Decision support tool for the innovative and sustainable renovation of historic buildings (HISTool)

W. Hüttler[1], D. Bachner[1], G. Hofer[1], M. Krempl[1], G. Trimmel[2] and I. Wall[2]

[1] Department of Building Research, e7 Energie Markt Analyse GmbH, Wien, Austria, Email: walter.huettler@e-sieben.at

[2] Trimmel Wall Architekten ZTGmbH, Wien, Austria

Abstract – The HISTool is a software-based tool for the analysis of the current building status, and a decision support tool for the innovative and sustainable renovation specifically of Gründerzeit buildings. These were built between 1840 and 1918 with partially standardized designs and components in Central-European cities. The tool is designed to be applied particularly in the preparation and decision-making stage of renovation projects in the Gründerzeit building sector, prior to the actual planning phase. For the decision-making process, it is essential to provide solid data on different renovation options in an early phase based on life-cycle costs, without a lot of calculation effort.

The calculation is based on a model of the building, which consists of 40 elements according to the specifics of Gründerzeit buildings and the selection of predefined renovation measures. The integrated energy performance and life-cycle cost calculation leads to the derivation of life-cycle costs of different renovation variants. A comparison of life-cycle costs of different renovation options leads to information-based renovation decisions.

The aim is to stimulate the Gründerzeit sector in the real estate market to implement more energy-efficient and innovative renovations, which are compatible with the specific requirements of historic buildings, and to contribute to the fulfilment of the climate-protection goals.

HISTool particularly reflects the environmental and economic goals of sustainable management of historic buildings according to EN 16883, and supports the planning and decision making procedure in the first phase as well as in the detailed planning phase when it comes to the selection of specific measures and assessment against the initial project targets.

Keywords – energy efficiency; refurbishment; decision support tool; life-cycle costs; Gründerzeit

1. INTRODUCTION

Gründerzeit buildings, also known as Wilhelminian-style buildings, date back to the period of 1840 to 1918. The term Gründerzeit refers to the economic growth period in the 19th century starting with the industrialisation. The need for living space in fast growing cities led to intense construction activities, mainly in the cities of the former German Empire and the former Austro-Hungarian Monarchy. The brick buildings share some key characteristics, such as standardised floor plans, standardised structural components, wall thicknesses, floor

heights, types of windows, and so on, which make them suitable for standardised analysis. Due to the fact that still almost 30 percent of all apartments in Vienna are situated in the 35.000 Gründerzeit buildings, substantial optimisation potential lies within buildings from this period. Even though many houses are made of good building substance, renovations are due simply because of the age of the buildings. Both the public call for conservation and complex elements, such as richly structured façades, vaulted ceilings in the basements, etc., call for special renovation techniques. Reliable information for building owners regarding innovative and technically feasible renovation options of these elements in particular, and for historic buildings in general, is scarce. Therefore, building owners often decide against thermal renovation measures. However, thermal renovation measures of the building shell, and measures in order to improve the technical building systems, are key to improved comfort and improved energy-efficiency of the building and therefore for climate protection. Another important aspect of renovation is the conservation of the building through protection of the historical building substance and a long-term increase of the building value.

The calculation of life cycle costs is already a well-established approach in the decision-making process of building renovation, with an ever-growing importance in real estate management. Building owners receive solid information and transparency to implement complex solutions based on long-term economic and ecological data. The application of life cycle cost analysis in the building sector is based on the observation that operational costs account for about 80 percent of the total costs of a building over its lifetime of 100 years [1]. For the optimisation of a building's total cost, it is therefore necessary to not only take into account initial investment costs, but all costs over the whole building lifetime need to be considered for a more holistic and transparent perspective. All costs are usually discounted and summed up to a present day value, known as net present value (NPV).

2. OBJECTIVE

The objective of this project is the development of a software-based tool (HISTool) to be applied in the status analysis and as a decision support tool for the sustainable renovation of Gründerzeit buildings. The tool is used at the earliest stage of the decision process, before the actual planning phase starts. It provides valid information about possible renovation measurement packages, their environmental and economic specifics and derives the variants life cycle costs, which essentially form the basis for the decision-making process of the building owner with nevertheless very limited calculation effort.

