



Facility management

Building commissioning, operation and maintenance manuals and the use of building automation as a tool for facility management

Timo Kauppinen

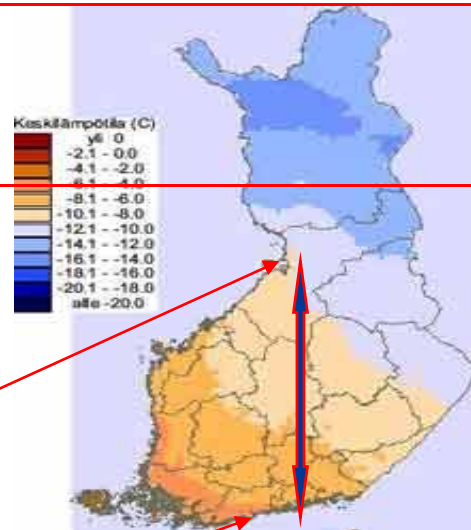
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Building performance and energy efficiency



Oulu

(Degree day number 5170) (S17)



60 Latitude

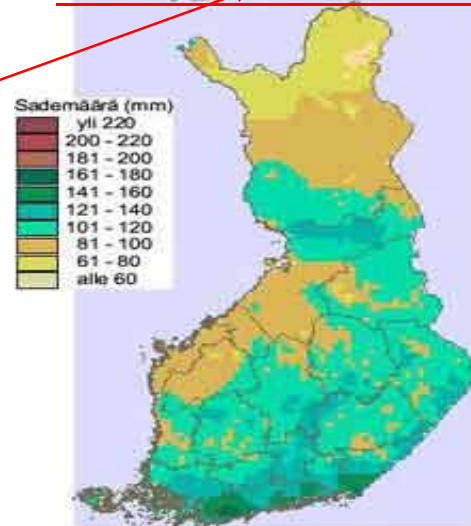
ARCTIC CIRCLE

600 km =
375 miles

50 Latitude



Helsinki



The presentation is based on:

- WP 3 Quality control toolbox

The contents of the above mentioned WPs are available at <http://www.brita-in-pubs.com/internal/index.htm>

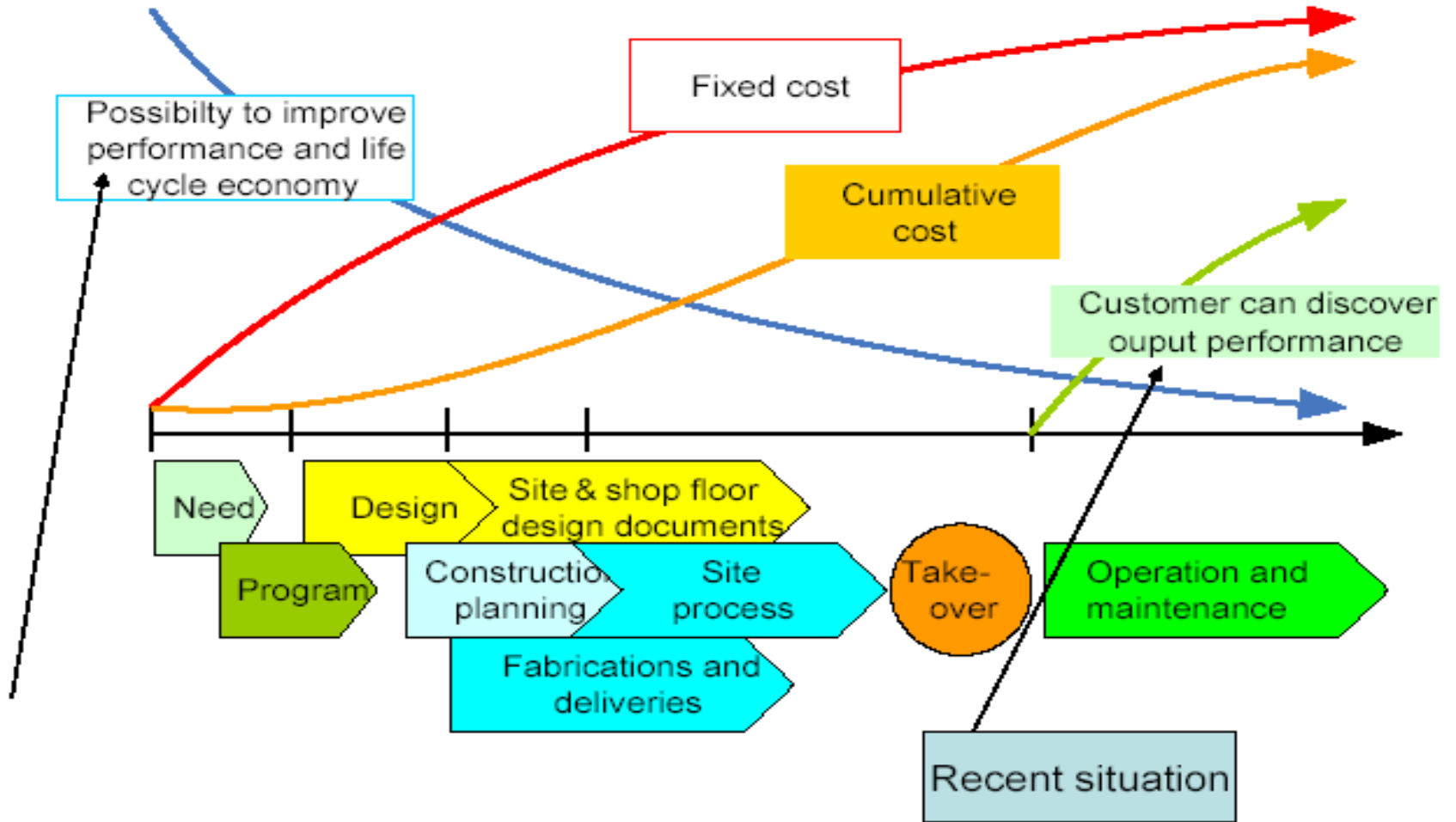
BRITA-in-PuBs website:

- The BRITA-in-PuBs **website/homepage** is a common website with national sub-websites. The website will function as the place for inspiration and will be the central element in disseminating the technical information. The website holds and presents the results of the project:
- BRITA information tool (BIT)
- BRITA quality control tool-box
- BRITA design guidelines
- BRITA report on financial schemes
- The demonstration projects

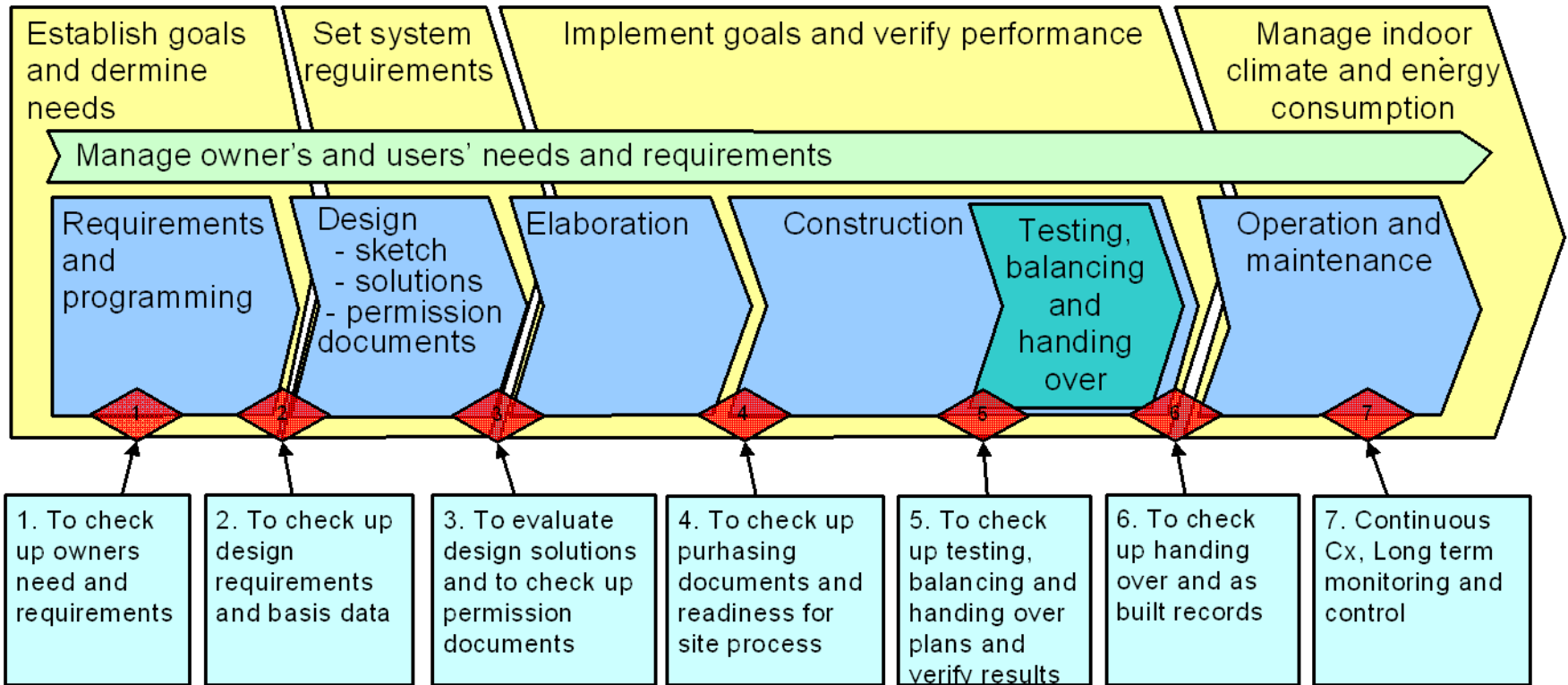
Building commissioning, operation and maintenance manuals and the use of building automation as a tool for facility management

- The content of this presentation
 - *1. Quality Control Toolbox – Building Commissioning*
 - *2. Operation and Maintenance Manuals*
 - *3. Building Automation – a tool for facility management*

Building performance and energy efficiency



Commissioning



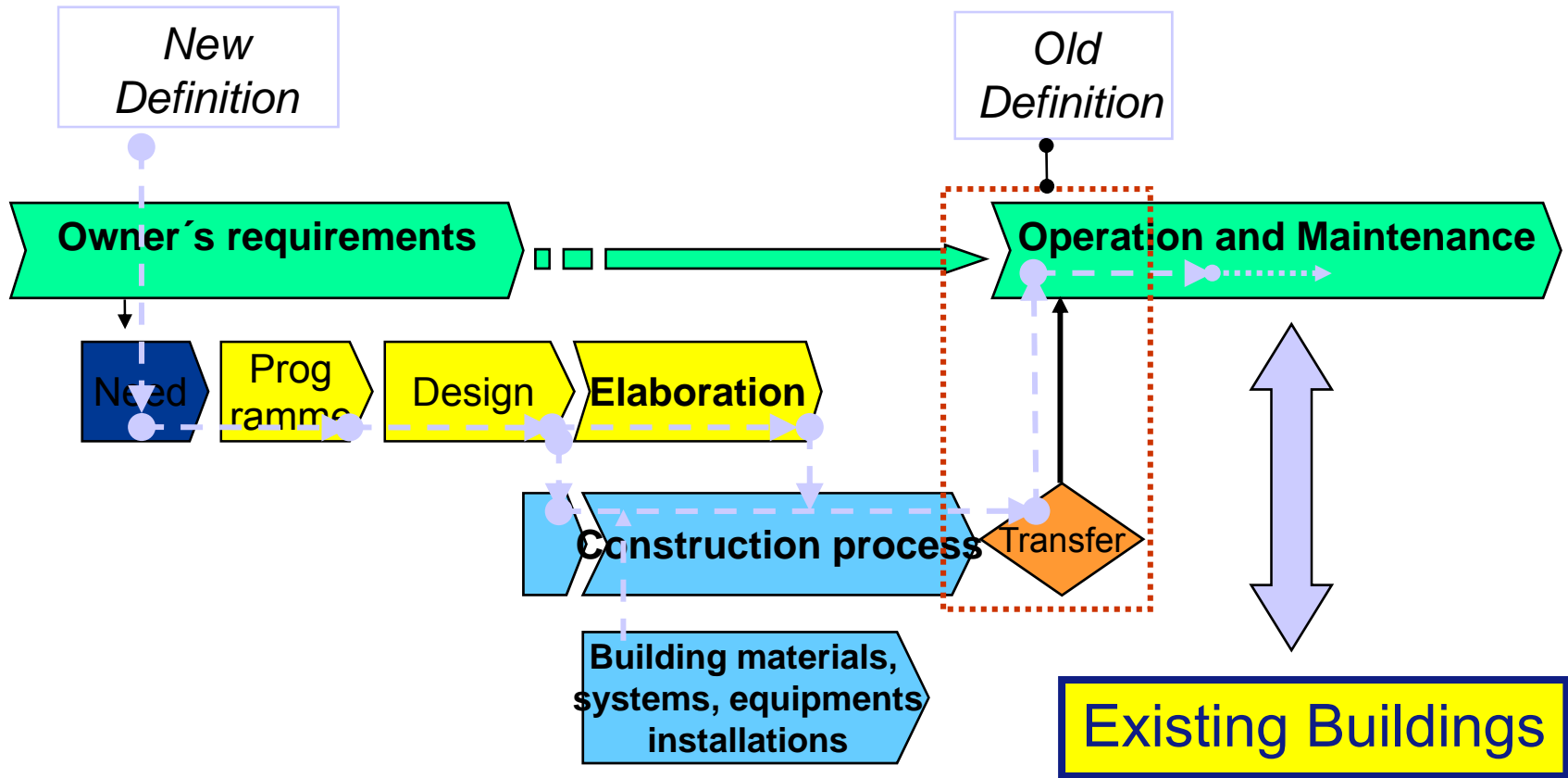
Topics

- Cx definition
- Cx aims
- Cx process
- Performance and energy efficiency risks
- Cx plans
- Organizing Cx
- Cx and quality management
- Cx profitability
- Cx principles

