control flow heating*	1	1	1	1	1	1	1	1	1	+		
Weather-dependent control start time heating*	1	1	1	1	1	1	1	1	1	+		
HR107 boiler*	1			1						+	+	+
Outdoor blinds		1	1		1	1		1	1	+		+
Heat pump (including low temperature radiators)		1	1		1	1		1	1	+		+
Heat or cold storage			1			1			1	+		
Wipe pulse circuit*	1	1		1	1					+		
Presence and daylight detection			1			1			1	+		
LED lighting*	1	1	1	1	1	1	1	1	1	+		
PV panels per m2			300			300			300	+		
Payback period (years)	5	15	25	5	15	25	5	15	25			
Energy	-	C	B	C	C	B	C	C	B			
Air quality	-	B	B	C	C	C	C	B	B			
Temperature	C	B	B	C	B	B	C	B	B			

Table 3. Sustainable measures package.

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costs. Some measures have a unit price. The IEQ effects of the measures were defined qualitatively. Only positive effects are presented. For example,if a buildings' fresh air supply is very dependent on infiltration, draught proofing could lead to worsened air quality. These effects are very dependent on the design specifics of the building, and therefore only function as awareness indicators. The effects are determined based on views by Van Bueren et al. [37] and DuurzaamMKB [38].

The measure packages are ranked based on the Program of Requirements Healthy School Buildings (in Dutch Frisse Scholen) [29]. For each specified theme, the healthy school class (A, B, C or D) was determined, if the packages would have been applied. Some requirements are formulated in such a way that it is not possible to determine the class given the generic character of the packages and because they are very dependent on the building. E.g. requirements about the amount of daylight or artificial lighting are dependent on the size of windows and number of light points. Such requirements are very building-specific. Therefore assumptions were made.

Decision flowchart

To assist school boards in choosing sustainable technical packages, a decision flowchart was developed. This flowchart guides school boards through a series of questions, leading to financial and organisational opportunities. Based on desk research and the first two expert meetings, an initial draft of the flowchart was developed. This draft was used as a basis for the third expert meeting, with the aim to reflect and build upon this work.

The structure of the decision flowchart follows the decision-making process. The top part of the flowchart determines the existing situation using the construction period of school buildings. The desired situation is expressed by three sets of technical measure packages per building period. These packages present an indication of investment costs, and thus the necessary funds to reach the desired situation. The bottom part of the flowchart starts after the investment costs for the measures are identified, and determines the way of financing. Some innovative organizational opportunities present ways to cope with split incentives and introduce a Total Cost of Ownership (TCO) approach that next to the investement cost take the operational cost, especially for maintenance and energy, into account. Others present ways to increase the scope of projects. Some opportunities do require long term commitment to a contract and trust towards market parties. By presenting other opportunities school boards are able to consider whether these issues are determining their choice.

Following the third, and final expert meeting, the flowchart was altered, resulting in a second version. Main changes to the flowchart was the addition of a legend, where supplementary information is presented. This version was used in interviews with members of school boards and in the focus group.

5. TESTING THE TOOLS

As written in the methodology section the designs were tested by organising a focus group with several experts and and by interviewing two members of school boards. With this input the tools were altered, and tested again by a school board member and by a member of a municipality by ways of qualitative interviews.

Focus group

The focus group approved the main characteristic of the second version of the flowchart. Members of the focus groups gave useful comments to facilitate the finalization of the design.

The experts underline that IEQ is a very important, although underestimated subject. A reason is that end-users: teachers and students, often do not experience the IEQ so bad. Also, the effect of behaviour on the IEQ is largely unknown and underestimated. Members of the focus group approved that the flowchart presents useful, important insights in the effects of IEQ. Those insights in IEQ can help to create problem awareness by school boards, which is currently an underestimated subject.

Interviewees

The interviewees acknowledged that the decision flowchart provides useful guidance and recognizable considerations. E.g. the financial opportunities are recognizable, mostly from presentations by Ruimte-OK and other organisations in this field. School boards can be reserved about these opportunities. Partly because they have sufficient reserves to finance renovation, and partly because schools need the municipality and warranties for such means.

If a school board does not have much in-house knowledge, the flowchart could be a very useful. It will not answer all questions, but will be useful in making considerations, broadening view, and equipping and preparing school boards in conversations with advisors and contractors. It would be useful to look at it together with the municipality, as they are often a critical stakeholder in making strategic decisions.