The calculation of life-cycle costs gives the building owner the chance to compare several renovation solutions and furthermore provides an early estimation of operational costs for the renovated building. This is an incentive for the widespread implementation of sustainable and energy-efficient renovations of Gründerzeit buildings.

Based on this pre-decision in the first phase of the planning process (decision on stop/go), the tool is used to support the selection of measures on a more detailed

level when it comes to the final assessment of packages of measures in relation to initial targets.

3. METHOD

A model of the building, which consists of 40 elements according to the specifics of Gründerzeit buildings, is the basis of the Excel-based software tool. Relevant elements and usage zones of Gründerzeit buildings are defined in diverse levels of detail, as displayed in Figure 1. The level of detail depends on the influence of a certain zone on the renovation costs. The zone General building is the most detailed as it contains all exterior building elements, which are key for the energy performance. On the other hand the zones Apartments, Basement, Common area, Elevator and Attic conversion, are defined less detailed.

Specific renovation measures are predefined for each of the 40 elements. The library contains a thorough collection of measures, e.g. to improve thermal resistance, to reduce thermal bridges, CO_2-neutral heat generation, to implement a ventilation system with heat recovery, measures to eliminate dampness in the basement, or for the static improvement of structural components. Every renovation measure is defined with its technical characteristics, thermal qualities (U-values), lifetime and costs, which compose data sets that are stored in a database, as can be seen in Figure 2. All data sets consist of a detailed description of the individual components, the cost of every component and the above described technical parameters.

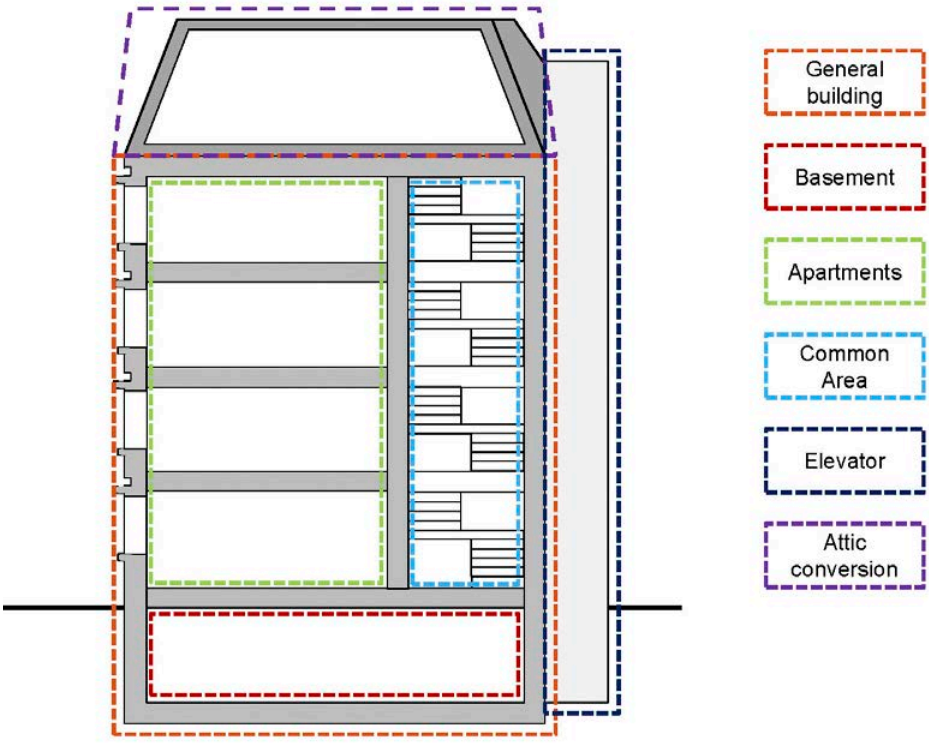

Figure 1. Building model, Source: e7 Energie Markt Analyse GmbH.

