DECISION SUPPORT SYSTEM FOR EVALUATION OF ENERGY SAVING INVESTMENTS IN BUILDINGS

Dalibor Vytlačil[1] and Ondřej Povýšil[2]

ABSTRACT

Paper deals with decision making in the field of energy saving investments in existing or refurbished buildings. The solution of the problem is based on an analysis of factors influencing energy consumption in the buildings. The relevant system is described by means of a network where nodes are connected by financial flows representing direct operating costs and financial outcomes from a particular project. The decision is undertaken on the basis of the evaluation of single projects and combinations of projects. The program has been developed for the selection of projects that meet requirements of desired energy savings and a level of investment costs.

A case study is presented for the demonstration of the described method. Eleven single projects and combinations of projects were evaluated. The calculated results help the building designers to find an optimal solution. The parameters of designed building structure and HVAC system have to ensure good internal environment and low energy consumption.

KEY WORDS

Energy savings, decision making, project evaluation, financial flow, network.

INTRODUCTION

The design process is usually focused on the design of building structure for low initial costs. A contemporary development of fossil fuel prices and an uncertainty in the future supply of the fuel push pressure on the building owners to deal with the operating costs and with the decision what kind of a heat source to install in the building. The owners are limited by the budget but concurrently they want the building with low energy consumption. This is new issue for the building designers. The solution can be found in the investigation of all factors influencing energy consumption and in the careful economic evaluation of all relevant elements of the system.

Figure 1 describes important factors influencing the energy consumption in the buildings. The factors are sorted by the time that is needed for the change of the certain system element. It is difficult to change the location of the building compare to the change of an occupant behavior. Long-terms factors are usually the external influences that have the strong

[1] Associate Professor, Department of Engineering Informatics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29 Prague 6, Phone +420 224354507, FAX +420233337349, vytlacil@fsv.cvut.cz

[2] Ph.D. student, Department of Engineering Informatics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29 Prague 6, Phone +420 22431111, FAX +420233337349, ondrej.povysil@fsv.cvut.cz

relationship to the outside temperature and the solar radiation. These factors together with the quality of the structure elements and HVAC system quality influence the heat flows from the internal environment to the external environment. The important decision is the choice of the fuel because of the price but also because of the possibility of the good control.

The presented factors can be investigated on the higher resolution level but for the purpose of this study the described factors are sufficient.