Commissioning Cx (ToVa)

- Cx (ToVa) process should be launched as early as in programming phase
 - To check that:
 - Owner's and users' needs and requirements are clearly documented
 - Indoor and energy performance requirements are included to owner's program
 - To audit that design solutions and installation outputs meet given requirements
 - To verify that the building satisfy given indoor and energy requirements in use
- Cx is included as a part of routine facility management process over building life cycle

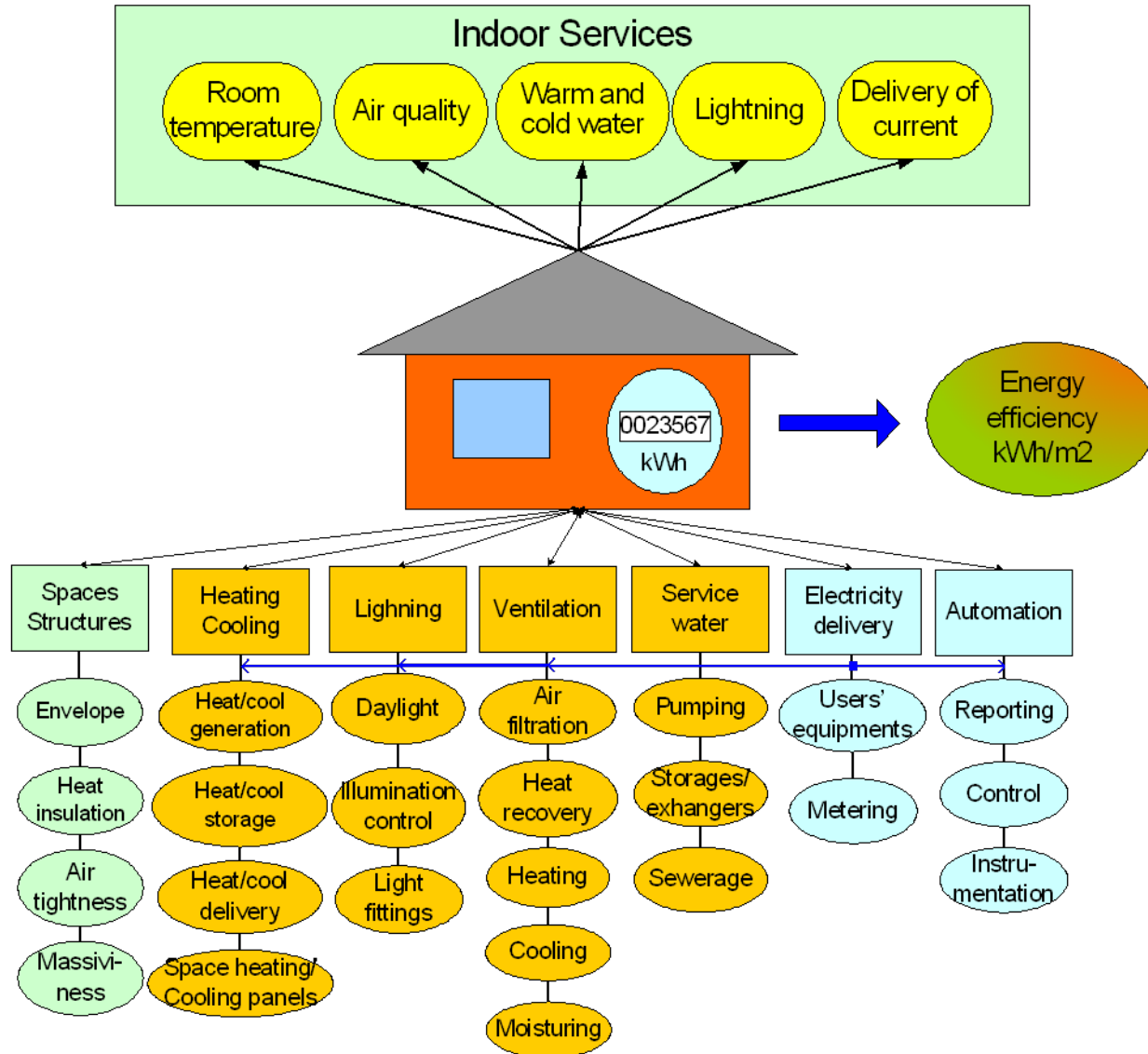
Cx definition in Finland



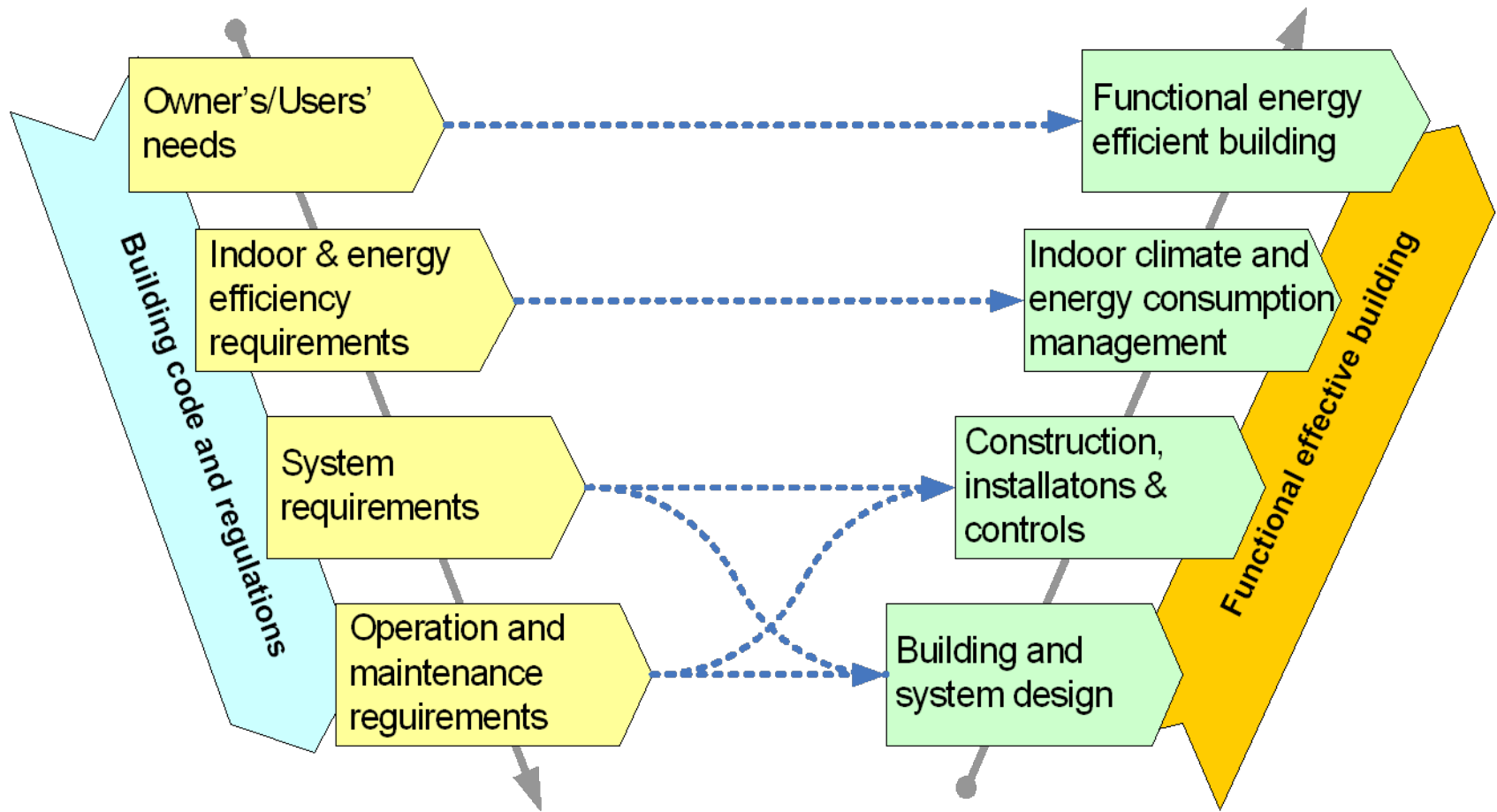
The goals of Cx activities

- To provide safety, healthy and comfortable spaces for living and business
- To improve design quality by more effective feedback
- To improve energy efficiency of buildings and building systems
- To decrease operation costs
- To improve operation and maintenance personnel introductory briefing and training
- To improve documentation during the building life-cycle
- To meet customer needs and expectations and satisfy customer requirements

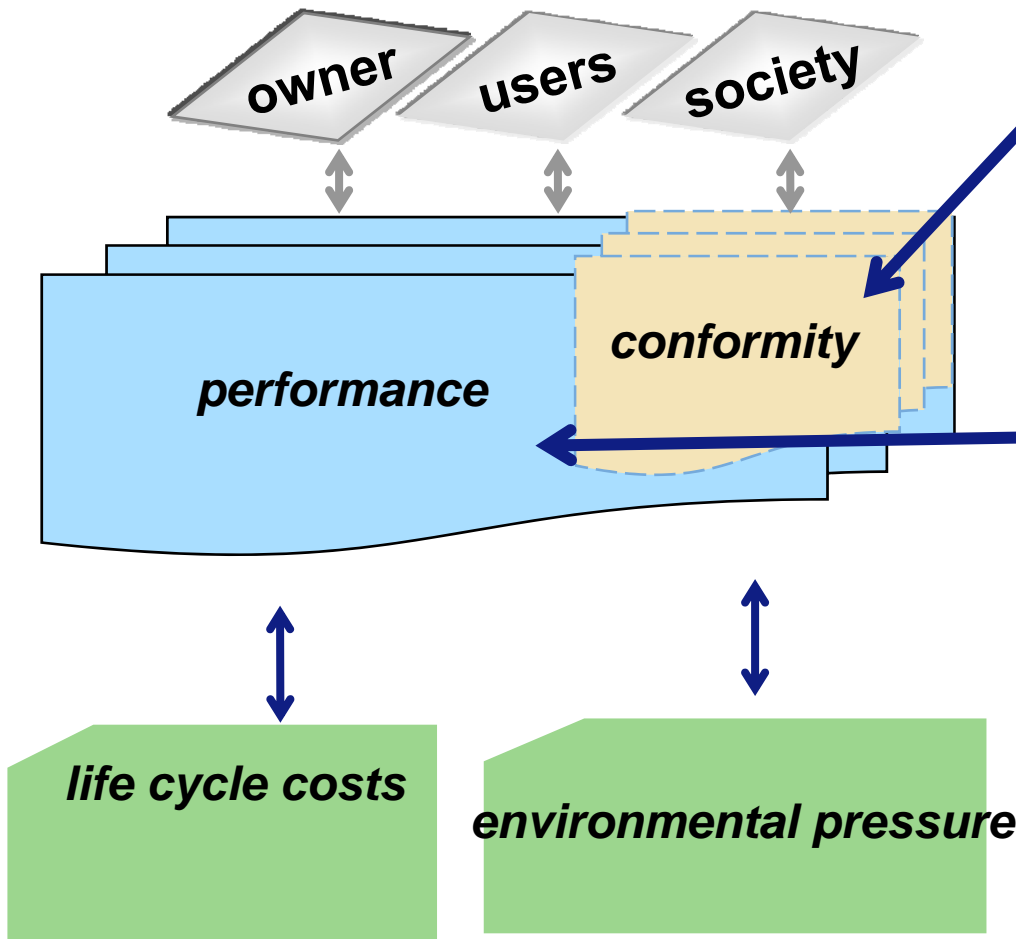
Components of indoor climate and energy efficiency



