

Risk management for planning and use of building service systems

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SUMMARY

The design, use and maintenance of buildings and building service systems have become more and more complex, in the sense of management of information and knowledge. The systematical risk management methods and applications are sophisticated ways to evaluate and manage the risks. This paper presents three case studies for risk management. The first case describes the management of risks and success factors in building service life-cycle project, and this is application for design phase. The second case describes the systematic approach for risk management of indoor air quality of ventilation system during the use of system. The method points out the biggest risks inside the system, which may cause problems in indoor air quality, and will help to find out the most important points in the technical system, to be checked and controlled. The third case is evaluating the risks when taking the responsibility of energy consumption of the building service system.

INTRODUCTION

The design, use and maintenance of buildings and building service systems have become more and more complex, in the sense of management of information and knowledge. The systematical risk management methods and applications are sophisticated ways to evaluate and manage the risks.

When planning a new building or renovation of the existing buildings, the best possibilities to effect on the costs, performance and conditions of the building is the pre-design and design phase (figure 1). If the requirements for the building are properly set and also the possible evident risks have been evaluated, the implementation of the conditions and their matching to needs and requirements can be checked following a commissioning procedure (or, in general, mutually accepted quality control procedure) [1] (figure 2). The main reasons, why the building does not fulfil the prerequisites can be divided roughly into three parts: 1) faults in pre-design and design stage, 2) defects in implementation stages and 3) malfunctions in TAB (testing-adjusting-balancing) and in use stage. The energy performance, energy efficiency and indoor conditions, as thermal comfort and indoor air quality, depend on the proper integration of building envelope, functioning of the ventilation system, heating systems, cooling systems, BAS (building automation system) and internal and external loads (weather conditions, use, etc). The crucial matter is how the operations of these factors are integrated together, and how these factors will cohere. In the pre-design phase, the building owner should set his requirements and demands as well as possible matching the needs. The problem has been earlier, that these requirements have not been properly set. In some cases, for instance, when planning a shopping mall or commercial building, the owner probably does not know the final

users, or not all of them. The needs of individual end users may vary, which would cause e.g. the use of distributed ventilation system.

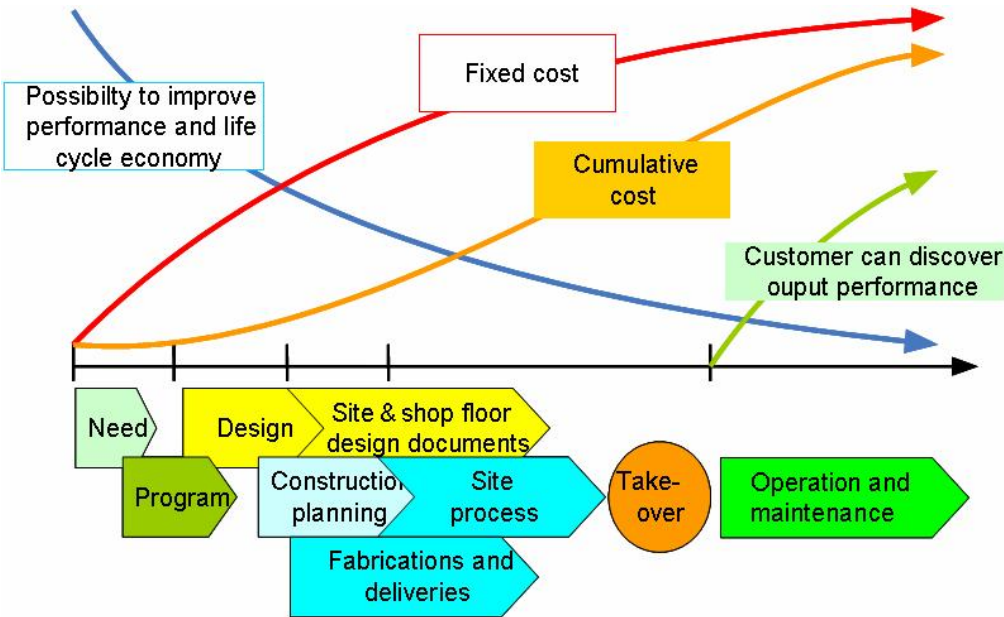


Figure 1. Building process [2].

