An evaluation-tool for building adaptability and operability – a case study from Switzerland
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Camill F. Marciniak¹ and Swiss Reinsurance Company²

¹ Department of Sustainable Construction and Facility Management, Intep, Dufourstrasse 105, CH-8008 Zürich, marci@intep.com; camill.marciniak@googlemail.com
² Swiss Reinsurance Company, Construction Management, Mythenquai 60, CH-8002 Zürich

PAPER ABSTRACT Buildings are constructed to be functional and meet the current and future user requirements. Unfortunately buildings are often constructed for a single specific use with resulting extensive and expensive refurbishments during their operability. In the worst case buildings are demolished even before the end of life because of high running maintenance cost and low quality of usability. Therefore, it is crucial to increase the adaptability of the building in order to increase the acceptance of the user and value of the building throughout its entire life cycle. The maintenance and replacement of building systems and the flexibility for conversion are crucial parameters to extend the buildings lifecycle. Additional, the separation of building components need to be taken into account too. Often building components with different physical life are connected with each other. With the ‘Systemtrennungsbericht’ (System Separation Report) from the Cantone Bern a guide is available to support the design. The limitation of this guide is the lack of assessing the building component partition, flexibility and its impact on the maintenance and replacement cost. There is a need to close this gap. For this reason, together with the client the tool was developed. The objective of the tool is to support the design and decision process during the planning and construction phase by evaluating the construction and providing information on its future adaptability and operational cost. This user-friendly excel based tool comprises the qualitative features of the building components across all building trades showing the potentials and limitations for future building conversions. For comparability and verification of life cycle costs, the tool is structured in line with the cost structure of e-BKP-H (planning) and BKP (construction). Based on a case study the applicability of this tool is shown on the conversion of an office floor into a conference area. After completion of the building the tool is used to evaluate and support the decisions on refurbishments and possible conversions.

KEYWORDS: Sustainability, Adaptability, Separation of components, Evaluation, Lifecycle cost

AUTHOR BIOGRAPHY: Camill Felix Marciniak works as Senior Consultant at Intep for Sustainable Construction and Facility Management. He has a background as architect with approximately 5 years of work experience and an additional Master’s degree in International Project Management and Business Administration. He worked for consulting companies focusing on Property and Project Management and has been with Intep since 2011. He gained knowledge and competencies in the analysis of lifecycle-costing and real estate benchmarking. His work is focusing on sustainable strategies for the entire real estate lifecycle.

1 Introduction

1.1 Requirements for adaptability

Any property is constructed for a specific use at a specific point in time. A high occupant satisfaction and low utility costs for the owner of the building are at the focus of cost-effectiveness across its entire lifecycle. Assuring operability for the owner is in relation to occupant’s acceptance of the building, which needs to support user business requirements. Buildings are subject to changes in form of adaptations, conversions, or extensions throughout their lifecycle because of changing market environment of the user, the micro location, legislation or technical requirements. In terms of sustainability, therefore, key factors for the building are not limited to energy efficiency but also include adaptability for alternative use and extension possibilities. As regards construction measures, the Swiss standard SIA 469 differentiates between monitoring, maintenance, and changes in professional and economic building conservation. If the aspect of change (conversion and extensions to assure occupant’s acceptance) in planning a building is neglected, future changes result in
intensive and expensive means for construction. In the worst case, the building is demolished before the end of its life.

1.2 Requirements for operability

Exchanging and replacing construction elements and material shall be possible throughout the entire lifecycle at low costs with minimal effort to affect the user’s operational processes as little as possible while keeping structural operability costs low for the owner of the building.

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Fig. 1: Owner’s and Occupant’s Requirements

1.3 Value Retention

The following criteria should be considered already in project development to assure operability and to meet different requirements:

   a) High flexibility for different spatial and occupant’s needs
   b) Low maintenance and repair costs
   c) Low material waste by maintenance, repair and demolition work

The concept of system separation opens the potential to meet the requirements of both stakeholder groups. It looks at the different life of operability of building components as determined by their physical life and separates them into three system levels.