The interviewees are rather sceptic about financial and organizational

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opportunities, often only based on a few success stories. In practice many other stakeholders are involved, e.g. municipalities and market parties, which puts up so much time and effort, that the ideas are not put into practice, while the ideas are very promising in theory. The interviews think that the flowchart is especially helpful for school boards managing a single school, which entails almost half of all Dutch primary school boards [39] , and during the initiation phase of a renovation.

The decision flowchart somewhat fails in speaking the same language as school boards. Their business evolves around the quality of education. School boards need to be aware of the effect that their buildings have on the quality of education. Using this as starting point can evoke problem awareness. Furthermore, school boards generally reason from the building portfolio level, starting with the strategic housing policy. Also, it is advised to work from a Total Cost of Ownership (TCO)-approach. Because this provides opportunities for a long-term vision. Finally, procurement is an important aspect. School boards are no experienced principals. If they would procure based on lowest price, the results could affectthe quality. One of the interviewees sais that schools should procure performance-based, challenging the market to come with smart solutions.

6. FINAL DESIGNS

Many small adjustments were made to the tools, based on the conclusions of the focus group and the interviews with the members of the school boards. After making adjustments, the 'final' tools were tested by a school board member and a member of a municipality through semi-structured interviews.

Final sustainable measures packages

The sustainable measures packages were formulated differently. The 'Basic package' was changed to 'Minimum Building Code'. This way it is instantly clear what the package is about and for what sustainability ambition. The 'Energy and Cost Efficient package' does not make clear how energy-efficient, cost-efficient and healthy it is. Therefore, the name of this package was changed in 'Energy label C & Healthy Schools B/C'. The third package, 'Energy neutral', tried to emphasize the ambitious character of this package. However, whether the package results in an energy neutral school building, cannot be ensured. Therefore, and to enable comparison with the second package, the name was changed to 'Energy label B & Healthy Schools B/C'.

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Final decision flowchart

The final flowchart helps decision-making about a single building and the building portfolio. Therefor the final flowchart presents a question ending the top half, asking whether the school board wants to improve a single building, or all buildings. In case of one building, the flowchart can be followed as before, in case of all buildings, the top half can be repeated for every building in the portfolio.

The bottom half did not provide the needed guidance in the selection between financing and organizational opportunities. Therefore, the final flowchart is provided with additional considerations, guiding school boards through the decision-making process.

The focus group indicated also that the way funding, financing and organization of projects is applied is unstructured. Th e addpaed flowchart tries to structure these different opportunities. First, funding opportunities are presented by ways of own means and municipal funds. If these are insufficient, third party financing options are presented. The organizational opportunities are presented after.

Final testing decision flowchart

The final decision flowchart was tested in qualitative and semi-structured interviews with a member of a school board and an employee of a municipality. The interviewees were positive about the flowchart. School boards can organize renovation projects better with the knowledge this flowchart provides. Additionally, this could also have a positive effect on the IEQ in the renovated school buildings. The interviewees regret the fact that the flowchart doesn't have a question that stipulates who is responsible for the quality of the school buildings. This should be clear, as well as the sustainability ambition for the school buildings. When this is clear, it becomes easier to determine how much funds should be brought in by the municipality. This way, the flowchart can also facilitate in the talks with the municipality.

In the technical measure packages, the interviewees missed a nearly Zero Energy Buildings (nZEB) alternative according to the EU Energy performance Building Directives. The nZEB option is important, because in 2020 nZEB is mandatory for new buildings and probably in 2040 or 2050 for existing buildings. If the life-time of a building is prolonged by 25 years in the coming years, it will still exist after 2040 and possibly subject to nZEB requirements. These requirements are less specific than the Program of Requirements Healthy School Buildings. Therefore, it is more complicated to provide a generic indication of measures, with substantiated assumptions.

The interviewees indicated further thatthe flowchart is less useful for large building portfolios. With a portfolio of 150 schools, it is quite a job to repeat the top part 150 times. This is only possible for medium-, and small-sized school boards.

Finally, more guidance could be given in the way funds are distributed between the municipality and school boards. The measures in the 'building code minimum'-packages, are energy-saving measures and can be added to the maintenance planning of a school board. This means that these measures are paid from their own reserves, or the lump sum subsidy. If the measures aim at extending the service life of the building, municipalities are also responsible. The rule of thumb for funding responsibilities in case of renovation is that the school is responsible for energy efficiency and the municipality for IEQ improvements and service life extension. Improvements for other reasons are negotiable. This distinction can be included in the decision flowchart, as it provides a basis for discussion between school boards and municipalities. It can help school boards in making municipal funds available for renovation.