Management of needs and requirements during building process



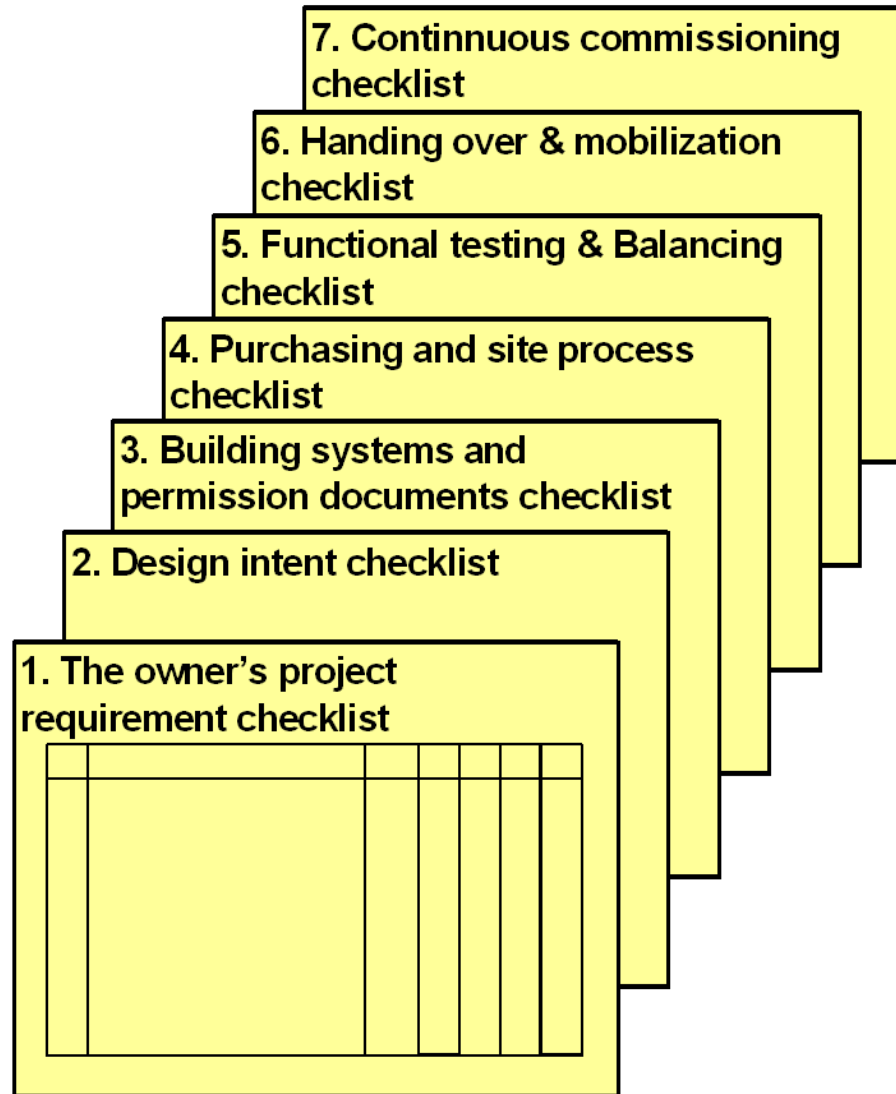
FRAME FOR PERFORMANCE SPECIFICATIONS



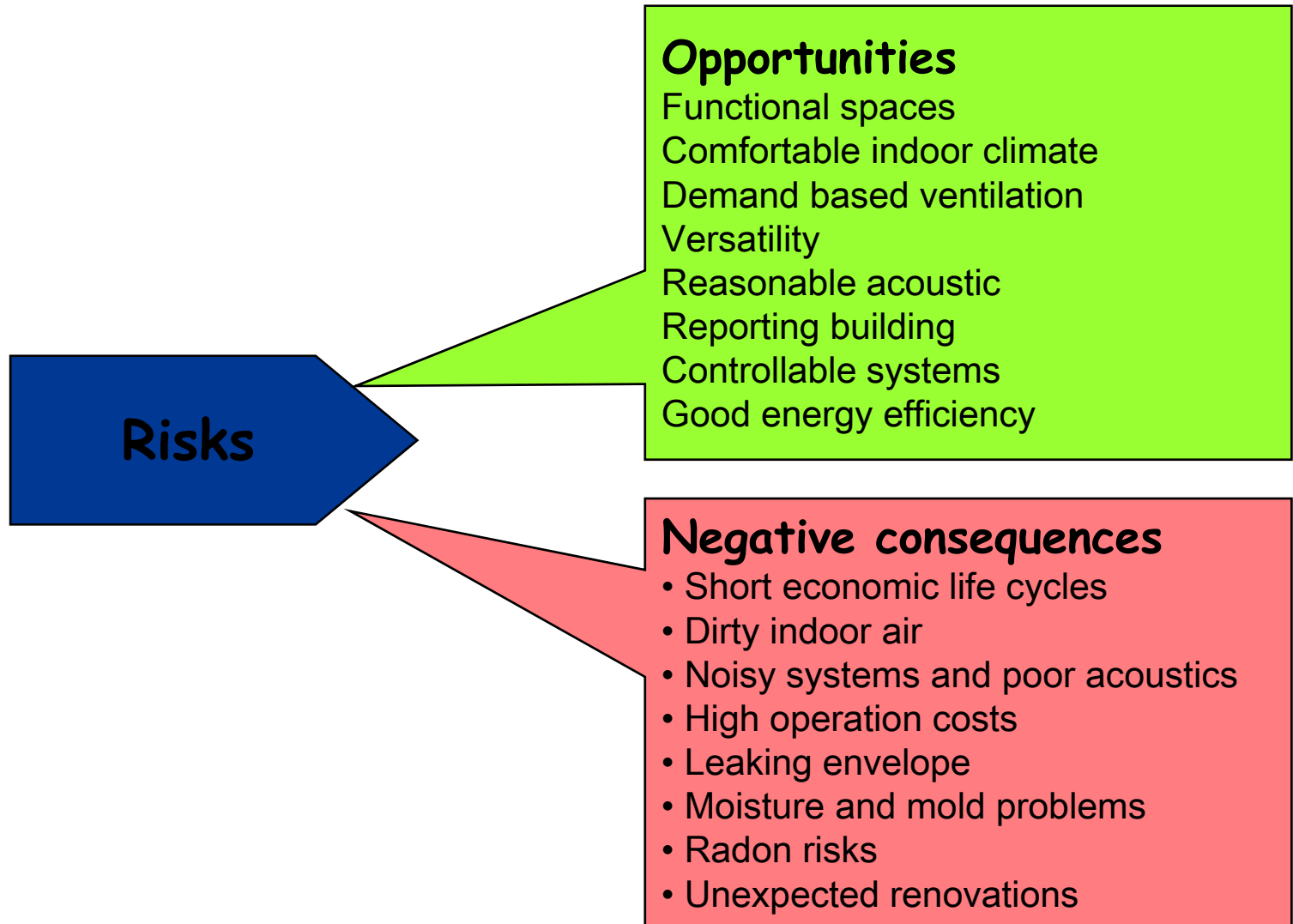
- A CONFORMITY** VTT ProP®
- A1 LOCATION**
 - A1.1 Site features
 - A1.2 Traffic services
 - A1.3 Environmental impacts
- A2 SPACES**
- A3 SERVICES**

- B FUNCTIONALITY**
- B1 INDOOR**
 - B1.1 Indoor climate
 - B1.2 Sound
 - B1.3 Illumination
 - B1.4 Vibration
- B2 LIFE CYCLE AND DAMAGE RISKS**
- B3 MODIFIABILITY**
- B4 SAFETY AND SECURITY**
 - B4.1 Structural safety
 - B4.2 Fire safety
 - B4.3 Operation safety
 - B4.4 Break-in-security
 - B4.5 Natural catastrophes
- B5 PLEASANT ENVIRONMENT**
- B6 ACCESSIBILITY**
- B7 USABILITY**