Different type of risks exists in the building process from design phase to operation phase. The quality and commissioning procedures are needed to support the building processes. The procedure includes the different stages of the building process. Figure 2 shows how the requirements and goals will be checked between each stages of the project [1]. Each 'diamond' contains check-lists of tasks and operations.

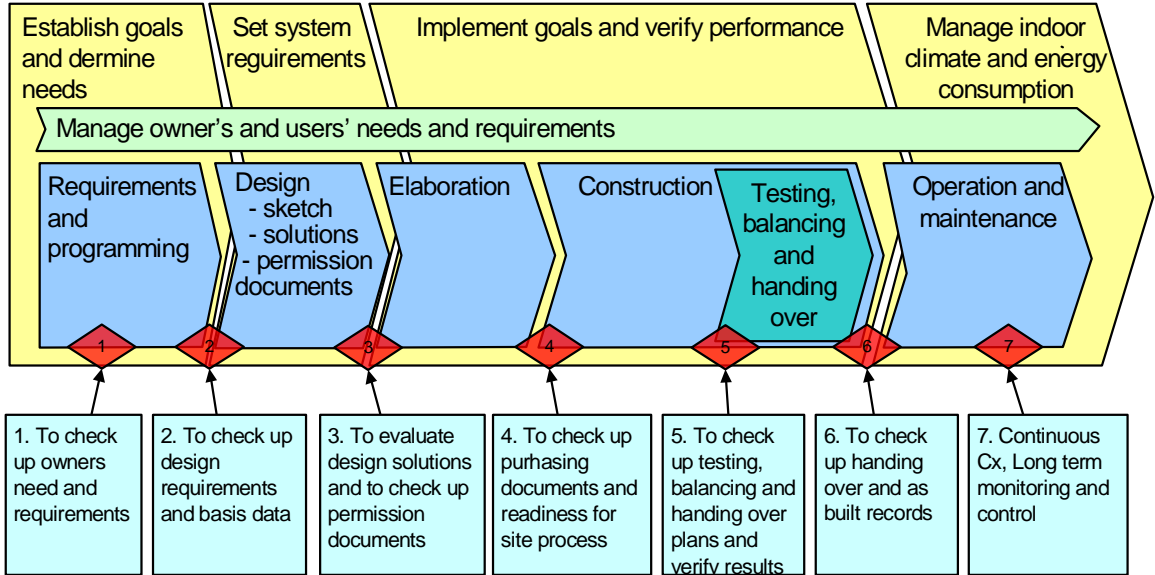


Figure 2. The phases of commissioning [1].

The objective of the paper is to present the methods and three case studies of systematical risk analysis and management, supporting the quality of the overall building process. The general systematic for identification, evaluation and sharing of risks are presented. Classification of risks, model for risk evaluation table (matrix) and risk number method are presented.

METHODS

Risk assessment

Methods in risk sharing and assessment have been developed for risk recognition and management. To assess the success factors of projects, corresponding assessment tables have been drawn up to help recognize the special features of successful projects [3].

Systematic risk recognition and assessment is the method for managing risks and pinpointing the responsible party. The stages of risk analysis are defining the target, recognizing hazards, assessing consequences, calculating probabilities, assessing the total risk, and finally, removing, reducing, and preventing the risk. The parties involved in the implementation of the project are assessed for their ability to take responsibility for the risk, and usually, the responsibility is given to the party that could handle it and to that it naturally belongs. Drafting a contract is a concrete tool for pinpointing the party responsible for risks. Through risk assessment, crucial matters to be included in the contracts are observed along with the necessary insurances and potential securities.

Classification of risks

One example of classification of risks is presented in [5]. Country related risks depend on the situation in the county, including economic risks, political risks and risk related to natural conditions. Implementation risks are risk caused by the realisation of the case, including technical, financial, contractual (caused by the juridical content), personnel risk (caused by actions of employees) and risks caused by methods of implementation. Force Majeure risks are unforeseen risks, which are not possible to remove.

In the project CUBENet [11], the risks were classified for practical building project. Implementation risks include source information, and quality of this information (e.g. conditions of structures in renovation project), technical risks in construction work, investment costs, timetable of construction work and quality of technical plans. Risks related of way of action during contract period include quality source information (e.g. energy consumption of previous years), availability and cost of finance (including interest rate), guaranteed savings and commissioning, maintenance costs (including changes in energy price and cost of maintenance investments). The risks related to partners of the project include economic status of parties and organisational issues (e.g. changes in personnel).