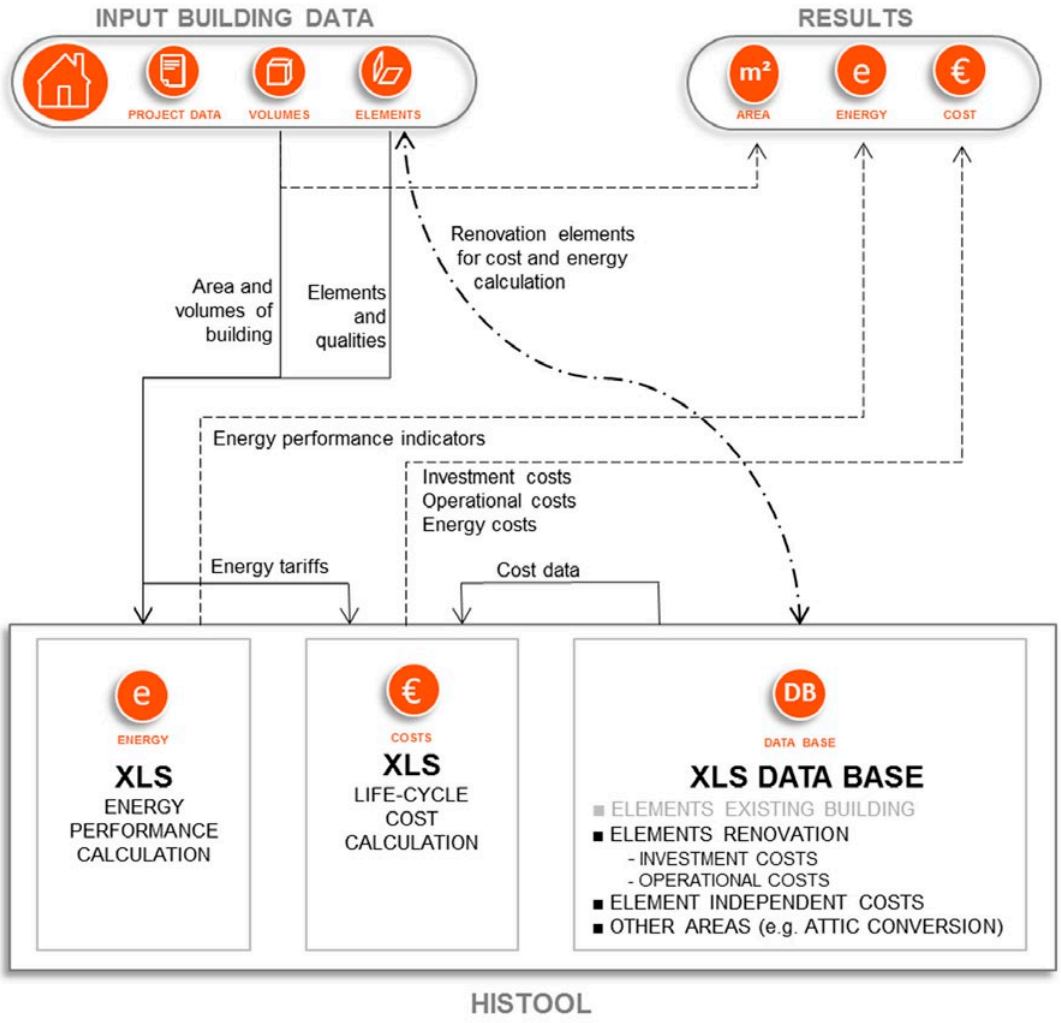

Figure 2. Tool structure. Source: e7 Energie Markt Analyse GmbH.

Database transactions are performed by the integrated energy performance calculation according to Österreichisches Institut für Bautechnik (OIB) and the life-cycle cost calculation according to ÖNORM M 7140. The energy performance calculation is based on the provisions of OIB Directive 6 and the referred Austrian standards. For a quick-and-easy calculation of heat transmission areas with limited input effort and parameters, pre-defined floor plan typologies and an automated area calculation are used. Alternatively, a detailed calculation is possible. All relevant inputs of building systems can be taken from the integrated database. The heat energy demand and energy costs are determined through defining the building model and the technical equipment.

The life-cycle cost calculation is a useful method to analyse all relevant costs of renovation solutions with a long-term perspective. Besides initial investment costs, operational costs such as energy, maintenance, service and repair, as well as replacement costs, are taken into account, see Table 1 (highlighted in blue).