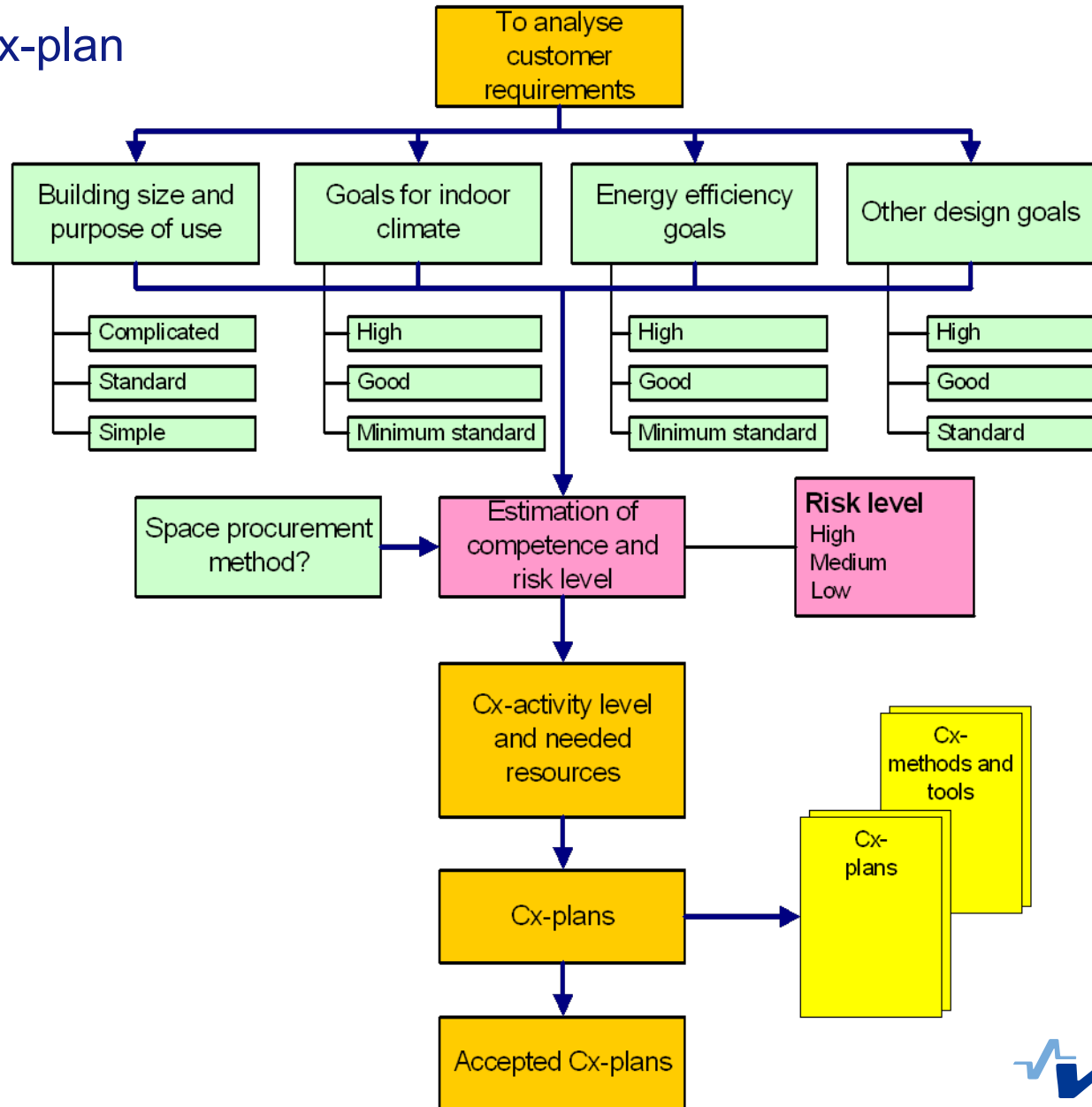
Checklists for commissioning manager



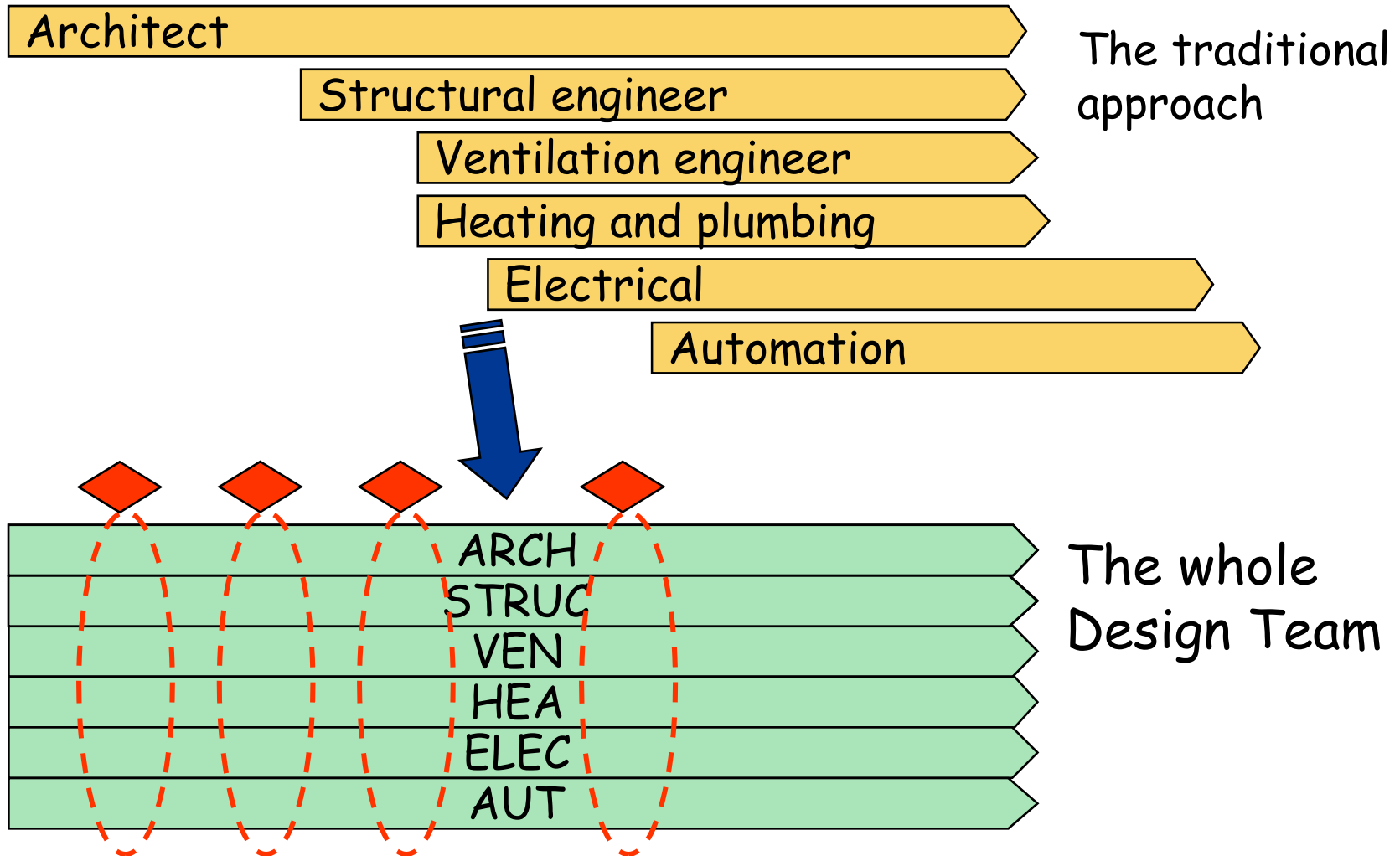
Risk range – positive and negative

























To set up a Cx-plan



To start design team as a whole



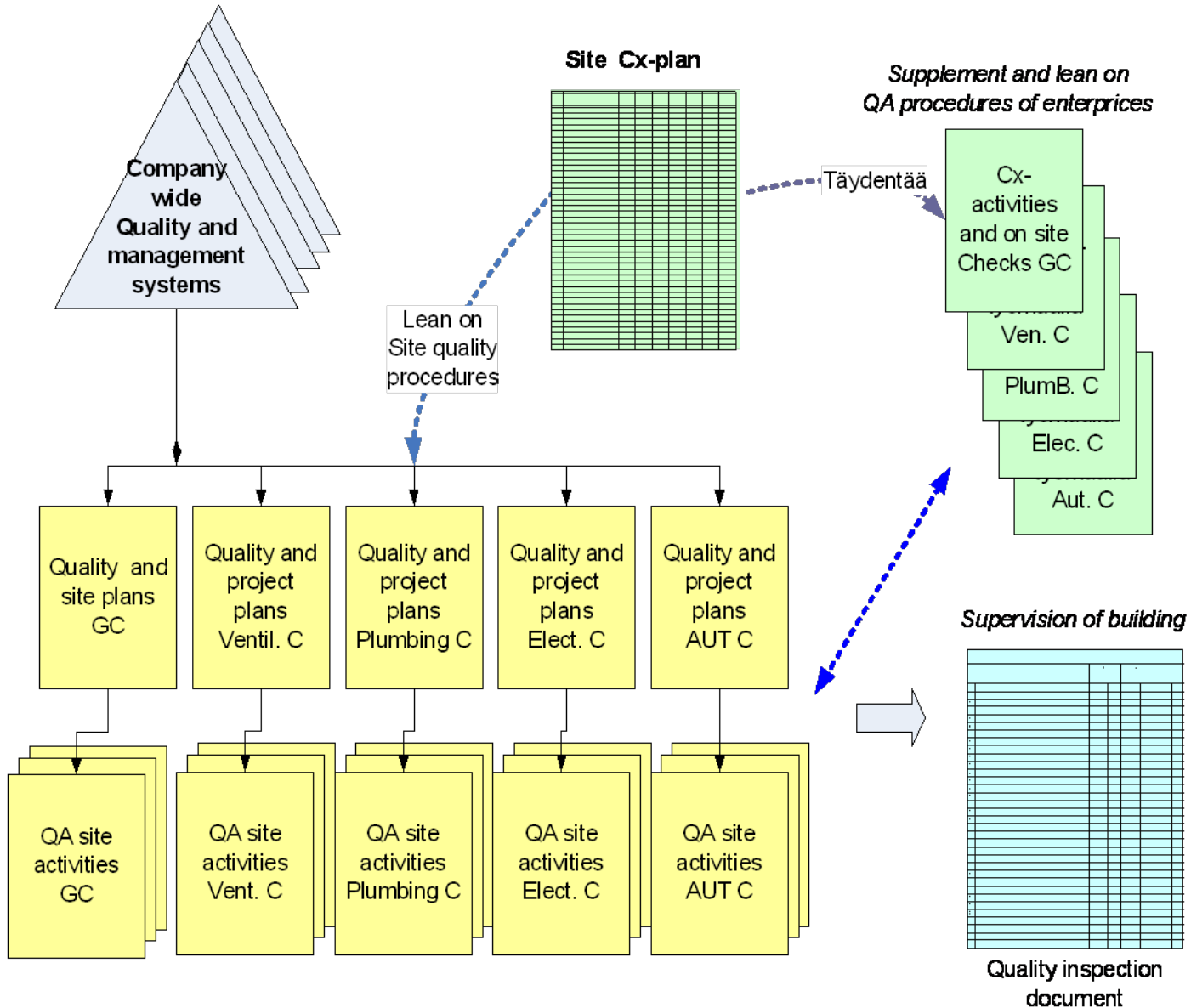
Options for Cx team

| Cx manager  Strong role  Participation  | Small DBB project | DBB project | DBB project | Design & Build project | Design & Build project | DBOM project |
|--|---|---|---|---|---|---|
| Principal designer |  |  |  |  |  |  |
| Independent Cx consult (ToVa) | | | |  |  |  |
| Owner's agent |  |  |  |  |  |  |
| General contractor's agent |  |  |  |  |  |  |
| HVAC designer |  |  |  |  |  |  |
| Electrical designer |  |  |  |  |  |  |
| Construction designer |  |  |  |  |  |  |
| Automation designer |  |  |  |  |  |  |
| FM service engineer | |  |  | | |  |
| Supervisor |  |  |  |  |  |  |
| HEPAC contractor |  |  |  |  |  |  |

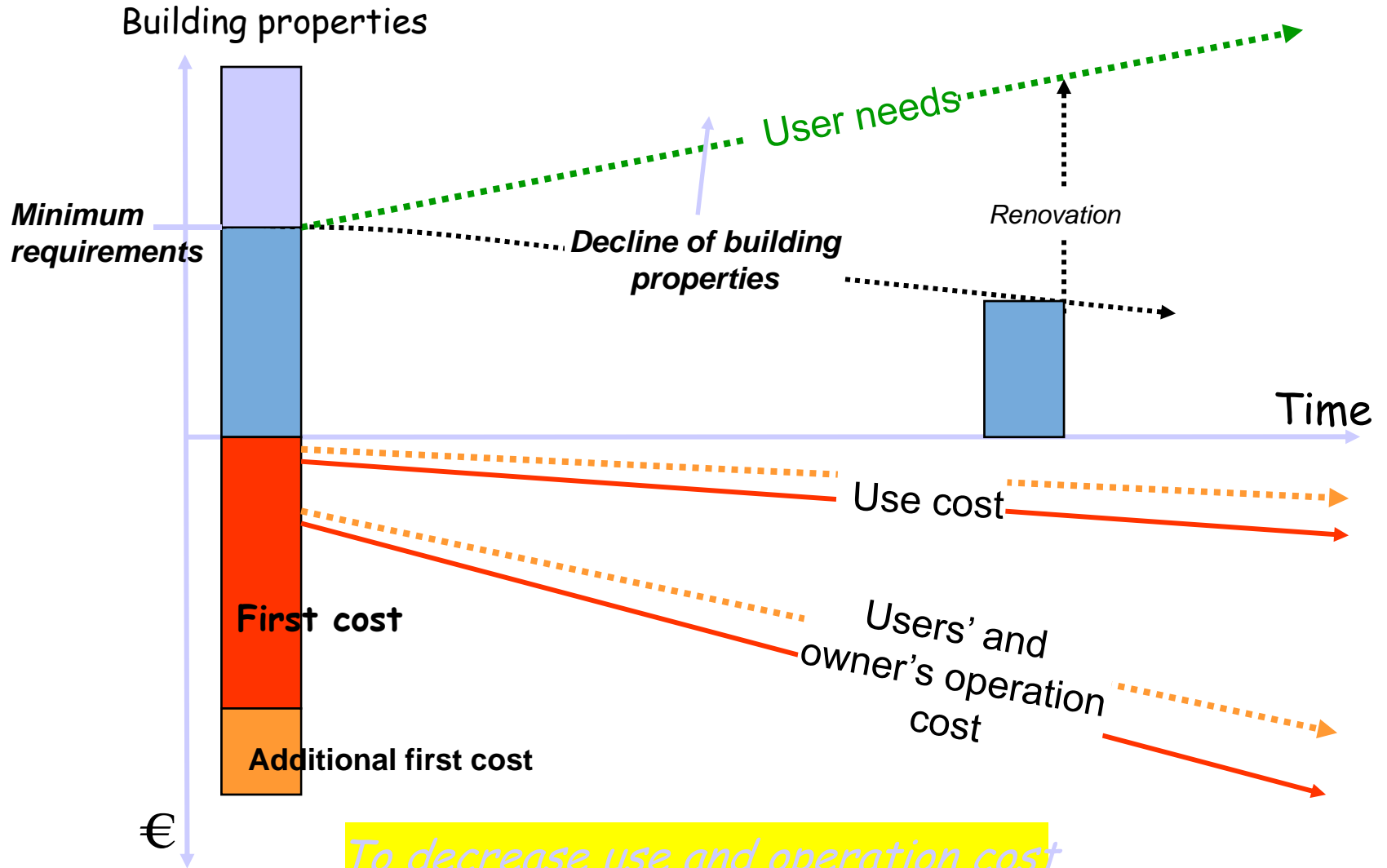
Task responsibility matrix for design phase (example)

| | Cx manger | Principal designer | ARCH | HVAC Design | Electr. design | Autom. design | Owner's agent | Project Manager C. |
|--|-----------|--------------------|------|-------------|----------------|---------------|---------------|--------------------|
| 1 Cx planning and management | | | | | | | | |
| • Cx planning | ◆ | | | | | | | |
| • To check and comment Cx plans | ◆ | X | | | | | X | |
| • Cx meetings | ◆ | X | | | | | | |
| • Cx activity control | ◆ | X | | | | | X | |
| 2 Cx design reviews | | | | | | | | |
| • To check design solutions | ◆ | ◆ | | | | | | |
| • Corrective actions | | X | X | X | X | X | X | |
| 3 Documentation of design goals | | | | | | | | |
| • Format for design goals | ◆ | ◆ | | | | | | |
| • Design goals for building systems | | X | X | X | X | X | X | |
| • Plans for O&M manuals | ◆ | X | | X | X | X | X | |
| • To check and accept design goals | ◆ | ◆ | X | | | | X | |
| • Corrective actions | | | X | X | X | X | | |
| 4 Cx plans for site process | | | | | | | | |
| • Cx site plan | ◆ | | | x | x | x | | X |