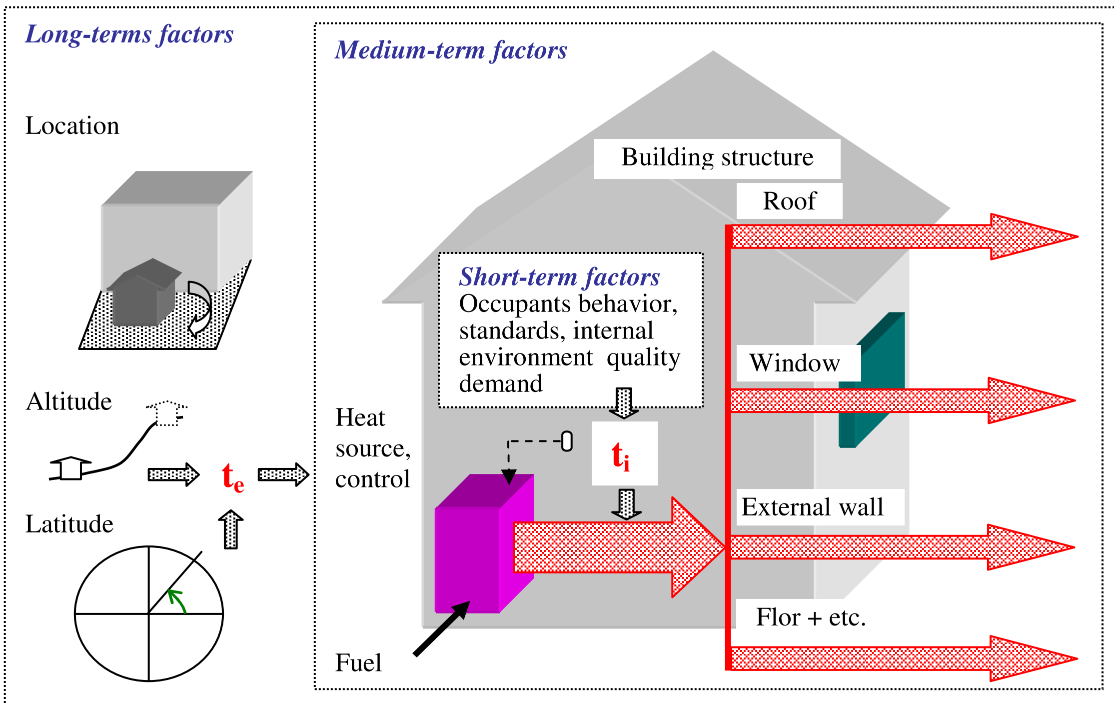

Figure 1: Factors influencing energy consumption

METHOD

NETWORK MODEL

The heat flows in Figure 1 can be transformed to the system of the financial flows. Additional flows can be derived from above described factors and the whole system is drawn in Figure 2. The connections are the financial flows that are associated with a pair of nodes. The node represents the decision influencing the energy consumption. The attached connections are the direct operation costs and the financial outcomes from implementing a concrete energy saving arrangement. The investment cost is a switch that changes the ratio between the output direct operating costs and the saved costs.

The problem situation is described as a network model where the node is one investment project and the links associated with the node solve for the evaluation of one single project.