Risk assessment in planning phase – risk matrix and success factor methods

One practical method for systematic risk assessment is a risk sharing table (or check-list, or matrix), figure 3. The potential (along with apparently impossible) risks are listed and shown to the project parties. Reference [4] presents the categorisation of risks in macro, meso and micro levels ('meta-classification approach'). Reference [5] shows the practical risk evaluation and allocation table for PPP (Public-Private-Partnership) project in Finland. With the risk sharing table, the parties share the responsibilities for the risks each party will assume. The responsibility for an individual risk is left to either party or to both parties according to principle agreed by parties. The client assesses the risks of the project and assumes responsibility for some of the parties involved in the project. In the invitation for bids, the bidder is asked to pay attention to the risks transferred to the provider and to describe how they will assume responsibility for the risks or will take these into account in the bid. In

practise, the provider may not necessarily take the responsibility of all risks offered but will transfer the risk back to the client in the bid. The responsibility for a risk will naturally have influence in pricing – the party taking the responsibility of the risk is setting price for the risk.

The risk assessment table helps the bidders in evaluating how they accept the risks the client is transferring to the provider. The table forms a foundation for the bidders' proposition in order to show how well the bidders understand the nature of the risk, how effectively the bidders forward or share the risks in the subcontractor chain, and how the bidders minimize the unfavourable effects caused by risks in relation to the client and the end users.

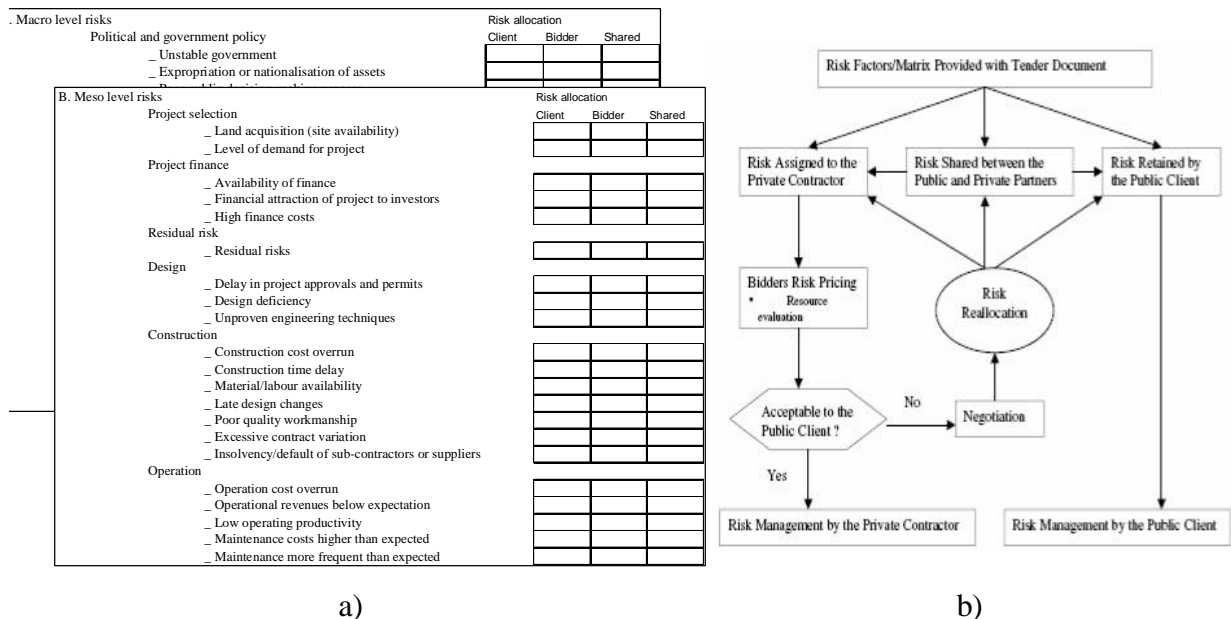


Figure 3. a) An example of risk allocation table [3] and b) Flow-chart of negotiations [4].