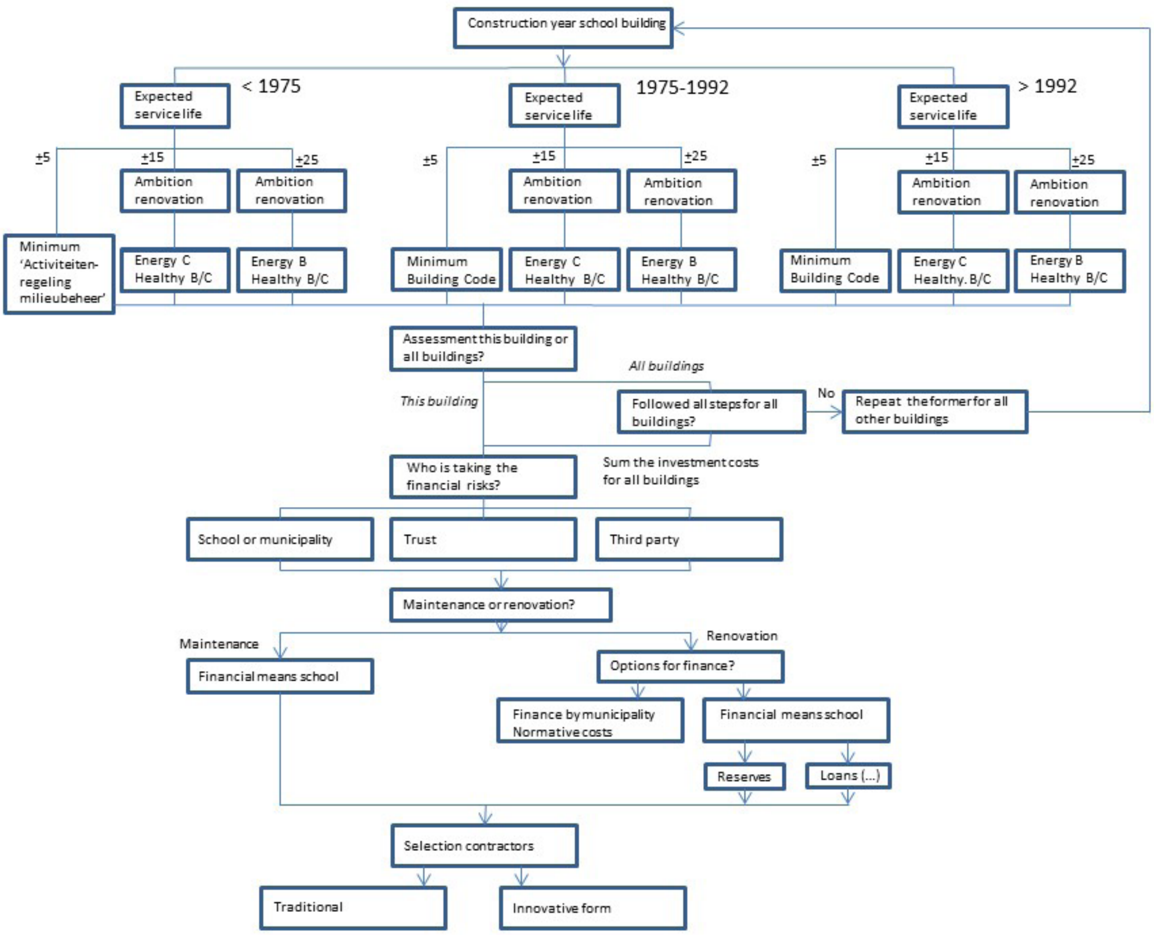

Figure 1. Decision flowchart.

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Design finalization

Following these final design tests, the design was ultimately finalized into the flowchart shown in Figure 1. In the final design the top part of the flowchart was expanded. Considerations are added about the horizon of the proposed intervention, and the ambition level for the school building. Furthermore, the names of the technical measure packages are changed to present sustainability ambitions. In contrast with the top part, the bottom part was simplified, because according the attendees in the second expert meeting, the financial opportunities should be more structured. Which financial means should be addressed is first determined by wether the measures are seen as renovation or maintenance. In case of maintenance (quick wins, payback period of 5 years of less), the costs are for the account of the school. In case of renovation (measures with a paybackperiod over 5 years), schools can involve the municipality for financial means, address their own reserves or apply for a loan.