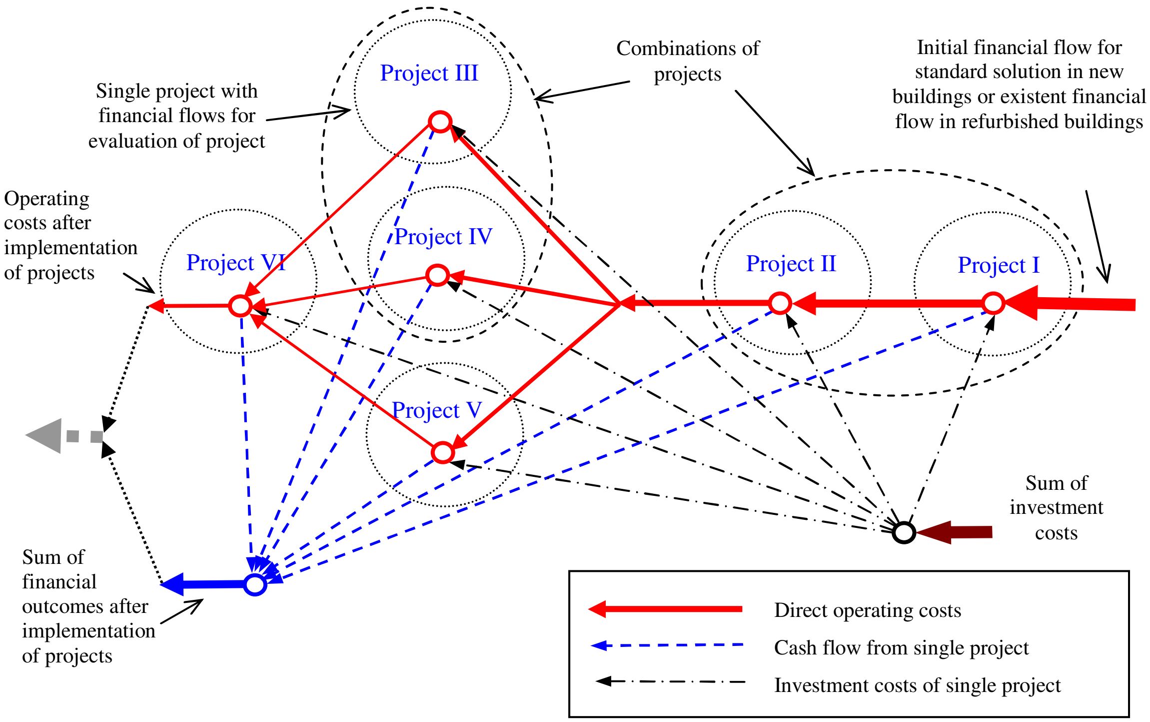

Figure 2: System of financial flows and projects

The network includes projects influencing other projects in the system – there are the dependent projects. The explanation of these projects is drawn in Figure 3. The amount of the investment cost in project 1 increases the financial outcomes from the project but concurrently influences the financial outcome from project 2 that will be decreased. Typical example such of projects is the improvement of the thermal properties of the building shell and the installation of new sophisticated heat source. Higher investment to façade will decrease the key project value in the source project. The example of independent projects is the improvement of window thermal properties and building shell thermal properties.

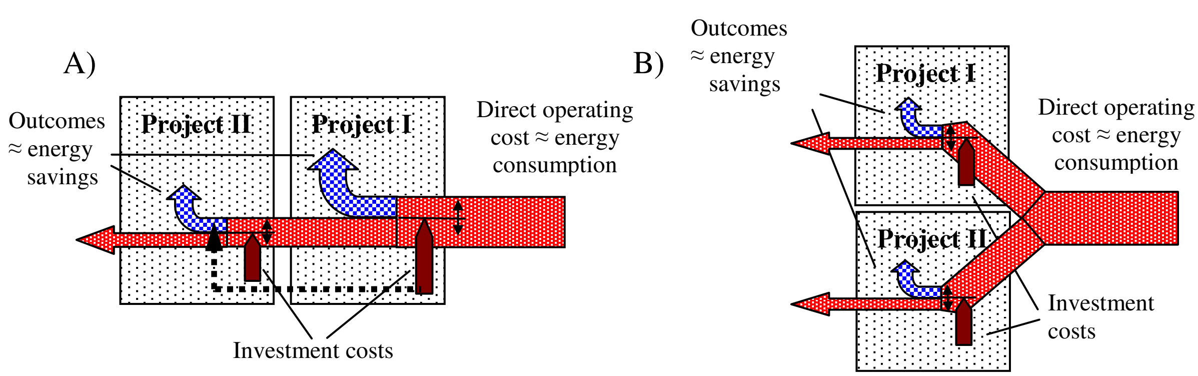

Figure 3: Combination of projects – A) dependent projects and B) independent projects

EVALUATION OF PROJECTS

The method for finding whether the project yields a return in an excess of an alternative equal risk is to assess net present value of the evaluated project. A positive value of NPV indicates that the project of the energy saving arrangements should be accepted (Behrens and Hawranek 1996, Drury 1995).

$$E(NPV) = \sum_{t=1}^{m} \frac{CF_t}{(1+i_t)^t} \tag{1}$$

Where CF_t is the cash flow from the project in year t and i_t is a discount rate for year t.

Internal rate of return (IRR) is another project value for making investment decision. This value represents the interest rate earned on the investment during the time that is defined as an economic life. It is the discount rate that will cause the net present value of the investment to be zero.

$$\sum_{t=1}^{m} \frac{CF_t}{(1+i_i)^t} = 0 \tag{2}$$

The evaluation of the single project or the combination of the projects is based on the assessment of the annual cash flows generated from the considered projects.

The computer program has been developed for the evaluation of the combination of selected projects. The program has to include same restrictions based on the experience from the design process in the practice. A future owner of the building is limited by the budget or by the possibility to gain a loan. Another restriction for the chosen projects is the minimal amount of the saved energy. The user of the program selects the projects that will be evaluated and the limit of the investment costs as well as the minimum limit of the saved energy. The program calculates the key project values (NPV and IRR) according to the input values. The resultant values are the basis for the selection of the project for the implementation.