Critical success factors and sub-factors have been analysed based on method in reference [7].

Risk management during use – risk number method

After the construction phase in the project has been completed, risks are also managed with the help of the information system, such as building management and monitoring system (BMS). The functionality of the technical system is monitored and measured, paying particular attention to the factors sanctioned in the contracts. The monitoring system can contain risk assessment tools which focus the monitoring and service to the risk points of the process. Disadvantageous factors of the various parts of the system are assessed based on three factors [6]. The probability of occurrence (showing how probable is the occurrence of factor) and probability of discovery or detection (showing how easy to discover or detect the factor is) as well as the severity (showing how harmful this factor is) of the disadvantageous factor are assessed separately on a scale of one to ten (or some other selected scale). The product of these three factors is the total risk number (example in table 1). The higher the risk number, the higher the risk caused by the disadvantageous factor. When the risk points have been recognized, the measures can be focused: the risk points of the AC system can be handled with the monitoring system (critical monitoring points), and service can be targeted to the system risk points. Additionally, measurements can be utilized in defining the numerical values (severity based on measured value). Moreover, applications can be developed to assess risks in energy consumption, which is crucial in some contract models, e.g. in energy service contracts.

Table 1. Criteria of the drawbacks.

Severity, S	Numerical value	Probability of detection, Pd	Numerical value	Probability of occurrence, Po	Numerical value
No influence (Category 1)	1	Drawback always detected	1	Occurrence of drawback improbable	1
Category 2	2,3	Category 2	2,3	Category 2	2,3
Category 3	4,5,6	Category 3	4,5,6	Category 3	4,5,6
Category 4	7,8,9	Category 4	7,8,9	Category 4	7,8,9
Health risk	10	No detection of drawback	10	Very probable	10
Severity S Describes the seriousness of the examined drawback factor significance from the point of view of the observed feature		Probability of detection, Pd presents how probable it is to detect the drawbacks by other means than by measuring		Probability of occurrence, Po describes how probable the occurrence of the examined factor is in the system	
The result of these three factors is total risk number: $RPN = S \times Pd \times Po$					

RESULTS

Case study 1 - risks and success factors of ESCO contracting models

New procurement models and service concepts, e.g. energy service concepts, have been developed actively. PPP (Public-Private-Partnership) and PFI (Private-Finance-Initiative) models have become more common in areas of transportation, health-care, power and energy and buildings [8]. The experiences of these projects and possibilities for Finnish applications in construction sector have been reported ([9], [10]). The concepts for building services, e.g. ESCO/EPC-services, have been presented in [11]. The first case study describes the management of risks and success factors in building service life-cycle project, e.g. ESCO. The main focus is in the planning phase. These concepts need risk management and risk sharing between client and energy service companies. The sharing of risks will be agreed in practice with contract documents. The risk and success factors have been evaluated based on risk allocation matrix (example in figure 3), success factor tables and interviews. The interviews were done separately for clients and service providers.

The following factors were evaluated the most important risks for the client in ESCO services: 1) control of timetables, 2) success in demolition work, 3) discovery of additional savings and 4) re-utilisation of old devices with new ones. The main risks for the service providers are: 1) initial information (given by the client), 2) trust and familiarity with the client, 3) success and correctness in planning, 4) success and fluency in construction works, 5) identification of 'grey areas', which are not easy to control based on the available information, and 6) knowledge of contractual issues.

The main success factors for client using ESCO model are: 1) the traditional ESCO is possible without investment, 2) in case investment is needed for construction work, the investment cost is smaller than in case of traditional, 3) service contracts guarantee extra savings and higher quality of buildings, 4) after 1st contract period, competition between service providers is possible, 5) in case savings are not realised, this is decreasing the fee for service provider. The main success factors for service providers are: 1) fluency in cash flow due to long contract period, 2) investigation of correct basic information, 3) success in evaluation of risks and forwarding the risk aspects in contracts.

In the analysed ESCO projects, there were no big conflicts between the opinions in sharing the risks between the client and service provider, therefore possibilities for successful sharing of risks exists. The concept of risk sharing table will help the discussions about existing risks and will speed up the contract negotiations. The concept of success factors was seen as a tool for strategic planning and selection of successful models for delivery, not as a tool for single building project.