1.3 Study limitation

The following case study shows the application of a tool to evaluate system separation including a presentation of quantitative and qualitative results. This case study follows a user-oriented approach because of project-specific client’s requirements and is not intended to represent a comprehensive view or to include a thorough review of the scientific-theoretical literature. In the following case-study the application of a user-friendly tool as a basis for decision-making in real estate management is presented.

2 Project objectives

2.1 General Project Information

With the project Swiss Re Next (SRN) a new headquarter will be realized at Mythenquai in Zurich. The new office area will take innovative approaches in the office work environment allowing workplaces to be more versatile, inspiring, communicative, and pleasant. As part of the project SRN, Swiss Re will build a new office building with a capacity of approximately 800 work places. The Dynamic Workplaces Concept plans with an occupancy rate of approximately 1.020 employees. Building service facilities, therefore, are designed for a maximal capacity of 1.200 workplaces (Maximum full occupancy). At this point in time, the project is in tendering and construction phase. The relocation phase is scheduled to begin in the third quarter of 2017.

2.2 Design Goals

At its prominent location, the headquarter will serve as a role model for sustainability; it will be certified by the Swiss label MINERGIE-P-ECO and by the US-American label LEEDv3 for New Construction and Major Renovation.
2.3 Operating Goals

From the perspective of real estate management, assuring building value and quality is a fundamental precondition. With the determination of lifecycle and operating costs, Swiss Re is provided with essential information on major cost types to enable potential cost optimization of the construction project and future budgeting of building operation and management. Intep applied the methodological approach as described in the Guideline of Lifecycle Cost Analysis of Real Estate to determine lifecycle costs and used the Cost Model for Real Estate Utilization provided by IFMA Switzerland to determine operating costs. As planning advances and specific materials are chosen, precise forecasts will be made for every construction element on the basis of its effective life for building operation. The potential and also limits of extension and conversion within the building should be demonstrated.

2.4 Development of instrument

Current instruments (IFMA/CRB) are used to evaluate lifecycle and operating costs on the basis of utilization defined for the entire utilization period. This, however, is not entirely in line with reality due to the limitation of not covering costs for structural extensions, conversions and building alterations. In addition, currently applied instruments to analyze costs do not adequately consider design dependencies of construction components (accessibility and connections) and respectively reduced effective physical life of construction components. Current literature on the concept of system separation recommends not only a separation of system levels, but also an analysis of project-specific technical dependencies of specific components in building elements. This developed tool has the potential to close this gap by covering the following issues:

1. Representation of potentials and respective limitations for conversions, extensions, and alterations
2. Calculation and evaluation of effective physical life of construction elements and components

Because the effective influence on lifecycle costs is most influential in early phases the tool shall enable assessment in early planning stages. Already in project design, statements on criteria listed in Chapter 1.3 should be possible. With the system separation matrix, project teams will be given a tool for future projects supporting decision-making by showing limitations and resulting consequences on the construction and building management on a qualitative and quantitative (cost) level. This constructional-technical approach of elements identifies cost drivers in utilization costs and provides Real Estate Management with a transparent instrument. The System Separation Report serves as a concept for partitioning construction components in conversions for alterations and allows selective and structured dismantling of building elements.

3 Evaluation-tool

The System Separation Report provides the client with a concept able to show the building’s utilization flexibility under planned conditions and resulting consequences, including a transparent and consistent budgeting for maintenance and repair. Conversions or alternations shall be enabled with little effort and resource consumption. By the concept of system separation, the principle of “construction component separation” describes the following criteria for the goal agreements on SIA 112/1:

- Achieving consistency in value and quality over the entire lifecycle
- Low maintenance and repair cost
- High flexibility for various conversion and room alterations

In the following chapters the structure and functionality, evaluation criteria, data inputs and outputs are described.