CASE STUDY

DESCRIPTION OF INVESTIGATED BUILDING

The evaluation of energy saving projects is demonstrated in the real project. The building is thirty years old block of flats. The building shell is fabricated from bricks. The presented calculation is performed for one flat in the building. The flat is on the 3rd floor, living area is 69 m^2 and the heat source is a gas boiler. In the beginning, 15 combinations of the projects existed for 4 single projects. With considering 170000 CZK investment cost limit, the number of the combination is 14. The implementation restrictions decreased the number of projects and the final figure is 11.

PROJECT DESCRIPTION

List of single projects:

Project 1 – Thermal insulation of the façade (thickness 80 mm).

Project 2 – The replacement of windows for new windows with better thermal parameters (U_{frame} = 1,13 $W.m^{-2}.K^{-1}$, U_{glass} = 1,4 $W.m^{-2}.K^{-1}$).

Project 3 – The installation of the window seal.

Project 4 – The replacement of old gas boiler for new boiler with higher efficiency (η = 92%).

List of combination of projects:

Project 5 – the combination of *Project 1-Thermal insulation* and *Project 2-Windows replacement*.

Project 6 – the combinations of *Project 1-Thermal insulation* and *Project 3-Window seal*.

Project 7 – the combination of *Project 1-Thermal insulation* and *Project 4-Boiler replacement.*

Project 8 – the combination of *Project 2-Windows replacement* and *Project 4-Boiler replacement*.

Project 9 - the combination of *Project 3-Window seal* and *Project 4-Boiler replacement*.

Project 10 - the combination of *Project 1-Thermal insulation* and *Project 2-Windows replacement* and *Project 4-Boiler replacement*.

Project 11 - the combination of *Project 1-Thermal insulation* and *Project 3-Window seal* and *Project 4-Boiler replacement*.

Project 5 and Project 6 are the independent projects, others are the dependent projects.

The project lifetime is considered 20 years that corresponds to the expected life period of the main parts of the building structure and HVAC system. The fuel price change is estimated 5% increase every year. This parameter is very important for the evaluation because the fuel price influences very strongly the cash flow from the implementation of the project. The value is usually based on the estimation and the prediction is done for long time period. Therefore the uncertainty is extremely high. The discount rate is 8%.

RESULTS

RESULTANT VALUES OF PROJECTS

The energy consumption after the implementation of the designed changes was calculated for every year. Consequently, the saved energy and the cash flow during the project life were assessed. The program uses these values together with the sum of the investment cost for computing main project output values. The summary of the resultant values for all projects is in Table 1.

Table 1: Resultant values of projects

	Investment costs [10^3 CZK]	Net present value [10^3 CZK]	Internal rate of return [%]
Single projects			
Project 1	65,2	-6,7	7
Project 2	76,5	-41,5	-
Project 3	5,2	3,7	17
Project 4	25	-4,8	5
Combination of projects			
Project 5	14,7	-45,7	3
Project 6	70,4	-2,3	8
Project 7	90,2	-15,3	6
Project 8	101,5	-45,4	1
Project 9	30,2	0,2	8
Project 10	166,7	-57,5	3
Project 11	95,4	-17,4	6

The results show how good the different projects are. According to NPV rule most projects should not be implemented. It is not a surprise because a payback period in energy saving projects is relatively long. The question is also the fuel price increase by 5% every year. After five years probably the speed of price increasing will be higher figure and therefore NPV will reach positive values. The projects are compared also in graphs in Figure 4.

The rank of projects is shown in Table 2. The application of NPV and IRR methods leads to the different order. In case of the discount rate lower than 10–12% the rank of projects is different (Drury 1995). The discount rate in the case of the energy saving projects is usually less than 10%. The investigation of the cash flow increments gives the priority to NPV rule.