Table 1. Structure of life-cycle costs acc. to ÖNORM B 1801-2

Cost Category	Property construction costs
0	Building site
1	Utility connection
2	Construction – carcasses
3	Construction – building systems
4	Construction – interior works
5	Furnishings
6	Outdoor facilities
7	Planning
8	Ancillary services
9	Reserves
	Oncost
1	Management
2	Technical building operations
3	Supply and disposal
4	Cleaning and care
5	Security
6	Facility services
7	Maintenance, reorganisation
8	Others
9	Demolition

Furthermore, revenues can also be considered in the calculation, which guarantees a high level of cost security at an early stage and presents the financial effects of the selected renovation measures. A calculation period of up to 50 years can be selected in the HISTool.

4. RESULTS

The result of the calculation procedure is a comparison of the life-cycle costs of different renovation variants, which reflect different thermal-energetic qualities. The detailed results contain the respective energy performance indicators, CO_2 emissions and a summary of all arising costs per variant structured in cost categories (carcassing, interior work, HVAC, electrical engineering, operational costs), the present value, the accumulated present value and so on, according to Figures 3 and 4.

Figure 3 presents the calculated life-cycle costs of the demonstration building Kaiserstraße 7 over a period of 30 years, including investment costs for a major refurbishment in year 0, replacement of the heat generation system (year 20) and windows (year 25), energy costs (electricity and heat) and costs for maintenance and repair of the technical building systems. Other operational costs are not incorporated. Energy costs depend on the energy performance level of the renovation variant.

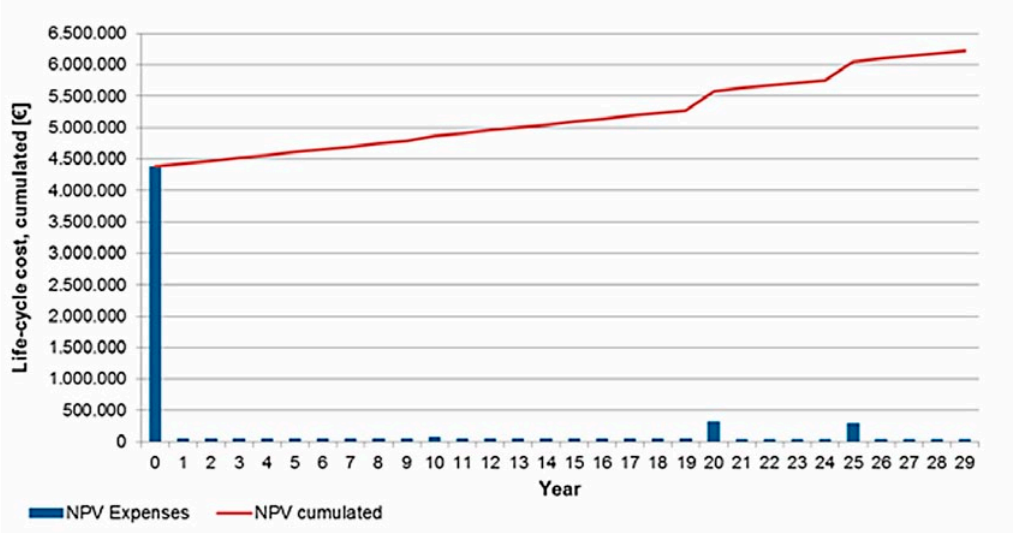

Figure 3. Net present value. Test result. Kaiserstraße 7, Vienna.

Figure 4. Demonstration building Kaiserstraße 7, Vienna. Source: akp Trimmel Wall Architekten ZTGmbH.

