Adding value using sustainable building construction in Cyprus: the case study of the Cyprus University of Technology in Limassol

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Summary

There is no question that the building industry in Cyprus is in the midst of rapid change toward more sustainable design and construction. The future of these rating systems include an emphasis on performance outcomes (such as global warming impact), the need for regional variations, the need for variations for different building types, the trend toward more requirements rather than point-based alternatives, and more focus on actual building performance during occupancy and operation.

Sustainable or green building design is still an evolving field with rapid advances in knowledge, technology, and methods of measuring outcomes. A key aspect of moving toward more performance-based outcomes in sustainable design is the use of Life Cycle Assessment (LCA) to determine the embodied environmental effects of materials used in the building construction, maintenance and demolition. LCA is a methodology for assessing the environmental performance of a product over its full life cycle. However, the LCA methods and tools that are currently available are not utilized by most stakeholders, including those designing, constructing, purchasing, or occupying buildings.

The purpose of this study is to apply life cycle costing and assessment for buildings that make use of 'new sustainable designs and technologies' and compare directly the results obtained using the 'existing traditional design'. Most of the decisions makers or valuers or engineers ignore in their value appraisal the major differences between the two types of construction.

This work is supported by the case study of the Cyprus University of Technology performed in the framework of the ValPro European Project (Eracobuild VDP call). The case study of the Cyprus University of Technology provides a different perspective and highlights the potential increase of added value in real estate when involving extensive renovation and rehabilitation of older buildings to serve new functions within an existing city infrastructure. For the purpose of this study a group of buildings is selected which are renovated and transformed from their original use as warehouses to modern University Laboratories. In these buildings an eco-design approach was adopted and various energy saving technologies are incorporated.

Keywords: Sustainable Buildings, eco-efficient technologies, life cycle assessment, costing, value

1. Introduction

The ValPro project is a part of the thematic framework “Value driven processes” of the Eracobuild project (http://valpro.eu/). The building sector today is mainly focused on reducing the initial (investment) costs, rather than applying any comprehensive approaches for optimizing total facility life cycle values for the benefit of owners, users, the environment and the society. This is partly due to lack of models, methods and tools for total life cycle value management, and partly due to current business models and contractual frameworks that do not provide for innovation and novel value sharing schemes. The Cyprus University of Technology, as a key partner of this project, is considered as an ideal case study of applying life cycle models for retrieving the real benefit both for University but also to the nearby community.

A key aspect of moving toward more performance-based outcomes in sustainable building design is the use of Life Cycle Assessment (LCA). Life cycle assessment (LCA) is considered as the internationally accepted method for evaluating the environmental effects of buildings and their materials or any other type of construction. LCA is a comparative analysis process that evaluates the direct and indirect environmental burdens associated with a product, process, or activity. Life cycle analysis quantifies energy and material usage and environmental releases at each stage of a product's life cycle (material extraction, manufacturing, construction, operation, maintenance and post-use disposal). Life cycle costing (LCC) involves in the financial forecasts of building performance based on construction, operation and maintenance costs. LCC relies on the time value of money and expresses the building life cycle cost as a net present value. In the Life cycle costing method the total cost of building, operating and maintaining the building is expressed as a single sum of money needed today to cover these costs over the study period selected for the life cycle costing scenario.

LCC for buildings is an important tool for involving the construction client better in early stage design decisions. However, regardless of its importance, LCC has found limited application so far [1]. Research [2] indicates that it is particularly important to show the relation between the design choices and the resulting lifetime cost (i.e. energy, maintenance, and operation cleaning) to the client prior to his/her final decision. It is important, therefore, to show the construction client in the early design phase the relationship between design choices and the resulting lifetime cost.

New materials and advanced building technology are continuously introduced into the market [3, 4]. The design team such as civil engineers, architects, mechanical and electrical engineers usually select the same old technology and materials as well as they use their experiences from previous projects for this purpose. It is important to highlight that by focusing on initial costs of materials and technology, no longer fulfils modern day needs of the construction development. It is necessary to consider several factors such as economic, aesthetic, environmental, durability, quality and life cycle.