The projects are mutually exclusive and therefore only one project or the combination of projects can be implemented. The best project according NPV and IRR rules is *Project 3* but it has the lowest energy savings. The best project from energy savings point of view is *Project 10* but this project has the worst NPV. In this case, *Project 6* was chosen for the implementation. The construction works were realized four year ago. The financial project outputs have been checked during this time period. Good agreement between computed and measured values was found. Expected development in the gas prices will cause the difference in cash flows and future yields from implemented project will be higher than calculated.

COMPARISON OF DEPENDENT AND INDEPENDENT PROJECTS

It is not easy to compare these two kinds of projects because usually there are not sets of the projects with equal investment costs. In this example, it is possible to compare e.g. *Project 6* and *Project 7* or *Project 5* and *Project 10*.

To demonstrate the described dependence shown in Figure 3, the energy savings were calculated for different thermal quality of the building shell and different changes in the efficiency of the heat source. The results are depicted in Figure 5. For higher thermal insulation thickness the increment of the energy savings for higher value of source efficiency is not so high value as for smaller thickness.

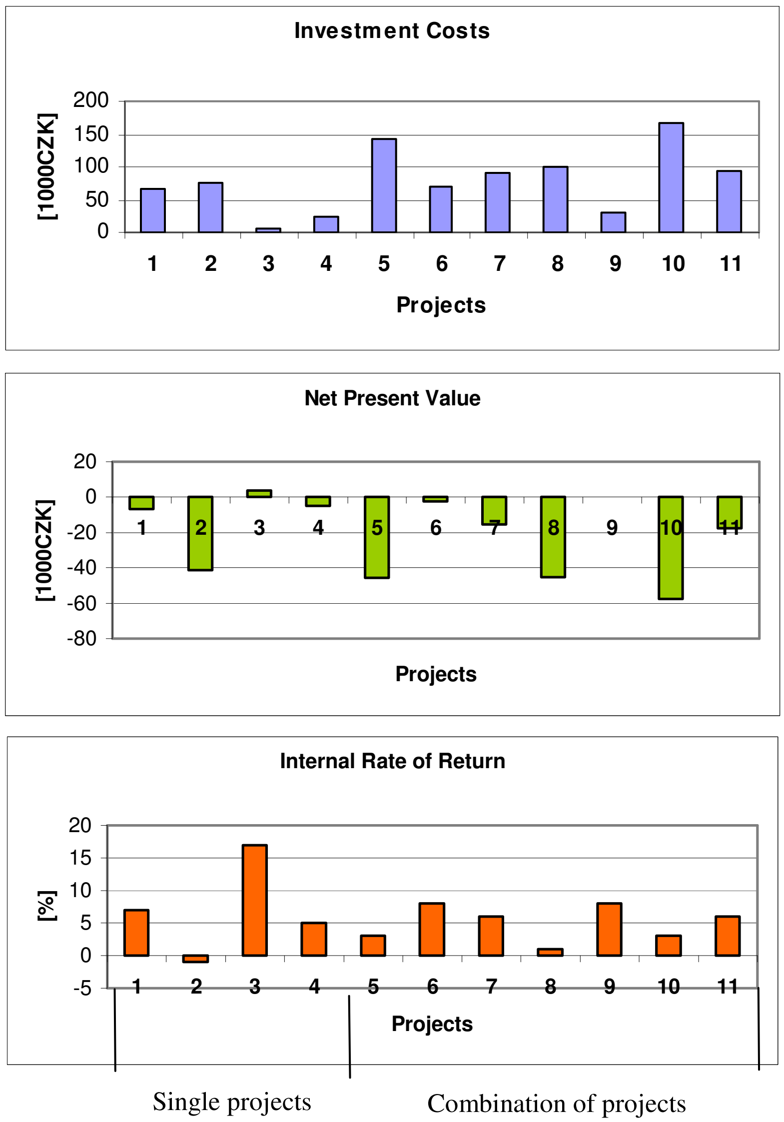

Figure 4: Resultant project values for single projects (1 – 4), combination of projects (5 – 6, independent projects and 7 – 11, dependent projects)