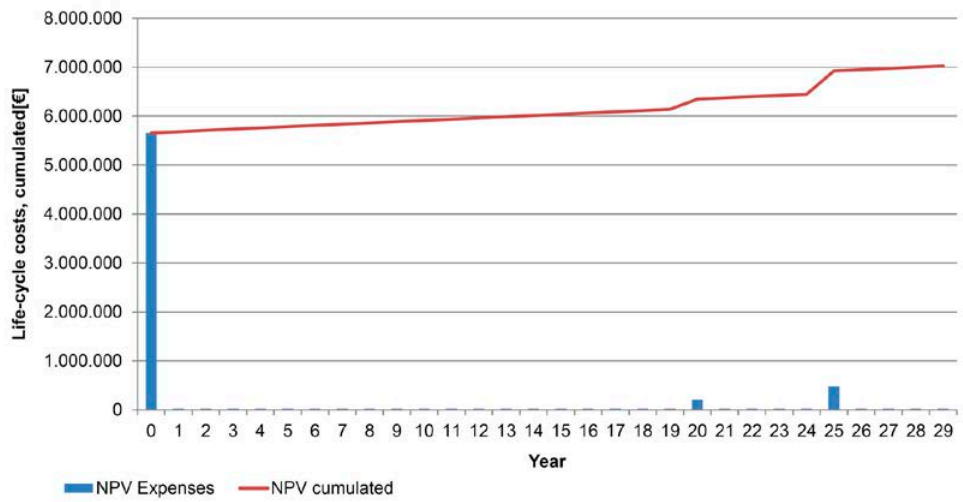

Figure 5. Net present value. Test result. Mariahilfer Straße 182, Vienna.

Figure 6. Demonstration building Mariahilfer Straße 182, Vienna. Source: e7 Energie Markt Analyse GmbH.

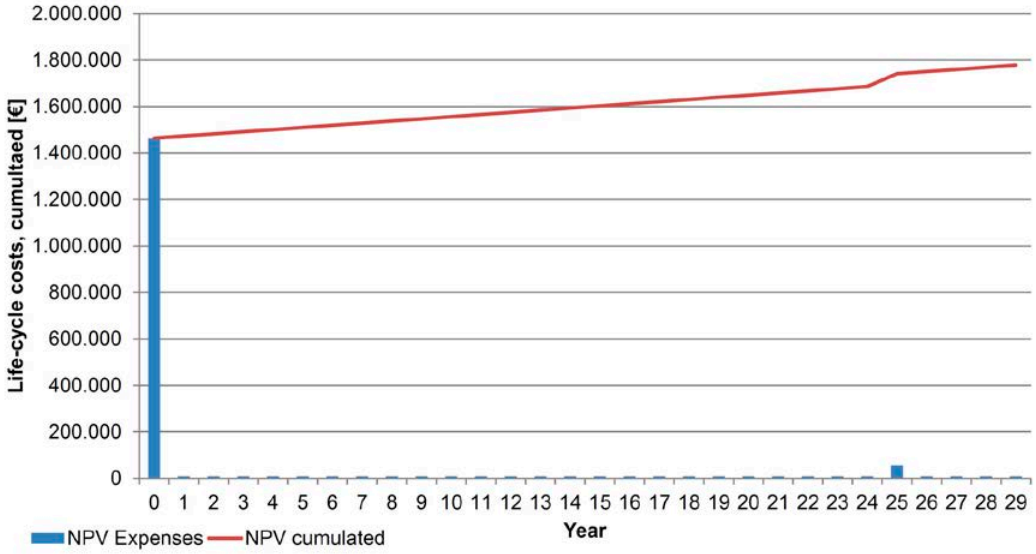

Figure 7. Net present value. Test result. Dingelstedtgasse 12, Vienna.

5. APPLICATION OF HISTOOL WITHIN THE DESIGN PROCESS

The tool is mainly used in the consultancy of building owners and real estate portfolio managers. It is applied in a twofold manner:

- During the preparation and pre-decision-making stage, prior to the actual planning phase. During this early stage of the process, it is essential to provide rough but solid data on different renovation options without a lot of calculation effort;
- During the detailed assessment and selection of measures in order to select and assess packages of measures in relation to initial planning targets.

This approach is closely linked to the new European standard “Conservation of cultural heritage – Guidelines for improving the energy performance of historic buildings” which was issued in July 2017 (EN 16883). The guideline describes

Figure 8. South view of demonstration building Dingelstedtgasse 12, Vienna. Source: akp Trimmel Wall Architekten ZTGmbH.

the decision making process of energy performance improvement measures in historic buildings. Similar to the objective of HISTool, the focus of the guideline is to guarantee a data-based and prudent selection of technical improvement measures.

The economic scope of refurbishment projects is mentioned in EN 16883 in a couple of passages. Economic assessment and economic sustainability are highlighted as important elements of sustainable management of historic buildings. The guideline states that the objectives of energy performance improvements of historic buildings shall consider economic viability (taking into account capital costs, operating costs including maintenance costs, economic return and economic saving). An economic assessment shall be undertaken and the guideline emphasizes that economic sustainability shall be one of the guiding principles for sustainable management of historic buildings. However, the guideline does not refer explicitly to life-cycle costs as a general decision making principle.