After the financing part, market party selection starts, where the choice can be made between traditional procurement or innovative procurement. The latter guides towards organizational opportunities. See Figure 1.

7. DISCUSSION

The decision-making process in school building renovation is very dynamic and cluttered. In general, many discussions with the municipality precede any decision regarding renovation. Key issue in most of these discussions is financing: What measures are necessary to take? What is the necessary budget? And who is going to fund which part of the renovation? For this reason, focus group members and interviewees often recommend that the flowchart should begin with the 'financing part'. Yet, beginning with the 'finance part' can limit their sustainability ambition, because school boards generally prefer funding with their reserves, limiting the budget. If they first state their ambitions, these are less restricted by budget. Then presenting ways to meet their ambitions can commit them to these ambitions, making them more willing to change their view regarding external financing. The respondents could find themselves in this explanation. In general, the respondents agreed with the general structure of the flowchart.

The respondents were positive about the way the flowchart presents an overview of available opportunities. Even though, some were sceptic about some of the more innovative organizational forms, it does inform them of the opportunities that are at hand, and their benefits. Although most

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respondents are aware of the available opportunities, because they are experts in the educational housing market, they indicate that in general the level of knowledge about renovation opportunities is insufficient. Thus, the insight in renovation opportunities is very useful for the average school board, who does not have the capacity to hire a housing expert. The respondents expect that the flowchart helps ease the organization and financing of renovation projects.

The attention the flowchart presents onfthe effects of indoor environmental quality on the quality of education, is regarded as a valuable addition to the flowchart. It evokes necessary problem awareness, which is currently an underestimated aspect in school building renovation. Respondents expect that the focus on indoor environmental quality can increase the attention to the indoor environment in the renovation of school buildings.

8. CONCLUSIONS

This research presents an elaborate overview of the existing situation in the Dutch educational housing sector and identifies several issues. By presenting the decision-making process in combination with renovation opportunities, the decision flowchart aims to support the renovation decision-making process by providing knowledge. Members of school boards often started as teacher who, after training, worked their way up to school management and eventually to a school board. Lack of knowledge, problem awareness, and power to get to solutions are indicated as main problems in educational housing, instead of financing. Money seems not to be always the problem. The decision support tools can provide a basic level of knowledge, partly tackling this issue.

The increase in problem awareness and attention to indoor environmental quality, could lead to more balanced renovations in terms of People, Planet & Profit, as the importance of the People dimension is emphasized and recognized. The Planet dimension, or energy performance, will remain important due to (inter)national pressure to improve energy efficiency. Also, the Profit dimension will remain important given the complicated financing structure. Whether the decision flowchart can increase the financial room available for indoor environmental quality improvement is dependent on the willingness of school boards to abandon their current views on funding and financing and to engage in more innovative ways of organization and financing. Additionally, the market should find ways to speed up the development and learning curve of these innovative opportunities, making them more trustworthy.

Apart from the effects of indoor environmental quality on health, productivity and performance, little scientific research is conducted regarding school building renovation. Especially the relationship between knowledge by school boards and the consideration of the People, Planet & Profit dimensions has not been researched to date. In this area, this research is the first in its form and can be built upon to further improve the educational building stock in the Netherlands. But, a lack of problem awareness is apparent. Not only at school boards, but also student and their parents. Improving the awareness of the effects that school buildings have on performance, productivity and health, could lead to more attention to IEQ improvement. Through the participation council, parents can influence school boards in the development of school buildings with proper indoor environmental quality. AlFaris et al. [40] outline a comprehensive energy management program for schools. The key element of the proposed strategy is to establish commitment by the organisation to follow up the program. The first step of the program is the establishment of an energy management committee from the schools staff including students and someone qualified in energy efficiency. We think that primary schools could benefit from the existence of such a committee for energy and IEQ.

To further improve primary school buildings, this research contributes to a better work & learning environment for staff and students. With better indoor environmental quality, their performance, productivity and health improves. Additionally, this can have direct and indirect monetary effects. Directly through e.g. sick leave, or indirectly through higher income in the adult life of students.

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