Table 2: Rank of calculated projects according to net present value (NPV) and internal rate of return (IRR)

Rank	Project	NPV [10^3CZK]	Project	IRR [%]
1	**3**	3,7	**3**	17
2	**9**	0,2	**9**	8
3	**6**	-2,3	**6**	8
4	**4**	-4,8	**1**	7
5	**1**	-6,7	**11**	6
6	**7**	-15,3	**7**	6
7	**11**	-17,4	**4**	5
8	**2**	-41,5	**5**	3
9	**8**	-45,4	**10**	3
10	**5**	-45,7	**8**	1
11	**10**	-57,5	**2**	-

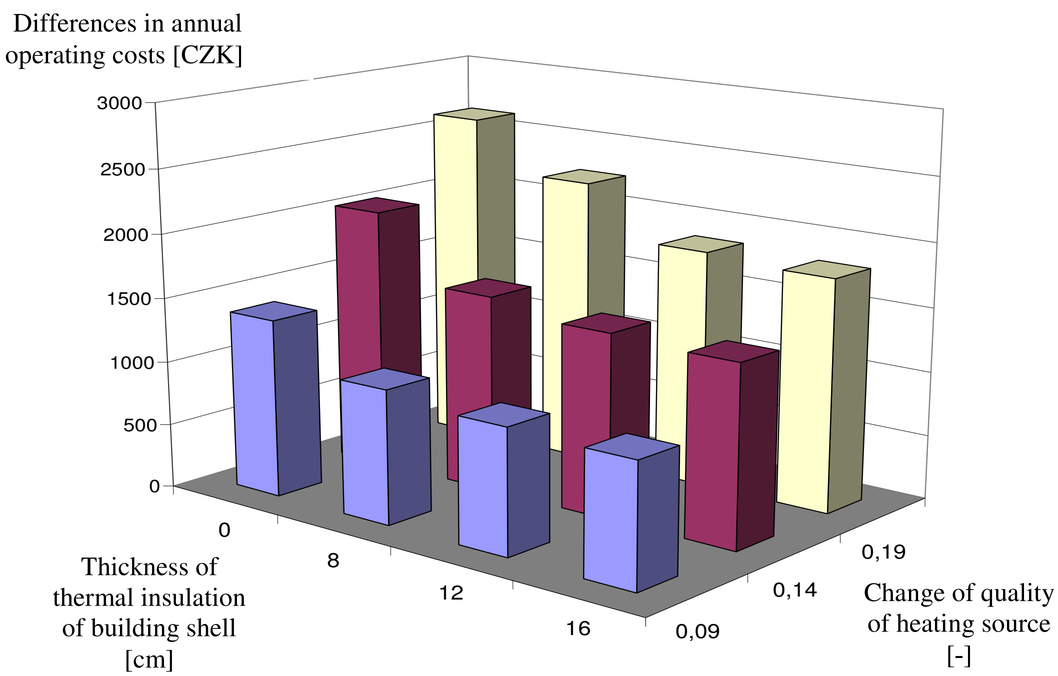

Figure 5: Differences in annual operating costs for different thickness of thermal insulation if the quality of heating source (efficiency) is changed

CONCLUSIONS

The conclusions from the investigated problem:

- To prefer the combination of independent projects that ensures better investment effectiveness.
- The results are very sensitive to the price of the fuel. The changes of this parameter strongly influence the resultant values of the projects.
- To do decision according to NPV method (in energy saving projects).
- To consider significant influence of the investment costs. The owner should spend enough time with the selection of the supplier of the construction works.
- To define in the beginning very precisely the goals that has to be reached in the project. This decision should be done together with the client.

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