Cx ↔ quality assurance procedures



Cx goals and value for money



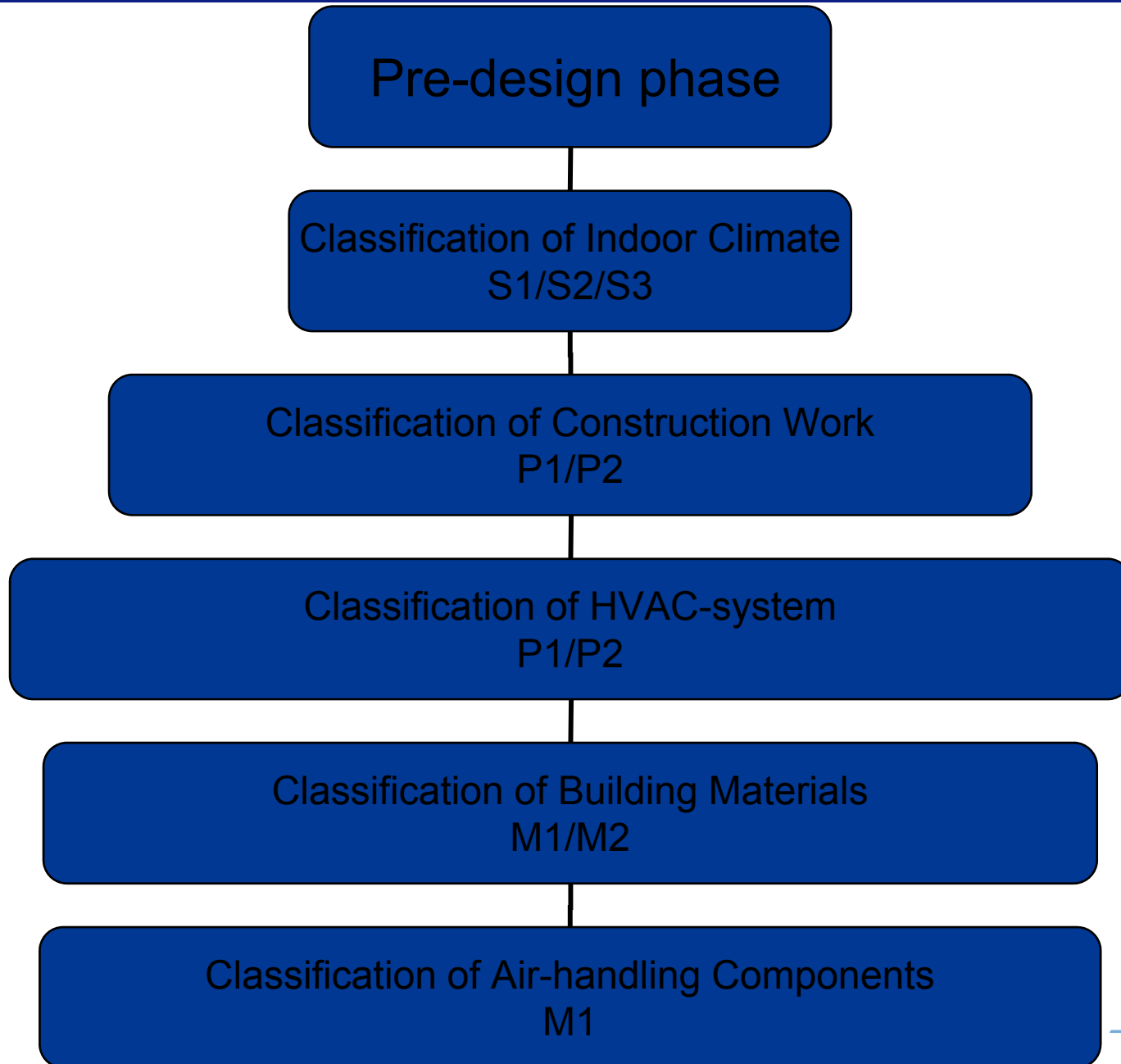
*To decrease use and operation cost
To increase users' output and profit*

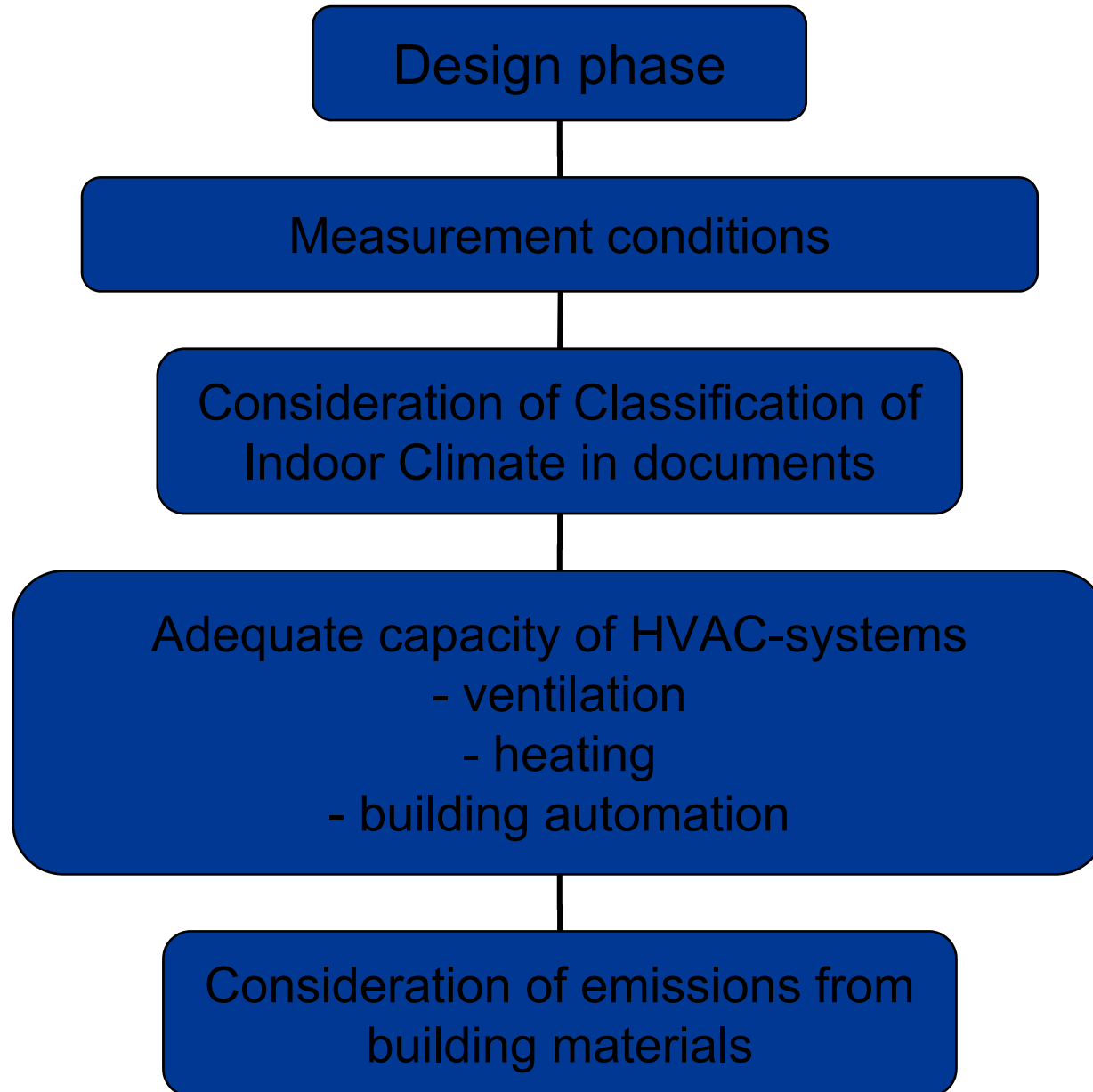
Principles for Cx-activities

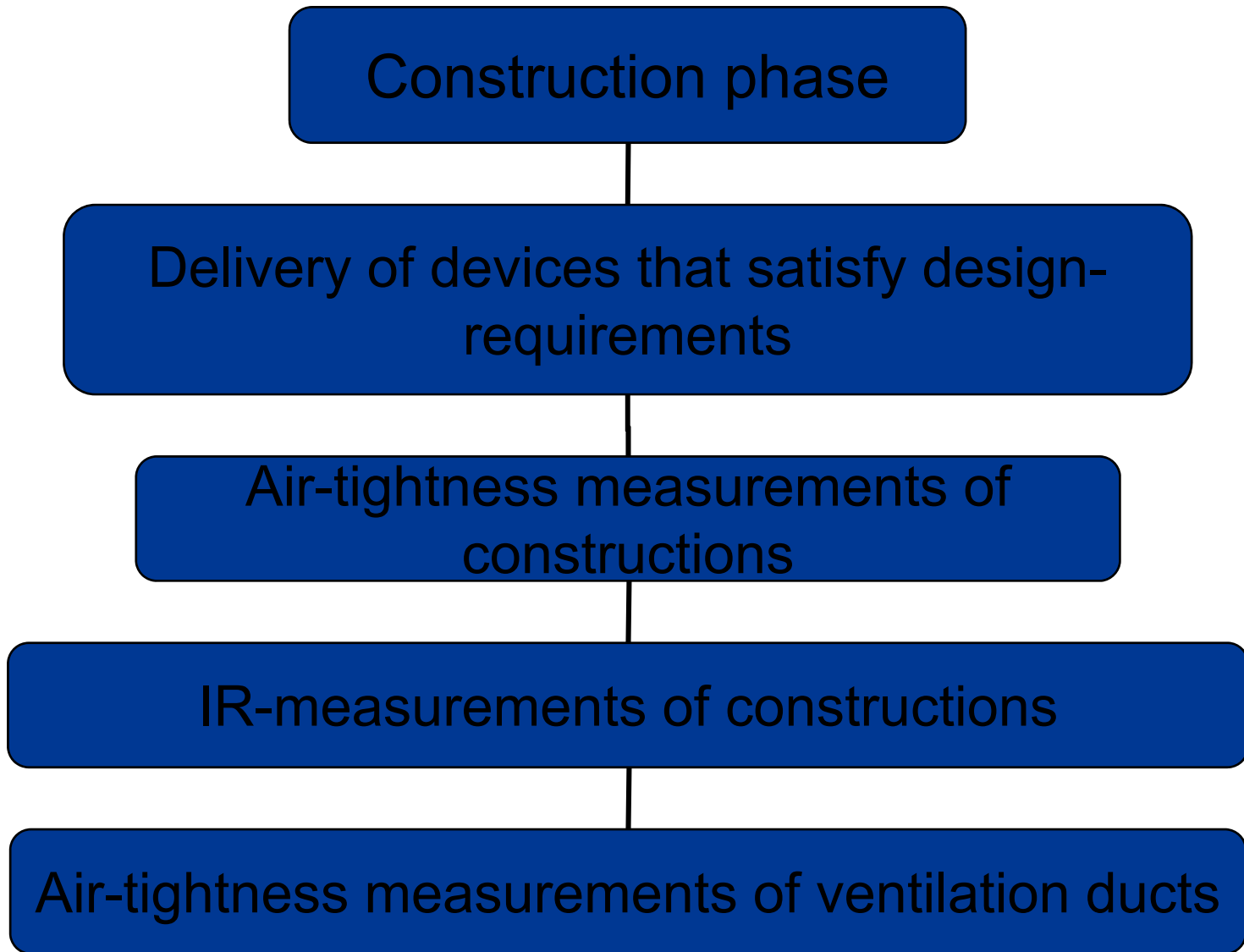
- **Cx manager**
 - Is responsible for implementation of indoor climate and energy efficiency goals
 - Plans goals and tasks for Cx process
 - Checks together with principal designer owner's goals and design goals
 - In large projects Cx team may be constructed of several professionals
 - In small and simple projects Cx manger could be for example HVAC designer
- **To start the whole design team before design phase**
- **System integration**
 - The same building systems produce good indoor climate and energy efficiency
 - The key goal is to integrate different systems during different projects phases that they co-operate well and reliably
- **To start early**
 - Schematic design: energy calculations and indoor climate design
 - Design phase: O&M manuals
 - Plans for metering and power distribution network hierarchy
 - Building automation side by side with the other design disciplines
 - Plans for functional performance testing and balancing
- **Indoor and energy efficiency goals**
 - Include this goals into all design and contract documents