Cyprus lacks for the use of models, methods and tools for total life cycle value management for the building construction society and several improvements must be made. Some recent research studies [5,6,7] provides encouraged remarks for further actions. Hadjimitsis et al. [5,6,7] demonstrated the importance of using life cycle models for comparing different types of transportation pavements in Cyprus using ‘traditional design and existing design procedures’ and ‘new eco-materials and design’.

In order to assess the economical and environmental aspects of existing buildings in the Cyprus University of Technology area located in the city of Limassol in Cyprus, intended for renovation life cycle cost analysis (LCCA) and life cycle assessment (LCA) studies were undertaken. For the purpose of this study a group of buildings is selected which are renovated and transformed from their original use as warehouses to modern University Laboratories /offices. In these buildings an eco-design approach was adopted and various energy saving technologies are incorporated. Direct comparison between the use of ‘eco-design’ and ‘traditional-design’ procedure for these selected buildings has been made.

2. Life Cycle Cost and Life Cycle Assessment

Very often, decisions about demolition or renovation of a building revolve around cost considerations without considering the environmental implications. Therefore, justifying major renovations can be difficult, as costs are uncertain and environmental impacts are not considered. Whether or not an existing, renovated building can perform as well as a new building in terms of operational energy is a key consideration in the decision to renovate or demolish existing buildings. Stakeholders tend to focus on the initial cost of the building without examining the cost of building operations and/or the environmental impact over the life of the building. In order to examine the cost of the building and the environmental impact over the life of the building, the techniques of life cycle costing and life cycle assessment can be used.

Life cycle costing (LCC) is a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs [8]. LCC allows for economical justification for the sustainability considerations, as implementing LCC in planning for construction projects shows that, over a project's life, incorporation of sustainable elements proves cost-effective as well as environmentally beneficial.

Life Cycle Assessment (LCA) is an essential design process for controlling the initial and future cost of building ownerships and is an effective tool for evaluating of existing building systems [9]. LCA is for assessing the total environmental impact associated with a product's manufacture, use and disposal and with all actions in relation to the construction and use of a building or other constructed asset throughout its life cycle. LCA is useful not only in determining the total cost of a building and its alternatives, but also determines which alternatives provide the best value. Although costs can be firmly attributed to some environmental factors, there is currently no widely agreed methodology for others and some cannot be quantified at all in cost terms. LCA can help decision-makers select the product or process that results in the least impact to the environment. This information can be used with cost and performance data to select a product or process.

LCA is not the same as life cycle costing (LCC). Although the two methodologies are complementary, LCC focuses on the dollar costs of building and maintaining a structure over its life cycle while LCA focuses on environmental performance. In conducting a LCC, it is critical to consider the following components:

- construction and renovation costs
- maintenance costs, including rents
- operational costs
- occupancy costs
- end of life cost, including demolition.

Traditionally, in order to conduct a life cycle assessment, first a life cycle cost must be conducted using the below formula:

$$LCC = I + Repl - Res + E + W + OM\&R + O \tag{1}$$

where

LCC=	Total LCC in present-value (PV) euros of a given alternative
I=	PV initial costs
Repl=	PV capital replacement costs
Res=	PV residual value (resale value, salvage value) less disposal costs
E=	PV of energy costs
W=	PV of water costs (optional)
OM&R=	PV of non-fuel operating, maintenance and repair costs.
O=	PV of other costs (including contract administration costs, financing costs, employee payroll)

However, this formula must necessarily be modified when conducting a life cycle cost on a renovation, especially when it is rented, expropriated, or given to the University outright.

$$LCC = I + Ren - Res + L(OM\&R) \qquad (2)$$

where

LCC=	Total LCC in present-value (PV) euros of a given alternative
I=	PV cost, which may include expropriation amount, or zero if there is no cost for the acquisition of the building
Ren=	PV capital renovation costs
Res=	PV residual value (resale value, salvage value) less disposal costs. This varies as the property may be rented from a third party
L=	Time period of the analysis
OM&R=	PV of non-fuel operating, maintenance and repair costs, including rental costs.