3.1 Function and structure ‘separation of components matrix’

Intep based the preparation of the System Separation Report on the specifications of AGG Canton Bern and
the requirements of MINERGIE-ECO for HVAC facilities and construction elements. Assessing a planned construction element separation, i.e. an easy-to-separate connection and determining the degree of flexibility for conversions and alterations, opens a scope for improvements including all consequences. A system separation matrix was established as a tool to budget maintenance and repair costs. The matrix is structured in accordance with construction costs for buildings e-BKP-H to allow comparability and verification with lifecycle costs, subsequently arising maintenance and repair costs. This cost structure allows identification of individual components and is to be used in early phases when design is not very detailed.

Fig. 2: Overview Construction scheme (Baukostenplan e-BKP-H 1./2. Level excl. asset cost

3.2 Valuation Criteria
All cost-relevant, by MINERGIE-ECO required construction elements are listed to assess the flexibility in regards to potential conversions for alternative utilizations and to estimate technical utility costs. The evaluation of construction elements is structured according to SiA 112/1 by these criteria:

1. System level
2. Construction element separation
3. Flexibility

The following section briefly describes these criteria.
3.2.1 System level

The system levels categorize construction elements according to their different life expectancies and its changeability. Three system levels are defined in the document “Project structure Office for Land and Buildings AGG (Projektstruktur AGG Bern)” as shown in figure 3. The systematic separation of system levels is a basic prerequisite for the concept of system separation.

Fig. 3: Definition of system level (Systemstufen) acc. to AGG Bern

3.2.2 Construction element separation

Construction element separation requires a systematic, extensive differentiation between construction elements to allocate them to various technical and operating functionalities so that replacing or repairing individual construction component does not detrimentally affect fully functional construction element. This increases the utility value and reduces resource consumption. As part of a selective dismantling at the end of a building’s life, the approach to distinguish between construction elements to allocate them to the various materials used is of great importance for recycling processes, separate disposal, and embodied energy. Construction component separation is qualitatively evaluated in a traffic-light-approach for accessibility and its connection (screwed, etc.). The deconstruction of entire construction elements and its components is also considered and subject of this qualitative evaluation. Interdependency of certain construction components is recorded in a construction element matrix and linked to qualitative features of the system separation matrix. Function and structure of the construction element matrix is described in the chapter 3.4.

3.2.3 Flexibility

A high degree of flexibility allows the building to adapt to future development of utilization and alternative use. The term alternative use describes a changed use of the entire building or a partial area, for example using an office floor as a seminar or meeting floor. This assures utilization value and generates acceptance (durability) for the Property. Flexibility should facilitate alternative use at minimum expenditure of material and financial resources.

3.3 Data input

When entering data and information every single e-BKP-H position is allocated to the respectively responsible planner. The input comprises information in regards to both quantitative (investment costs) and qualitative (for example construction component description, revision, maintenance) aspects. These specifications
provide important information on project-specific features, which must be considered during operation, inspection and maintenance works, and dismantling/deconstruction. The construction component is evaluated by choosing criteria in regards to accessibility (easy, difficult) and connection (loosely laid/bolted/jointed/glued/welded) to other components of construction elements. The responsible planner makes the choice on the basis of technical plans and descriptions.

### Informationsfelder

| Kostenstruktur | Erläuterung der Kostenstruktur nach e-BBP-H mit Zuordnung der entsprechenden BKP
| Systemstufe | Darstellung der wesentlichen Bauteile mit den größten Kostenblocken in Erstellung und Betrieb
| Kennwerte | Darstellung der Systemstufe gemäss “Systemtrennungsbericht” des Aargau Kanton Bern