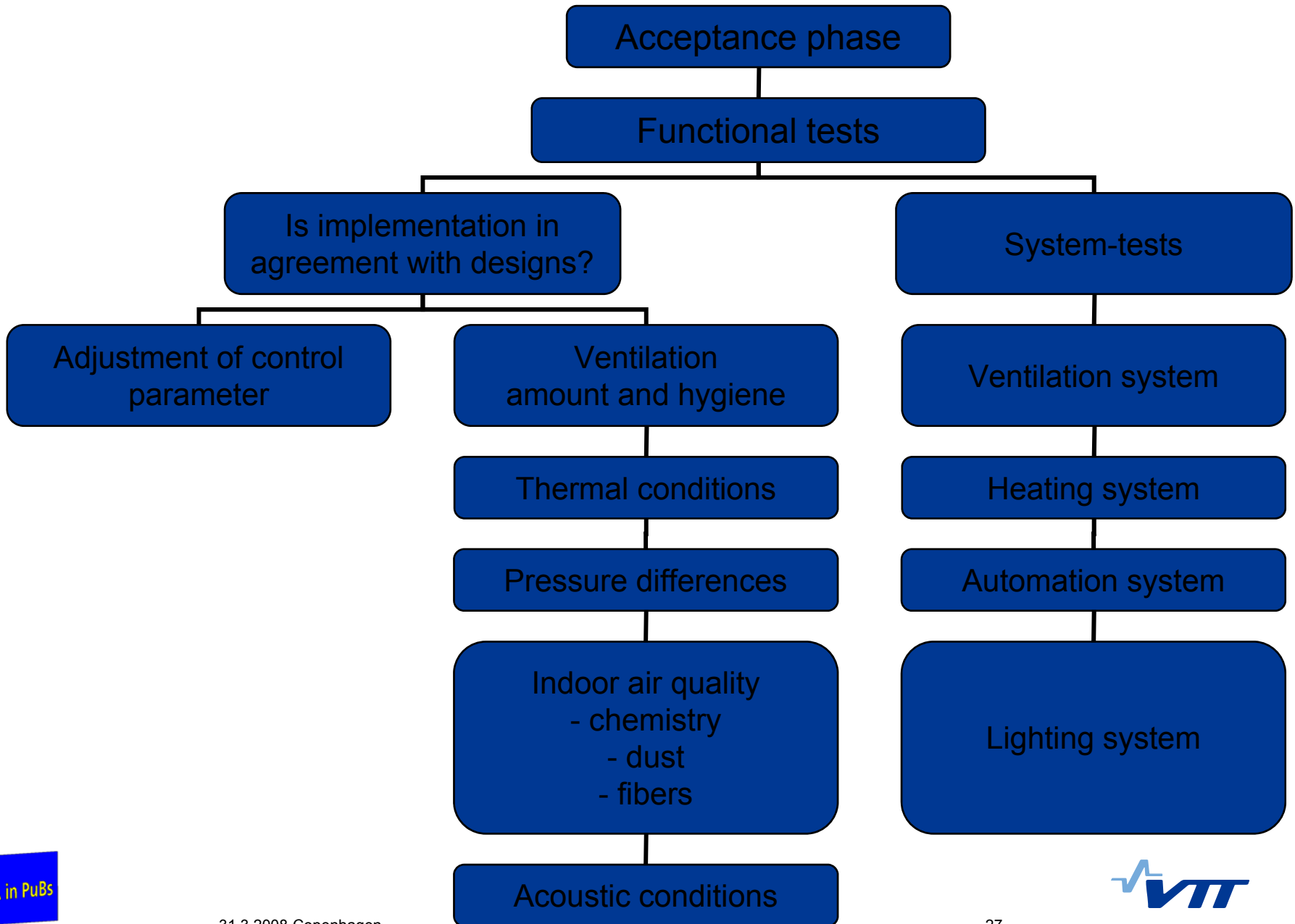
Examples on the procedures

- Structures and building envelope
 - Thermal comfort and IAQ depend on
 - Performance of the building envelope
 - Performance of the ventilation system
 - Performance of the heating system
 - Performance of the automation system
 - Internal loads and external loads (weather, heat sources etc.)









Operation and maintenance phase

Verification of Classification or other norms

Ventilation amount and hygiene

Thermal conditions

Pressure differences

Indoor air quality
- chemistry, microbes
- dust
- fibers

Acoustic conditions

Others measurements

Air-tightness measurements of constructions

IR-measurements of constructions

INDOOR AIR AND CONDITIONS - MEASUREMENTS

Effecting factors:

- Performance of building envelope
- Heating system
- Ventilation system
- Automation system
- Loads, user`s activities
- Weather conditions
- Use

Design of user's requirements

Design

Elaboration

Implementation

TAB - Testing adjusting balancing

Operation and maintenance

The detailed design of possible risk points in building envelopes:

- Window and door structures
- Junctions of the structures
- Lead-ins

- Integration of systems

The performance of structures and systems will be confirmed in the implementation stage and with performance tests



Design of user's
requirements

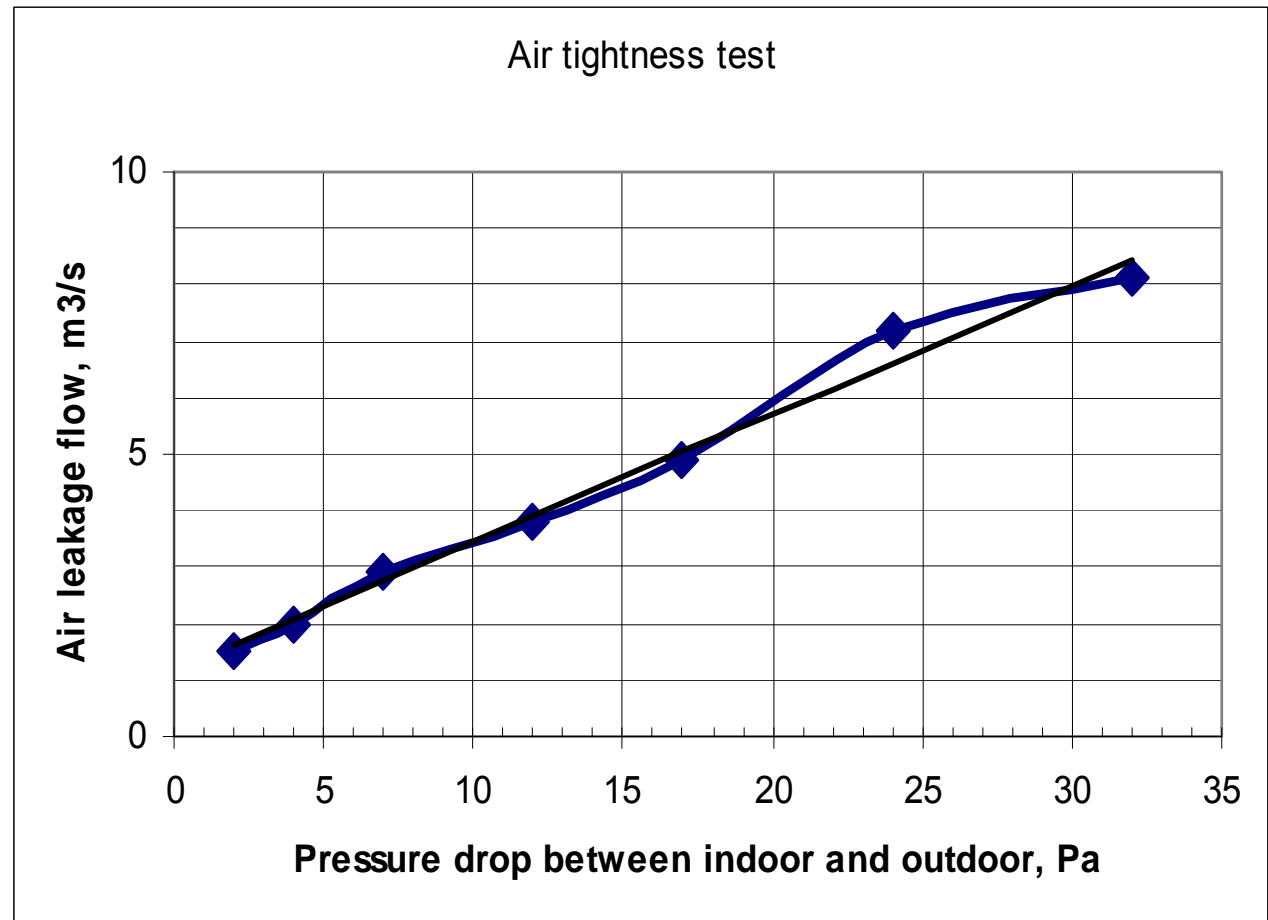
Design

Elaboration

Implementation

TAB - Testing
adjusting
balancingOperation and
maintenance

**Structures and
building envelope :
Air tightness test
(blower-door test) –
with the ventilation
system of the
building**



Design of user's requirements

Design

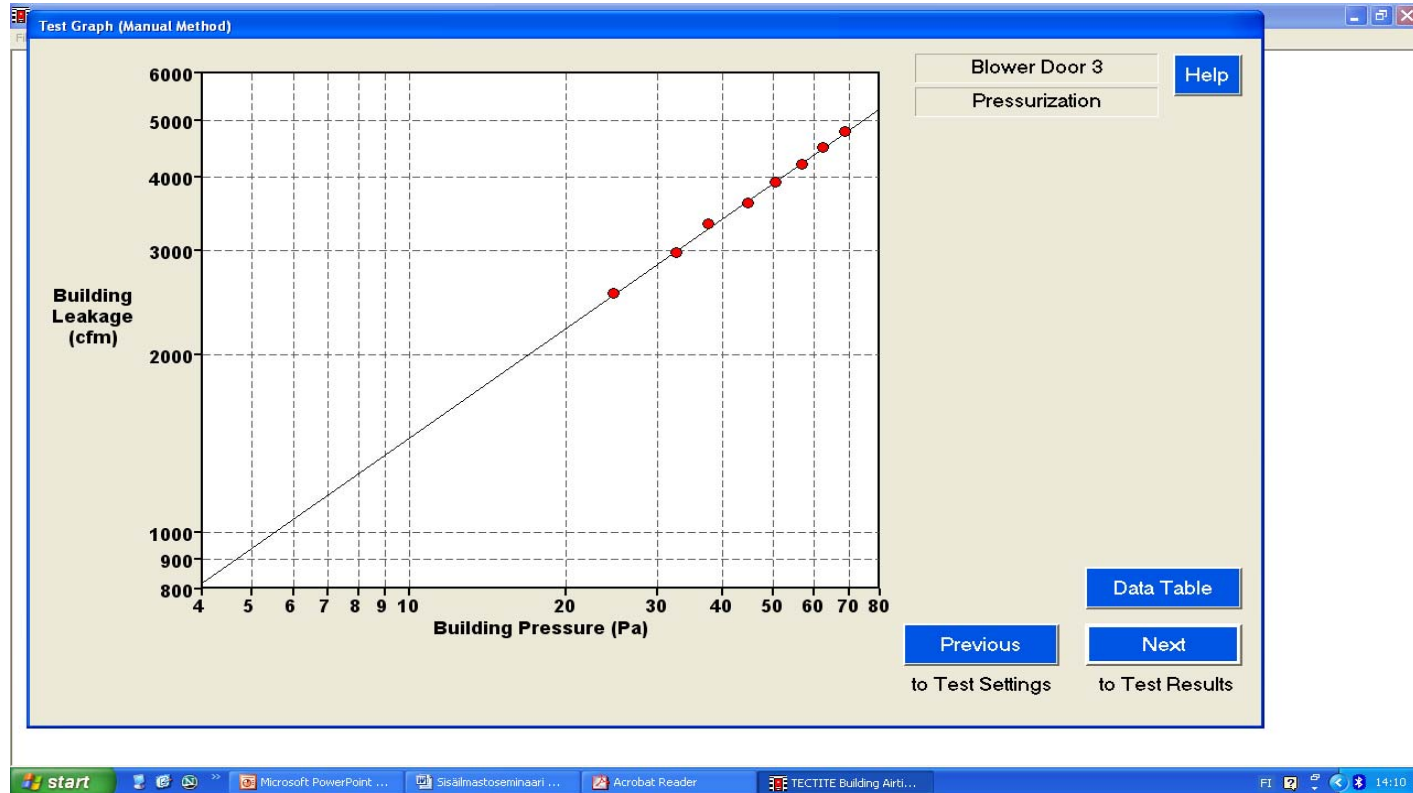
Elaboration

Implementation

TAB - Testing adjusting balancing

Operation and maintenance

**Structures and building envelope:
Air tightness test (blower-door test) – with separate equipment**



Design of user's requirements

Design

Elaboration

Implementation

TAB - Testing adjusting balancing

Operation and maintenance

By thermography one can determine the Temperature distribution of external wall

- Scanning mainly from inside
- Can also be done from outside (details),
- Sufficient temperature drop needed (20 C)
- Steady-state conditions
- Effect of sunshine and wind must be minimized