In this study, the Gabi software (developed by the University of Stuttgart in cooperation with PE Europe GmbH) was used to conduct a Life cycle assessment. The LCA was conducted to:

- estimate the 2 key embodied environmental impacts, primary energy use and global warming potential measured in terms of CO_2
- estimate the avoided impacts associated with the demolition of the existing buildings and construction of new buildings of approximately the same size designed to serve the same purpose currently served by the renovated buildings
- identify the differnces, if any in the estimated opeating energy use between the new and existing building
- identify any significant impacts incurred to renovate the existing buildings
- qualitatively examine the issues related to sustainability.

This study is essentially a pilot study designed to investigate the process to examine the environemntal side of the equation using the Gabi software to examine the identified case studies. This study is not intended to provide precise estimates regarding the embodied or operating energy aspects of the buildings, but rather to provide reasonable approximations in order to guide value-driven decision making for further building renovations at the Cyprus University of Technology campus.

3. METHODOLOGY

The overall methodology of this study consist the following basic steps:

- The first step is the development of a 'Database' where all available building materials and technology with their characteristics such as initial cost, LCC, durability, eco-characteristics, technical specifications, insulation, strength and stability and other performance requirements or criteria for a particular building element, such as Roof, windows etc., are inserted and stored.
- The second step is the knowledge base which consists of a set of rules for selecting the appropriate combinations of materials and technology from the database to elicit knowledge, the material selection process by incorporating cost estimation process.
- The third step is to apply LCA and LCC using existing softwares or models, revised to incorporate existing Cyprus Building construction situation (prices, materials etc).
- The fourth step is to run the LCA/LCC in order to compare directly the following scenario: renovation of existing buildings in the Cyprus University of Technology area using 'new sustainable designs and technologies' and compare directly the results obtained using the 'existing traditional design'.
- The authors aim to post the proposed database and methodology on an open web access so as to facilitate all the involved parties either clients or designers (architects, civil engineers etc) to run the model and produce their own LCA/LCC results.