<table>
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<th>Eingabefelder</th>
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| Beschreibung | Im Beschrieb wird die projektspezifische Eigentümer des Bauteils qualitativ beschrieben. Hierzu kann der Auszug aus dem Baubeschrieb nach BKP eingegangen werden.
| Verbindung mit | In dieser Zelle wird die Verbindung des Bauteils mit den für die Instandhaltung und Instandsetzung relevanten Bauteilen eingegangen. Die Informationen werden aus dem Register ‘Bauteilmatrix’ entnommen.
| Rückbau | Das Verlegen eines Demontageplans oder der Beschrieb zur Demontage/Rückbau wird eingegangen. Mit Hilfe eines Ampelsystems wird die Bauteiltrennung auf Grundlage der Zugänglichkeit und Verbindungsart bewertet.
| Revision / Wartung | Kurzer qualitativer Beschrieb über die Perioden und den Aufwand der Wartungsarbeiten zum betrachten Bauteil.
| Erweiterung | Qualitative Eingabe der möglichen Erweiterung oder Ergänzung (technisch, räumlich) im Betrieb.
| Einschränkung im Betrieb | Wiege eines qualitativen Beschriebes, der die betrieblichen Einschränkungen aufgrund der Bauteileigenschaft aufzeigt.
| Lösungsvorschlag | Ein baulicher Lösungsvorschlag (Umbruch, um einen Defekt bzw. eine Einschränkung im Betrieb aufzulösen.
| Investitionskosten | Die Eingabe der effektiven Baukosten des Bauteils.

### Ausgabefelder

| Bewertung | Ergebnisse aus dem Drop-down Menü im Eingabefeld Rückbau in Darstellung eines Ampelsystems.
| Instandsetzungskosten | Berechnung der Instandsetzungskosten aus den Investitionskosten und der Nutzungsdauer.
| Instandhaltungskosten | Berechnung der Instandhaltungskosten aus den Investitionskosten und einem Rennwert des CRB.

### Fig. 4: input/output section in tool

- **Einfach zugänglich** Lose verlegt
- **Einfach zugänglich** Verschraubt / Gesteckt
- **Einfach zugänglich** Verklebt / Verschweißt
- **Schwer zugänglich** Lose verlegt
- **Schwer zugänglich** Verschraubt / Gesteckt
- **Schwer zugänglich** Verklebt / Verschweißt

### Fig. 5: Assessment of Separation of construction components

### Fig. 6: Selection box for construction component assessment (excl. construction component description)

### 3.4 Data output

Qualitative description of construction component separation using the traffic-light approach allows a quick overview of expenditures for future refurbishments or conversions. Already in a very early stage, the current
planning status may be optimized to meet utilization needs and to reduce utility costs. Calculation of utility costs is based on parameters such as effective physical life and investment costs. Maintenance and repair costs are calculated on the basis of investment costs, benchmarks from CRB, and internal benchmarks (Values from experience). Future construction alterations may rely on transparency in regards to construction elements allowing a direct comparison of investment costs with projected operating costs.

3.4 Function and structure ‘construction component matrix’

To ensure a better overview, both the construction element matrix and the system separation matrix are structured in accordance with e-BKP-H. All positions on the vertical axis are mirrored on the horizontal axis so that theoretically every component of a construction element may be connected to any other component. The connections are marked. This view is necessary to model the effective exchange rate in a realistic, project-specific manner. The adjusted useful life results in updated expenditures and operating costs. In current literature, it is recommended to assess this construction component dependency from an economic point of view.

4 Application on a case study

The developed tool offers an integrative approach between the requirements of construction management and facility management. It was directly applied and developed to the project circumstances. The tool was used to analyze maintenance and repair costs, and to model the potential and limitations of future conversions for alternative use. The following chapters describe how the tool is applied to evaluate operability and adaptability.

4.1 Evaluation of operability

From the owner’s perspective it is crucial to maintain the building value by keeping the operability. The building maintenance is the responsibility of the ownership. The Swiss standard SIA 469 (Maintenance and repair) provides project participants a directive for mutual understanding of concepts and conservation measures and activities. The respective components of the building are the structure, the building envelope, the interior fit-out and technical equipment. In order to ensure functionality, maintenance and repair are relevant. Because there are differences in the definition of terms between DIN 31051 (Principles of maintenance) and SIA 469, only the terms of the SIA 469 are used. According to SIA 469 maintenance and repair costs are defined as follows:

Maintenance: Keep the usability through simple and regular measures.
Repair: Restoring security and operability for a specified duration

The maintenance is determined by the intervals of the inspection and maintenance to enhance the optimal use of building device’s lifespan. The repair is defined by the effective physical life of the respective components. The repair includes, for example, preventive maintenance, replacement of parts to restore the expected operability. With regard to the required criteria of the goal agreements according to SIA 112/1 and the requirements for MINERGIE-ECO the following parameters have to be considered for the building maintenance.