Design of user's requirements

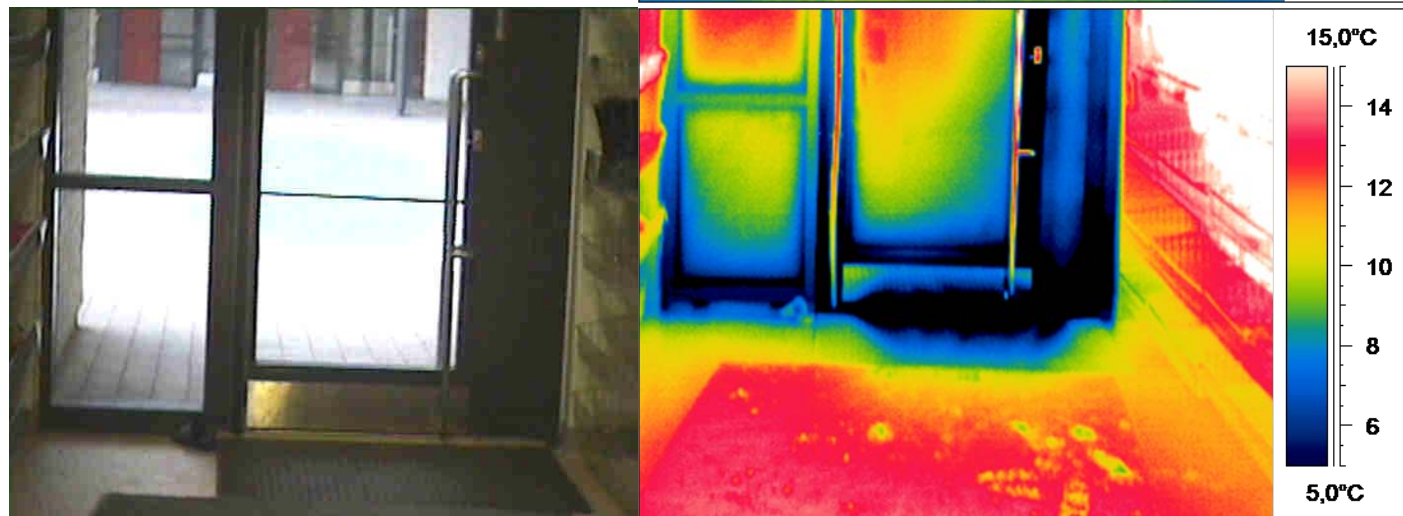
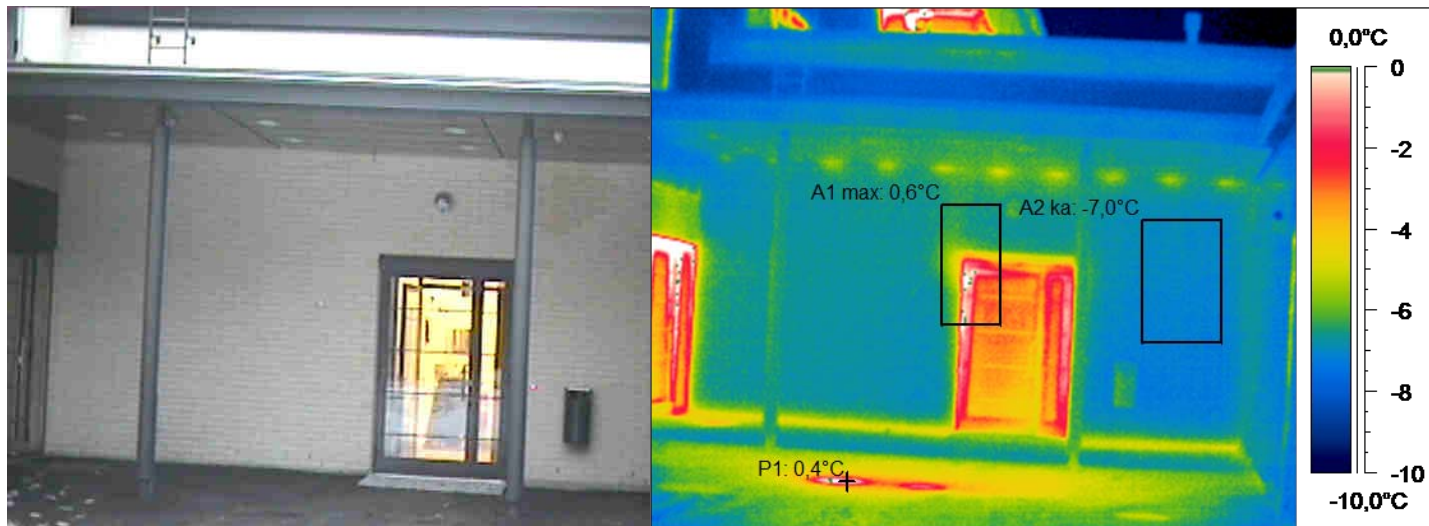
Design

Elaboration

Implementation

TAB - Testing adjusting balancing

Operation and maintenance



Design of user's requirements

Design

Elaboration

Implementation

TAB - Testing
adjusting
balancingOperation and
maintenance

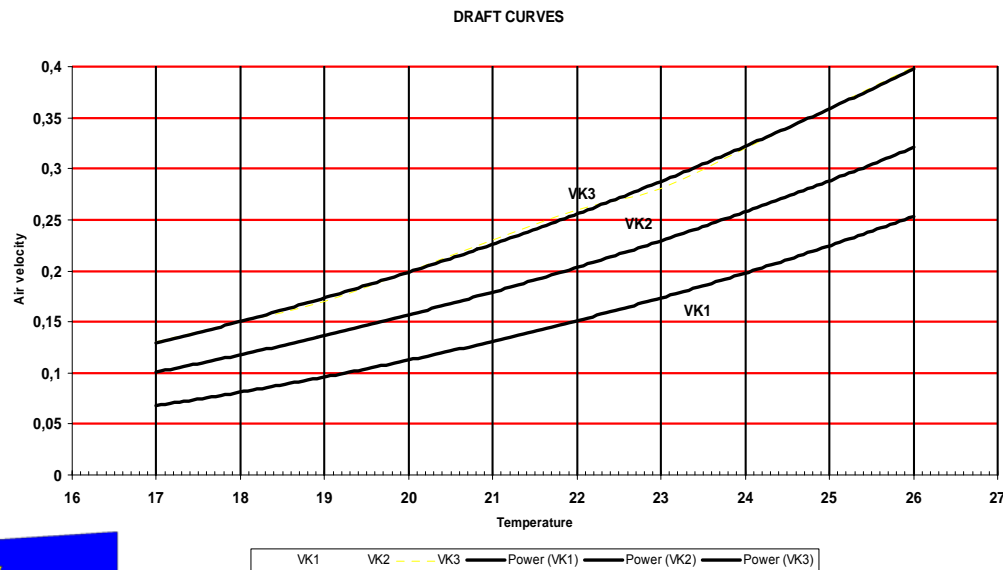
Thermal comfort measurements:

Draft measurements – results must be compared with draft curves

Temperature measurements

Other measurements:

Heat flow measurements by heat flux meters

Operative temperature measurements
(globe temperature)

Design of user`s
requirements

Design

Elaboration

Implementation

TAB - Testing
adjusting
balancing

Operation and
maintenance

- Inquiries for the users
- Monitoring and reporting – building automation system should produce well defined information
- Verification by measurements

Operation and Maintenance Manuals

Maintenance manual can be determined as a file of detailed documents and information that are needed in maintaining a building or a real estate during its lifetime. There are several advantages that can be reached by creating good quality maintenance manual and using it regularly. It helps for instance in:

- Managing facilities and buildings
- Optimizing the service lives of the building elements and HVAC-systems
- Verifying their performance and usability during the service lives
- Optimizing the maintenance and life cycle costs
- Keeping up good indoor climate
- Monitoring energy use
- Reaching the energy consumption targets
- Ensuring security
- Identifying risks
- Taken into account the environmental values

Operation and Maintenance Manuals

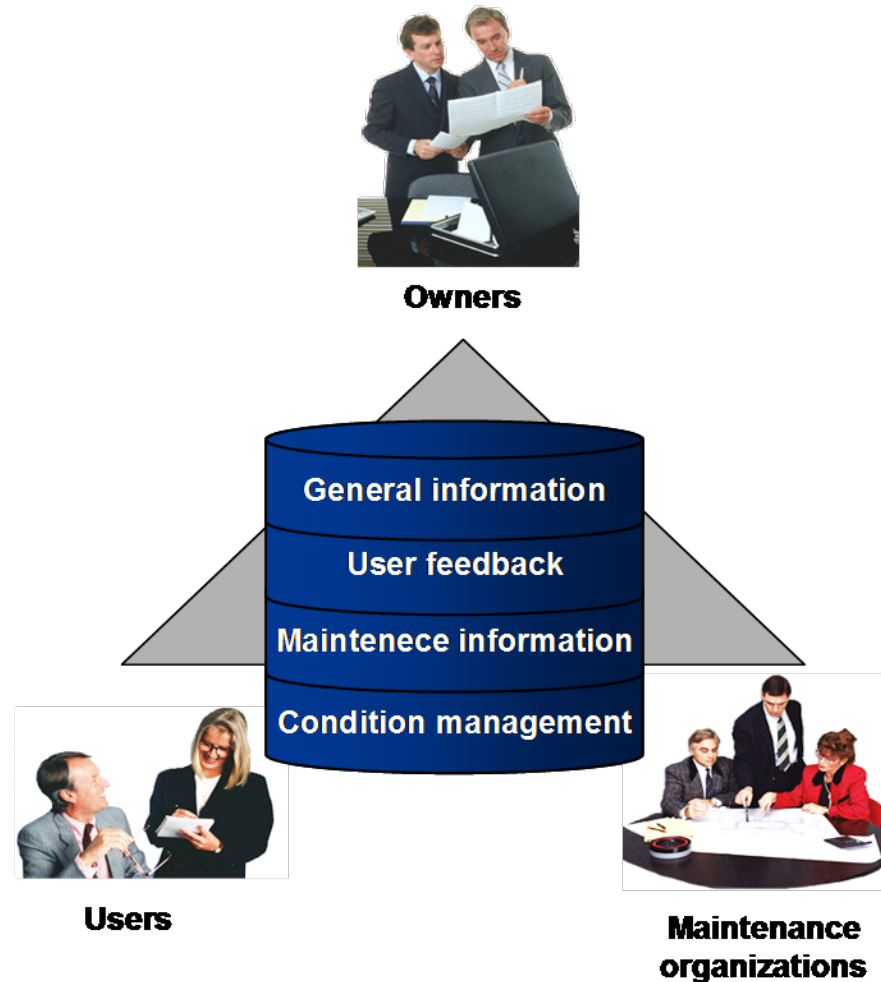
There are many ways to create a successful maintenance manual. These solutions vary from paper versions to modern sophisticated information technology solutions.

Modern software solutions can be divided roughly into three categories:

- stand-alone versions,
- versions used via intranet and
- versions used via internet.

Well organized modern maintenance database can be utilized in real time by building owners, maintenance or service companies and even the end-users. Data available for different interest groups can be determined and restricted (see figure).

Operation and Maintenance Manuals



Operation and Maintenance Manuals

Contents of the operation and maintenance manual

- The execution of the maintenance and operation manual for new or retrofitted buildings should be started in the early designing phase of the building project. Several decisions have to be made in the early stages of the project, for instance:
 - What kind of maintenance manual software or system should be chosen?
 - What data should be collected and from where?
 - Who is in charge of the data collection and coordinating?
 - In what kind of format should the collected data be converted?
 - Who is paying the costs caused by the maintenance manual execution and its upkeeping?
 - How and when to organize the maintenance personnel training?
 - How to organize the administration and upkeeping of the manual?

Operation and Maintenance Manuals

Contents of the operation and maintenance manual

Today there are dozens of different maintenance manual software trademarks available. Selection should be done in line with required functional targets. It is desirable to test and compare between different software systems before the final decision.

Operation and Maintenance Manuals

Contents of the operation and maintenance manual

It can be put a huge amount of data into the latest maintenance software systems. That is why it is very important to determine exactly what data is important and useful for the maintenance. It is good to bear in mind that the basic function of the maintenance manual is simple. A good quality manual gives the answers to the following questions:

- What to maintain and where?
- How to maintain?
- When to maintain?
- Who is in charge of the maintenance?
- What kind of information should be recorded in the manual from each maintenance action?