Case study 2 - risk management of indoor air quality of ventilation system during the use of system

The second case describes the systematic approach for risk management of indoor air quality of ventilation system during the use of system. The effects of the component level performance on the system overall performance and existing risks were evaluated using risk number approach. The method points out the biggest risks inside the system, which may cause problems in indoor air quality. This approach will help to find out the most important points in the technical system, to be checked and controlled during the use and maintenance. Figure 4 presents the ventilation system, table 2 evaluation criteria and table 3 risk numbers of the drawbacks [12]. The number values are based on expert opinions, and should be updated by experiences. In this case, the control and service should be focused especially on pre-filter and supply air duct, to guarantee the high quality of the ventilation air.

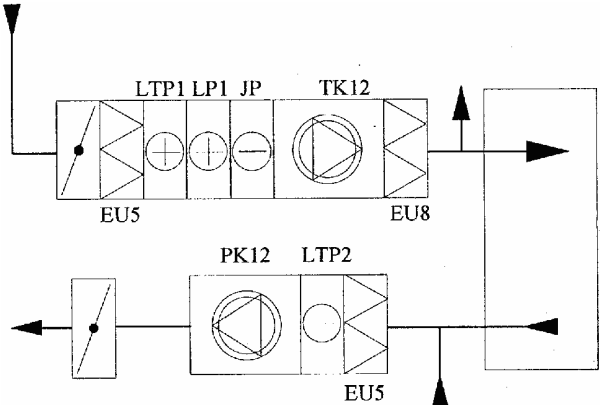


Figure 4. Ventilation system in case study.

Table 2. Evaluation criteria for risk analysis in case study.

Severity, S	Numerical value	Probability of detection, P _d	Numerical value	Probability of occurrence, P _o	Numerical value
No influence on quality of supply air	1	Always detected/noticed	1	Improbable	1
Small decrease in quality of supply air	2,3	In most cases detected	2,3	Small	2,3
Decrease in quality of supply air	4,5,6	Sometimes detected	4,5,6	Possible	4,5,6
Bad quality of supply air	7,8,9	Seldom detected	7,8,9	Probable	7,8,9
Bad quality of supply air has influence on health	10	No detection of drawback	10	Very probable	10
Severity S describes the seriousness of the examined drawback factor significance from the point of view of the observed feature		Probability of detection, P _d , presents how probable it is to detect the drawbacks by other means than by measuring		Probability of occurrence, P _o , describes how probable the occurrence of the examined factor is in the system	
The result of these three factors is total risk number: $RPN = S \times P_d \times P_o$					

Table 3. Risk numbers for drawbacks in ventilation system case study.

Part of system	Drawback	Severity S	Probability of detection Pd	Probability of occurrence Po	Risk number RPN
inlet grid (at roof)	smell	5	6	4	120
inlet chamber	microbes	4	8	8	256
prefilter (EU5)	microbes	4	8	7	224
	VOCs	5	8	6	240
	fibres	2	9	4	72
	particles	7	9	8	504
	leakage	4	4	4	64
heat recovery device	not evaluated				
heating coil	VOCs	5	8	3	120
cooling coil	microbes	5	8	2	80
supply air fan	VOCs	5	8	3	120
fine filter (EU8)	microbes	8	8	5	320
	VOCs	5	8	5	200
	fibres	4	9	2	72
	particles	7	8	4	224
	leakage	8	4	2	64
supply air duct	microbes	8	8	7	448
	VOCs	5	8	5	200
	particles	7	8	6	336
control dampers	not evaluated				
material of sound damper	microbes	8	8	5	320
	fibres	4	8	8	256
Air inlet valves	particles	8	4	8	256

Case study 3 - evaluation of the effects of the quality of building on energy consumption

The third case deals with evaluation of the effects of the quality of building on energy consumption. The quality of structures and HVAC is evaluated from point of view of effects on energy consumption. Case simulations and sensitivity analysis can be added to risk evaluation procedure. The energy performance of the building is depending strongly on the efficiency of the ventilation systems. The example shows the influencing factors and ways to reduce heating energy consumption. Three factors are considered: 1) air flow rates and running times of ventilation, 2) heat recovery of ventilation and 3) air tightness of the building envelope. This case is evaluating the risks when taking the responsibility of energy consumption of the building service system.