- a) Dismantling ability with assembly sequence
- b) Type of constructive connections with other building components
- c) Accessibility for inspection, maintenance and repair work
- d) Inspection and maintenance intervals during the period of physical life

In the following chapters the parameters are assessed for the main building components in the respective system level.

4.1.1 1st. level (Primärsystem)

For dismantling of the primary system it was paid attention on separation into components. For the reinforced concrete composite floors in the upper floors the compounds are constructively developed, that they can be separated at the end of their life. The reinforced concrete cores, slabs and walls of the basement floors are well divided with a dismantling into its components. The sewer pipes are installed within the new bottom plate.
4.1.2 2nd level (Sekundärsystem)

In the secondary system care was taken to Mechanical fixing and, if possible, welding or adhesive bonding was dispensed. In general, the use of filling and sealing foams is prohibited by MINERGIE-ECO prerequisites. For the mechanical fixed parts of the facade there is an assembly sequence available. With the system separation matrix it is detected, however it is clear, that a relevant connection from the exterior facade to the sunshades and the engines is present with an impact on the effective life of these components. The building equipment installations are designed for a replacement of equipment at any possible time. Wherever possible, care was taken that no building equipment and appliances are installed in the primary structure. Vertical building installations are accessible, repairable and replaceable on all floors. The replacement of electrical wires is designed to be feasible at any time based on the selected access systems, as they are performed either in accessible raised floors, in underfloor ducts, in tracks directly on the open ceilings or via inspection openings accessible ceiling. In the upper floors, a hollow or raised floor is provided. Inspection and maintenance can be performed with little effort. Wherever possible a loose laying or mechanical fixing system was designed for the floor. Flooring in all restrooms is equipped with ceramic tiles applied directly on the ground. In some areas of the ground floor a sand bed is provided with free lying natural stone panels as flooring system.

4.1.3 3rd level (Tertiärsystem)

The sprinkler installations are already mandated by the legal requirements for component separation. The accessibility to the center is ensured for the fire department as well as the technical service at any time.

4.1.4 Result

For most components easy accessibility is ensured without significantly affecting other components. This results in an increase in the effective life of building elements. Based on the component connections, the designed systems, the accessibilities and the maintenance periods, the effective physical component lives can be determined in order to budget the repair and maintenance costs.

4.2 Requirements for adaptability

"Flexibility" defines the openness of the building for future alternative use developments or conversions. To meet the future occupant’s demands the scope with potential reserves has to be defined by the client’s representative. In the Swiss standard SIA 469 the flexibility is summarized by the following terms:

- Refurbishment: restoring an entire building or parts thereof in a similar to the original comparable conditions.
- Extension: Adaptation to new requirements by adding new parts of building
- Adaption: Adapting a property to new requirements, without significant intervention into the structure

4.2.1 1st level (Primärsystem)

The primary level is a long term investment and regards itself as largely unalterable framework of the secondary level. The structural quality of the primary level is increased significantly by the long-term expedient dimensions of the factors that are crucial to the alternative use developments and conversions (e.g. room height, loads, etc.). In the design a large column grid with few inner walls (access cores), thin blankets (without building equipment inlays) and a linear load distribution was chosen. The entire structure is not designed for a future vertical addition on top. The façade grid of 1.7m allows flexible room layouts. However, due to the specified column grid the room dimensions are defined.