Operation and Maintenance Manuals

| Building condition data | Room/Space condition data | Maintenance object data | Maintenance task data | Maintenance calendar | Economical data | Other useful data |
|-----------------------------------|---|--|--|--------------------------------------|--|---|
| General building condition data | General room/space condition data | Maintenance object classifying system | Maintenance task classifying system | Maintenance task scheduling | Energy and water consumption targets | Regulations, recommendations, instructions, best practices |
| Fault- and repair history | Room/space condition targets | Maintenance object identifying data | Preventive maintenance task instructions | Daily and weekly maintenance tasks | Actual energy and water consumption measurement data | Security, guidelines for state of emergency |
| Condition survey data | BAS/BEMS System information and user interface | Maintenance object basic data (equipment certificates) | Preventive maintenance task cycles | Monthly and yearly maintenance tasks | Maintenance cost targets | Contact information (designers, builders, FM-services etc.) |
| Energy audit data | Instrumentation and sensors information | Operational principle of maintenance objects | Instructions for unexpected maintenance | Long period maintenance task data | Actual maintenance cost data | Service contract data |
| Service life data | Indoor air quality measurement data | Operation and use history data | Task history data | Maintenance diary or notebook | LCC- and LCA- data | Building user/tenant data |
| Replacement and repair cycle data | Indoor air quality data analysis | Device-specific data | Help desk data | Maintenance feedback data | Economical data analysis | Training procedure |

Operation and Maintenance Manuals

It is useful to include some general data of the real estate of building to be maintained into the manual. This general information should cover at least the following:

- Identification data of the real estate or building (codes, locations, addresses etc.)
- General information of the scale of building (volumes, areas, number of storeys etc)
- General information of land use and its rights, site
- Essential documents of the building or retrofitting project (planning material like drawings, layouts etc.)
- Reports and surveys (condition surveys, energy audits, etc.)
- List and contact information about architects an designers, contractors and entrepreneurs, manufactures and suppliers and maintenance & FM-organizations
- Maintenance and FM-contracts
- Information about tenants and occupiers and their contact persons
- List of apartments and rooms including the data of areas and the occupiers
- Main maintenance and indoor air quality targets (room temperatures, maintenance and cleaning cycles etc.)
- Maintenance cost and energy use targets and guidelines for their monitoring.

Operation and Maintenance Manuals

- One of the most important tasks in creating the effective maintenance manual tool is to systematize and classify the actual maintenance targets (building elements and HVAC-systems that need maintenance) and then gather and store the basic information of these targets.
- Each maintenance object should be easy to identify easy to be found. Furthermore plenty of data about these objects is often needed during the maintenance task. Identification systems vary from case to case.
- One useful way is to give identification code to each separate maintenance object. These kinds of numbering can be done by dividing the objects into main- and subcategories.
- Clear information about the location of the object and the access to the object is essential to carry on the tasks efficiently.
- Basic data of the maintenance targets should include at least the information about manufacturer/supplier, installation year and targeted service life.

Operation and Maintenance Manuals

- Maintenance instructions constitute a know-how databank about how to maintain the building and its elements.
- Usually this information is based on the manufacturer's or supplier's instructions and the practical experience of the maintenance organization.
- Manufacturer's or supplier's instructions should be stored already in the early phases of the building or retrofitting projects.

Operation and Maintenance Manuals

Generally maintenance tasks are often classified into two categories:

- planned maintenance tasks and
- unexpected maintenance tasks.
- Concerning planned maintenance it is often appropriate to classify the tasks into different categories by the cycle of the task. Terms like daily tasks, weekly tasks and monthly tasks are often used. Task scheduling should be done in a line with the condition targets and resources. The answer to the question "when to maintain" can be reached simply by creating a service calendar where each maintenance task is determined and scheduled.
- This requires careful maintenance planning.
- In the calendar view the maintenance tasks to be executed are listed. Sophisticated maintenance tools of today enable the access to the maintenance instructions via calendar view.
- Calendar view should clearly show which tasks are completed and which are unfinished or delayed.
- Modern maintenance software systems can be linked with the building automation systems. The cooperation of these two systems is essential in order to manage unexpected maintenance successfully. There are also the help desk systems available for the occupier feedback in modern high level maintenance tools.

Operation and Maintenance Manuals

- Operation and maintenance manual/record book should be connected into BAS, which generates information for OMM and which can be utilized.
- On the other hand, building automation system should produce information and report in such a form that could be used easily in OMM. Unfortunately, all the useful features of existing BAS are not fully utilized (In practice at the moment).
- The integration of BAS/BEMS and operation and maintenance manual is the essential task in planning facility management and maintenance. For instance, most of the systems do not provide useful reports on operation, from which one could see the most important factors and key figures.
- Generally, there are facility management tools available, by means of which one can customize such reports, but the problem is to create proper and targeted information for the end user, building owner or manager.
- When the maintenance task is done the task should be noticed by the workers and the vital information about the duty should be stored into files as the maintenance service history (maintenance diary). This information may be utilized later in maintenance planning or in practical future maintenance work.

Operation and Maintenance Manuals

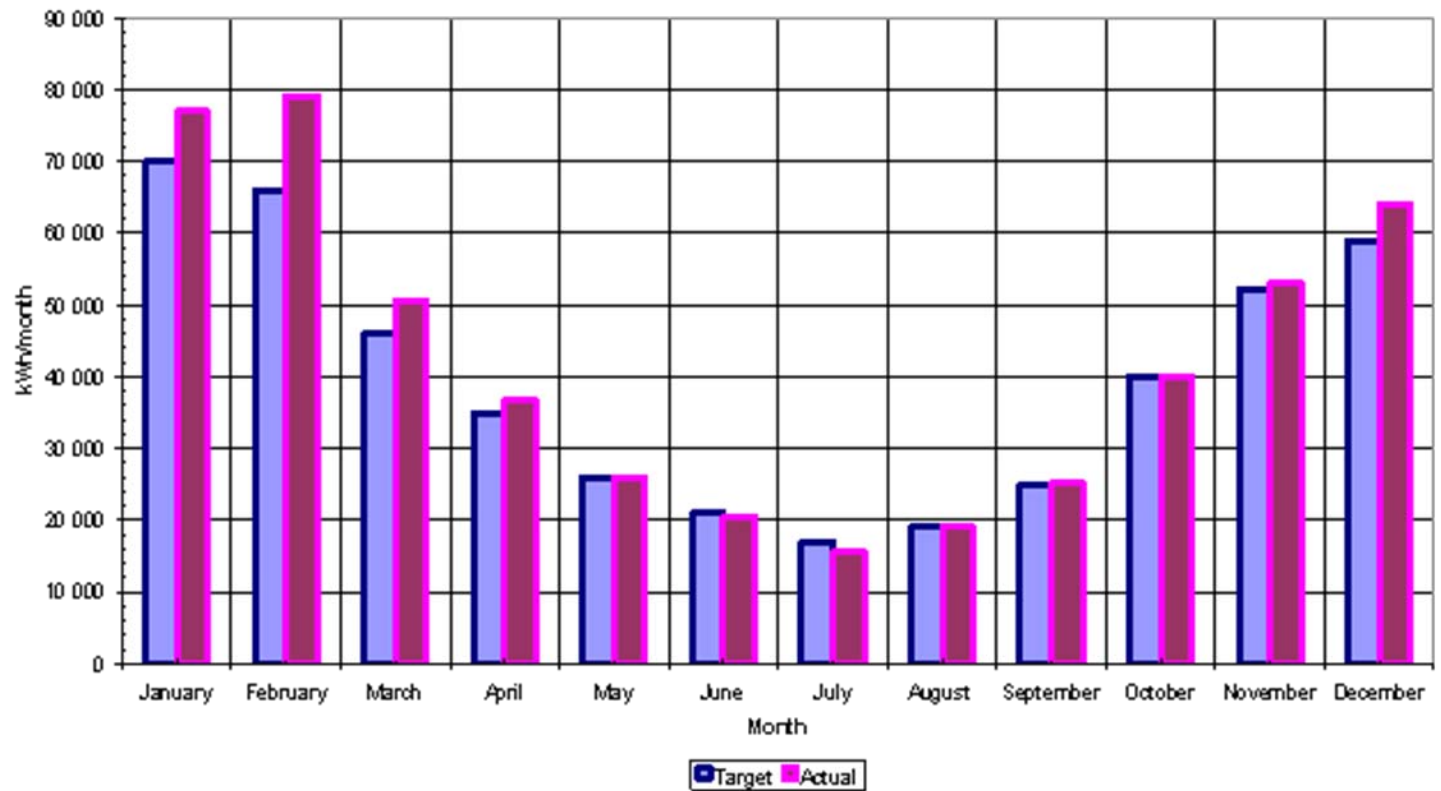
The importance of energy and cost analysis

By means of Operation and Maintenance manual it should be possible to produce at least the following energy and cost analysis data:

- Monthly target consumptions of heating energy, electricity and water (kWh, kWh/m² or kWh/m³, water-m³/m² etc)
 - In energy units per floor area, volume, users or other factor (e.g. production, worker etc). and
 - costs per the same factors, detailed key figures selected by the customer
- Actual measured monthly consumptions (kWh, kWh/m² or kWh/m³)
 - the key figures selected by customer
- Weather corrected consumptions (heating)
- Difference analysis (actual compared with targeted, quantities and costs)
- Difference and trend analysis (actual compared with the previous years, quantities and costs)
- Comparison with the similar buildings or same type of buildings (if data available)
- Trends (the changes in the use and cost changes during the time of operation, 5 -10 years period if possible, quantities and costs)

Operation and Maintenance Manuals

ACTUAL HEATING ENERGY CONSUMPTION COMPARED WITH TARGET VALUES



Operation and Maintenance Manuals

The significance of instrumentation

- The performance evaluation and determine of possible savings potential is based on measured and calculated values, or partially on some other factors, like plate records, equipment certificates etc.
- If the instrumentation level in the building is extensive (in any case it must be reasonable, no inappropriate measurements), it is possible to customize various reports, graphs and tables according to the customer's needs based on actual on-line measurements.
- The level of instrumentation can be compared with the instrumentation in the industry: What kinds of measurements are needed to control the production process and the product quality?
- If the building and indoor air conditions will be considered as a process where thermal comfort and indoor air conditions are the products, the analogy for industrial processes and instrumentations is relevant. The right magnitudes must be monitored and reported by proper way.

Building Automation Systems (BAS) definition

Building automation systems include different kinds of automatic control, supervise and command functions for controlling HVAC processes and the overall functionality of the building. According to the real estate management objectives, the purpose of building automation is to guarantee the following issues

- Building and its technical systems are functioning correctly
- Indoor climate is kept at a desired level
- Building energy consumption is kept at a desired level
- Routine work is decreased
- HVAC system is operated correctly
- Service and maintenance is efficient

Building automation system is a tool that has an effect on the indoor climate, lighting and also broadly interpreted on the building safety. Building automation controls the technical systems, minimizes energy consumption, prevents equipment breakdown, noise level and other drawbacks. The benefits of building automation depends on how it is used.

Why BAS is needed?

BAS equipments are procured for two basic functions

- **Physical**: basic control, alarm and scheduling functions
- **Software**: optimization, control, compilation of statistics and graphical functions

BAS is commonly used for

- Maintaining **energy efficiency** of the building by controlling HVAC operating time and controlling heat recovery
- Minimizing the **fault situations** by alarm monitoring and analysis
- Protecting the building and its equipments
- Quarantee customer satisfaction by using knowledge to control **indoor conditions** and HVAC technical systems (BAS is a central tool for this purpose)

Basic software functions of BAS

- Alarm handling
- Energy consumption follow-up
- Exploitation of historical measurement information
- Trend (time series) information follow-up
- Heat recovery efficiency calculation
- Demand response programs for utilities (e.g. electricity)
- Operating time calculation and control for equipments
- Protecting the building and its equipments
- Exploitation of measurement information to control building systems
- Exploitation of alarm history for service and maintenance
- Exploitation of AMR (Automatic Meter Reading) information to optimize energy consumption

Typical facility management routines where BAS is used

Daily

- Review the alarm information log and take necessary actions
- Review the process charts to find possible abnormalities

Weekly

- Review the whole alarm information log to find and document possible repetitive alarms for taking further actions
- Review the history measurement information for indoor conditions to find possible abnormalities and to decide needs for changes

Monthly

- **Energy report:** Print the A4 montly basis graph for realized consumptions (electricity, heat and water). The graph visualizes the monthly consumptions for this and the previous year and the consumption targets. Report the possible abnormalities and make possible corrections to the target consumptions.
- **Fault report:** Print the A4 realized alarms. Comment the reasons and possible corrective actions to be taken.
- **Indoor conditions report:** Print the A4 realized indoor temperature and other agreed measurement information. Comment the possible abnormalities their reasons and corrective actions to be taken.