Figure 5 shows an energy balance of a building in cold climate conditions. In this example the biggest losses are caused by ventilation. If building owner or facility manager has set targets for energy consumption, they must have possibility to monitor the distribution of energy. By generating energy balance chart (e.g. Sankey-diagram) it is possible to observe, which are the main factors influencing on heat and electricity usage.

Even in well-performing buildings the energy consumption may vary within relatively wide range. The estimated consumption of district heating (DH) of a new school in Southern Finland was 26,3 kWh/m³/year (real building, calculations based on Finnish Building Code, part D5). The biggest component of heat losses is ventilation 25,7 kWh/m³. Changing the operation time from daily 12 hours to 10 hours decreases the heating energy consumption to 23,1 kWh/m³. Increasing the efficiency of heat recovery device from 50 % to 60 % decreases the heating energy consumption to 20,1 kWh/m³, and finally improving the air tightness of the building from 0,1 change/hour to 0,05 change/hour decreases the heating energy consumption to estimation 18,1 kWh/m³. This decrease of 32 % in heating energy consumption (DH) is

realised by optimising operation hours, selecting more energy efficient heat recovery device and realising the air-tight building. This case simulation is showing the influence and risks of these factors on heating energy consumption ('severity' is presented as energy consumption). The most important influencing factors should be analysed in a systematic way showing the influence of the factor on consumption. This analysis could be presented in form of table or Sankey-diagram including basic value and sensitivity to influencing factors (e.g. heat recovery device has influence $0,3 \text{ kWh/m}^3/1 \%$ change in efficiency).