4.2.2 2nd level (Sekundärsystem)

Heating and cooling is created with a heating and cooling ceiling, carried out in a four-wire principle. Each office floor is divided into four façade oriented zones. These zones have each a separate heating zone with its own flow temperature control. Room temperature is controlled by defined space modules. For ventilation and air conditioning a reserve area in a plant room is kept to install additional ventilation or air condition at any given time. The vertical riser ducts have a reserve in order to install additional ducting. For heating and cooling systems an area in the plant room is kept in reserve to have the potential for additional systems. The horizontal allocation in the basement and the office floors can be converted. However, it is associated with a significantly high cost (e.g. Demolition of ceiling claddings). Due to the design of high ventilation rates, a
conversion from office to meeting rooms is (during the planning in XO6 implemented) is possible. The installation heights of sanitation are determined by the existing building structure (e.g. steel beams). In principle a subsequent installation and connection to the system is possible but affected by non-removable ceiling parts. Conversions, such as layout adjustments within the cores are allowed, but due to the high rate of installed media as well as the maximum distance to the ducts (slope of the waste water pipes) limited.

4.2.3 3rd. level (Tertiärsystem)

Appliances, furniture and equipment can be exchanged for a conversion in a meeting floor or different office layouts without great effort for a change.

4.2.4 Result

According to the review and evaluation of the elements, limitations in the conversion due to the defined zones, load, grid and component constructions (e.g. ceilings, room height, mechanical equipment) could be identified. For the operative building management, the limits of flexibility can be already demonstrated. However, the structural and spatial reserves in the HVAC-systems allow to a certain level a conversion from offices into meeting rooms. Despite the open structure concept of the building restrictions in the conversion exist, due to interior finishes (e.g. ceilings) and defined zones (sanitary). Future structural extensions or additions are not feasible.

5 Prospects and obstacles

Although the evaluation tool was only applied to this case study (office / administrative building), it enabled relevant findings on the property's projected operating costs and conversion potential. It is, however, entirely feasible to apply this tool to other building utilization types (Retail, Residential, etc.), as it is independent from building utilisation and based on construction cost structure (e-BKP-H) for all kind of properties. Its benchmarks (life expectancy and maintenance factor), however, must be adjusted for other uses, because use and ownership structure of the property highly influence utility costs. The effective physical life of, for example, components of construction elements on the retail market is much shorter in comparison to residential buildings due to the fast changing business environment. The tool has been applied in the planning and construction phase. The application during the operative building management has not taken place. Further integration with existing tools as well as a supplement to other databases for a useful adaptation in a BIM system was not analyzed. These topics were not been addressed in the presented case study.

6 Conclusion

With the presented evaluation tool the Swiss Re obtains a tool with the ability to show the flexibility of the building with the planned conditions and the resulting implications. It also allows the transparent and consistent budgeting of measures to be taken for maintenance and repair. Related to the physical life of the property a value and quality consistency is achieved by the assessment of the following key criteria.

1. High flexibility for different spatial and occupant’s needs
2. Low maintenance and repair costs
3. Low material waste by maintenance, repair and demolition work

The traffic-light approach provides the user with an indication of the structural situation of future changes or adaptations. With the component-matrix the design of component interfaces is evaluated in order to gain a more realistic model of the effective physical life and for future renovations. A key finding from the study is that the tool has been recognized and applied in the project by the planners and the owner representatives, represented by Construction Management and Facilities Management, as a supportive communication and management tool. This instrument facilitates making decisions on technical concepts based on quantitative and qualitative results. The potentials and limitations within the building are detected by this trade-crossing tool and discussed in the project team. To optimize structural limitations the addition and comparison of solutions is enabled. The evaluation-tool provides so a significant contribution for an appropriate handover from construction to operation and provides a strategic tool for the Real Estate Management.
7 Literature


Swiss Engineers and Architects, *SIA Recommendation 112/1 Sustainable Construction – Building*. Zürich, 2004

Swiss Engineers and Architects, *SIA SN 506 511 Construction Cost Scheme*. Zürich, 2009