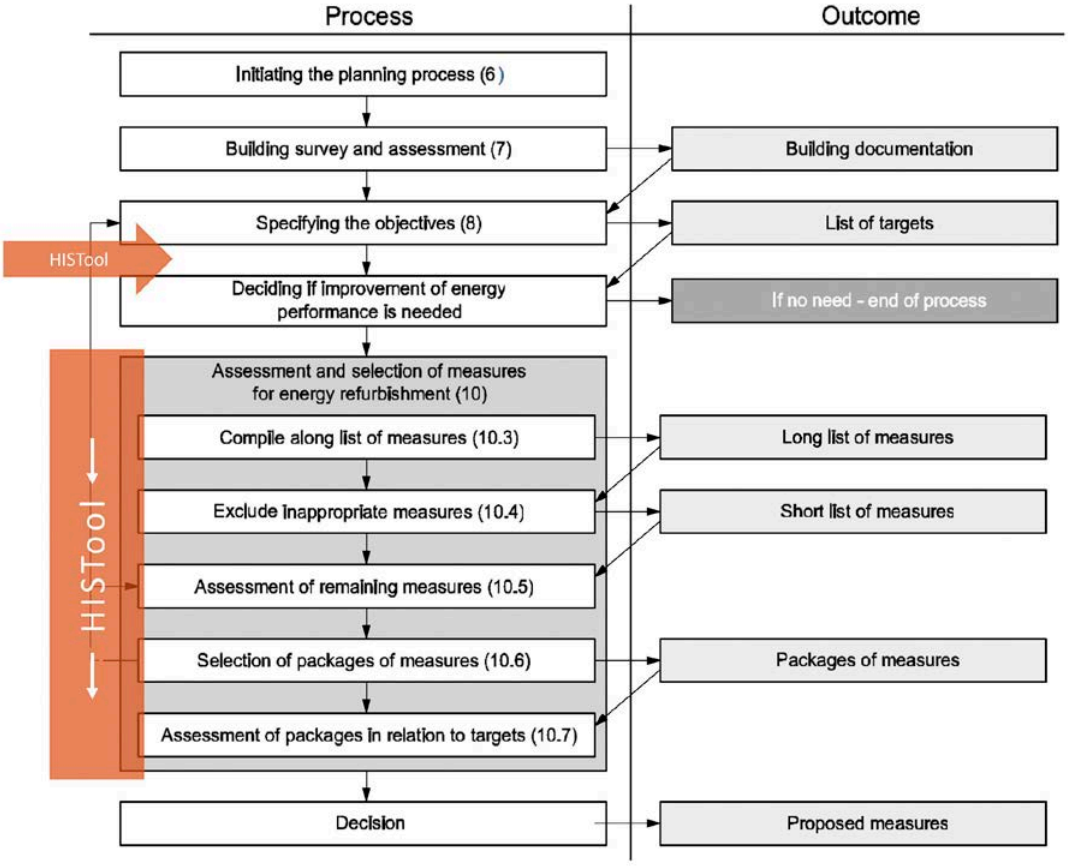

Figure 9. Flow chart showing the proposed procedure in EN 16883 (2017) and application of HISTool.

Figure 9 shows the proposed procedure from EN 16883 as ideal planning process from the initiation until pre-decision (stop/go) and the detailed assessment of measures until final assessment against the initial targets and final decision (highlighted in grey).

HISTool supports as well the initial process until pre-decision as the detailed design process when it comes to selection of specific packages of measures. After deciding if improvement of energy performance is needed and possible (initiation of planning process, building survey and assessment, definition of objectives have to be completed), the HISTool can be used for the assessment and selection of measures for energy refurbishment according to the standard EN 16883.

6. CONCLUSIONS

HISTool particularly reflects the environmental and economic goals of sustainable management of historic buildings according to EN 16883, and supports the decision making procedure in the first phase as well in the detailed planning phase when it comes to the selection of specific measures and assessment against the initial project targets.

7. REFERENCES

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