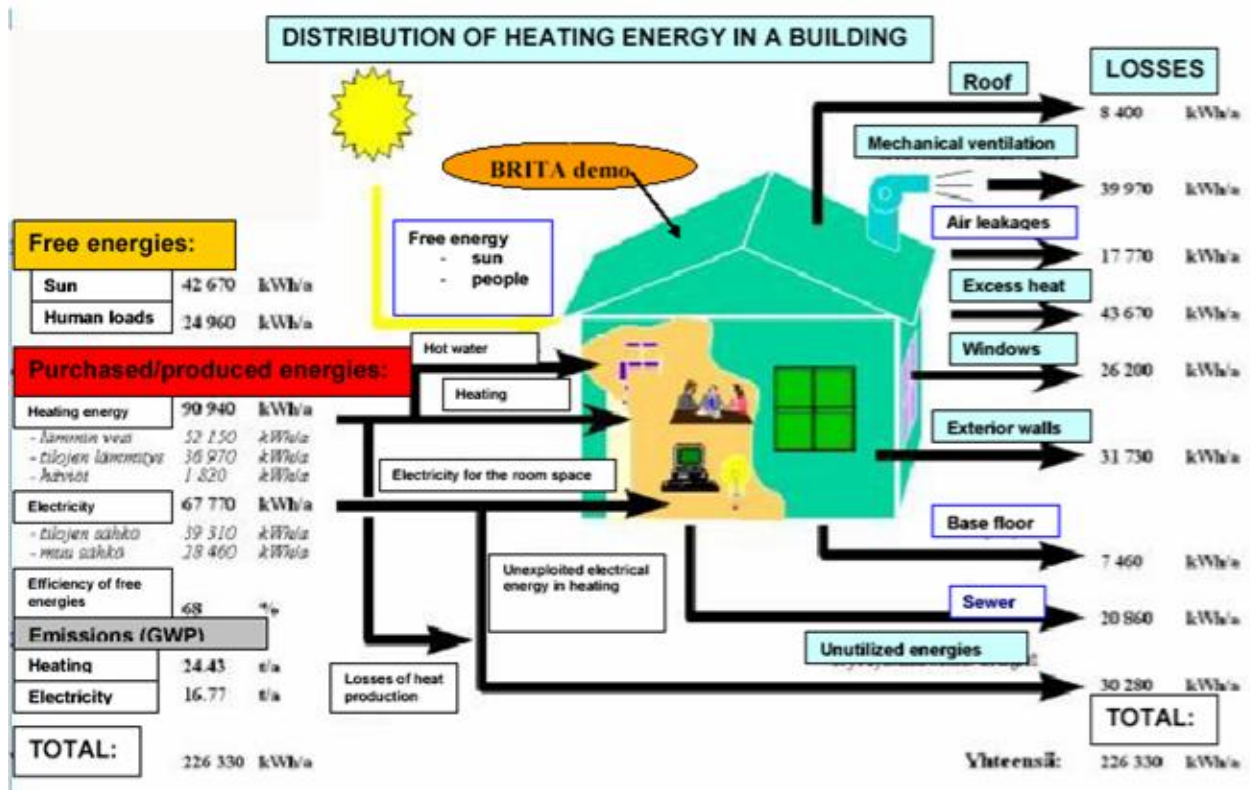


Figure 5. An example of the energy balance of the building.

DISCUSSION

The systematical risk management methods and applications are sophisticated ways to evaluate and manage the risks during the life-cycle of the building and the associated technical systems. Three presented cases show possibilities to utilize methods in pre-design, design and operation phases. The risk table approach is a checking-list type of method, which is a good tool for assessment of all the possible risks existing in the building project. The risk table can be used as part of invitation for bids, as annex of contract documents or as check-list during the negotiations. The risk number approach is a simple tool for pointing the drawbacks or risk components of the complicated systems. The strength of the risk number approach is evaluation of drawbacks based on three sub-factors (severity, probability of detection and probability of occurrence), which all are evaluated separately, based on experts opinion or measured values. This is giving more confidence on evaluation. The simulation tools can be used as part of risk assessment, when evaluating the effects of the quality of the building structures and HVAC components on the energy consumption and costs.

ACKNOWLEDGEMENT

Financial support from TEKES buildings service program CUBE and participating companies is gratefully acknowledged. Results of projects CUBENet, Cx/Commissioning and EU/Brita in Pubs are included.

REFERENCES

1. Nykänen, V, Paiho, S, Pietiläinen J, et al. Systematic process for commissioning building energy performance and indoor conditions. Will be published in Clima2007 conference, June 2007.
2. Kauppinen, T, Kovanen, K, Nykänen, V, et al. 2007. ToVa-käsikirja (Finnish Commissioning Guidebook). Rakennuksen toimivuuden varmistaminen energiatehokkuuden ja sisäilmaston kannalta. Espoo:VTT. (VTT Research Notes xx – Manuscript).
3. Immonen I. Talotekniikan elinkaaritoimitusten riskit ja menestystekijät. DI-työ, 2006. TKK Konetekniikan osasto, teollisuustalous. 103 s + liitteet 8 s.
4. Li Bing, A, Akitoye, P.J, Edwards, C, Hardcastle, The allocation of risk in PPP/PFI construction projects in the UK, International Journal of Project Management 23 (2005), pp. 25-35.
5. Räsänen R. Kiinteistöpalvelusopimukset elinkaarihankkeissa. Liiketaloudelliset riskit ja niiden estäminen. DI-työ 2004.
6. IEC Standard, Publ. No.812, 1985, "Analysis Techniques for System Reliability – Procedure for Failure Mode and Effect Analysis (FMEA).
7. Xueqing Zhang, Critical Success Factors for Public-Private Partnerships in Infrastructure Development, Journal of Construction engineering and management ASCE/January 2005, 12 p.
8. Delivering the PPP promise, A review of PPP issues and activity, PriceWaterhouseCoopers, 84 p.
9. Lahdenperä, P, Nykänen, V & Rintala, K. 2005. Design-Build-Operate. Alternative modes of operation for accommodation services. Espoo, VTT. 56 s. VTT Research Notes; 2315. ISBN 951-38-6749-8; 951-38-6750-1 .<http://www.vtt.fi/inf/pdf/tiedotteet/2005/T2315.pdf>
10. Lahdenperä, P & Rintala, K. Thoughts on DBFO. A study of UK accommodation service procurement for the benefit of Finnish practice. VTT Research Notes 2192. 2003. 52 p. + app. 2 p.
11. Heimonen, I, Mervi Himanen, M & Junnonen, J-M, et. al. Life-cycle models in building service technology. Will be published in Clima2007 conference, June 2007.
12. Kolari S. et. al.. Ilmanvaihdon hygieniariskien hallinta (Management of risk in hygiene of ventilation air). Unpublished presentation of VTT project. 10 slides.