4. CYPRUS UNIVERSITY OF TECHNOLOGY: CASE STUDY

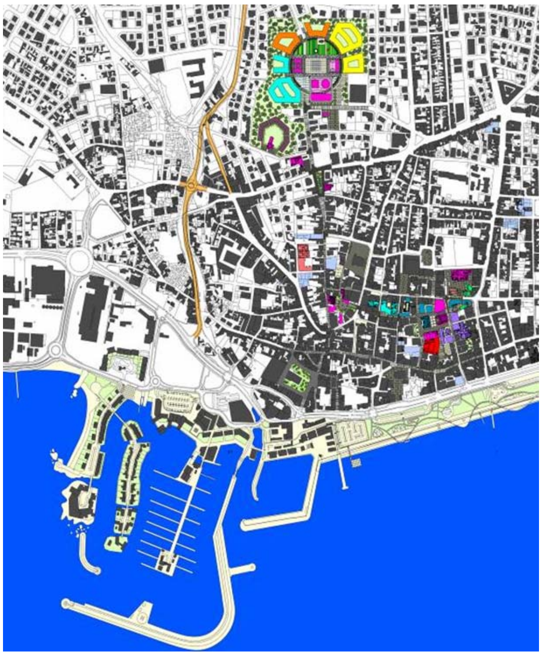

Fig. 1 Cyprus University of Technology

One of the 'ValPro Project' (Eracobuild VDP call) case studies concerns Cyprus University of Technology, which is based in Limassol, Cyprus (http://valpro.eu/joomla/case-studies/cyprus.html). The Cyprus University of Technology is a new public university located in the historic center of the city of Limassol that was established in 2004. The master plan was formulated in two phases, with phase 1 focusing on the development in the historical center of Limassol (from 2004-2020) and phase 2 focusing on the development in the north area of the center of Limassol (from 2020-2035) (see Figure 1). The Cyprus University of Technology extensively renovated several older buildings in the Limassol city center by utilizing eco-efficient, sustainable design in order to repurpose these buildings within an existing city infrastructure. The concept behind the campus design was to provide added value in real estate through extensive renovation and rehabilitation of older buildings to serve new functions within an existing city infrastructure. In the Cyprus market, real estate appraisals were conducted only using comparable prices depending on location, and recent sales of comparable buildings, without taking into consideration all the aspects and features of the buildings such as drawings, specifications, and materials.

The campus is located in the city center of Limassol. In the past two decades, the city center of Limassol has slowly declined in economic desirability. The introduction of the CUT campus has significantly affected the local economic and social dynamics. The establishment of the campus in the city center has created an economic and social impact in the area. The campus has also improved the economic use of the area, as more businesses are opening around the campus in response to increasing numbers of students. The influx of increasing numbers of students in the area has resulted in the establishment of more cafes and restaurants opening in the city center. To maintain the cultural element unique to the city center, the Cyprus University of Technology incorporated appropriate refurbishment and remodelling of listed buildings and re-used buildings where possible and appropriate. The repurposing of building took into consideration the local context and was respectful of the historic city fabric in terms of materials and built tradition. The renovation took into consideration the local context, including traditional building materials and design traditions, while at the same time creating eco-efficient buildings.

One of the main aims of renovation was to attach new meaning to the existing buildings. The buildings examined in this case study are the University Library, that was originally a court house, the offices for the electrical engineering department, which was originally the Ttofi Kyriacou department store, the offices and laboratories of the Mechanical Engineering and Geomatics labs of the Civil Engineering Department, which were originally a warehouse (Dorothea) and the Hero's square, home to the Multimedia department, student housing, and student café, which previously considered the "red-light district"of Limassol. These renovations changed the character of the whole area and this renovation increased the value of the area, both economically and socially.

Detailed information on each building follows:

Library of the Cyprus University of Technology (figure 2)**:** The library is a listed (historical) building originally built in 1920 and used as a Court House. It is owned by the Government of Cyprus and was given to the Cyprus University of Technology, so there was no initial cost involved. The library has a total building area of 900 m^2 and the cost of the renovation was 2 million euros.

Fig. 2 Library

Considerations included:

- Listed historical building
- Maintain the original character of the building
- Structural reinforcement was required
- Energy efficient technologies were incorporated in the renovation

DOROTHEA building (Figure 3) (offices and laboratories of the Mechanical Engineering and Geomatics labs of the Civil Engineering Department)**:** This building was built in 1980 and originally used for ware houses. The total building area is 2,300 m^2, over 5 floors. It is currently rented from the owner on a 20 year lease. The total renovation cost is 2 million euros, with 1 million being paid by the owner an 1 million being paid by the Cyprus University of Technology. The basement has 300 m^2 of useable space for the instrument storage of the Mechanical Engineering Department. The ground floor has 133m^2 of useable space and the first floor has 245m^2 useable space for the labs and offices of the Mechanical Engineering Department. The second floor has 263m^2 of useable space and the third floor has 264m^2 of useable space allocated to the labs, offices and storage of the Civil Engineering Department. The forth floor, with 184m^2 of useable space and the fifth floor with 165m^2 of useable space are allocated to the labs, offices and stores of the Mechanical Engineering Department.

Fig. 3. Dorothea Building

Considerations included:

- Other than the main structure (including foundation, walls, beams and floor slabs), the entire building elements were replaced.
- Energy efficient technologies were incorporated in the renovation

TTOFIS KYRIACOU building (Figure 4) (offices for the Electrical Engineering department)**:**
This building was built in 1980 and originally used as a department store. It was acquired by the Cyprus University of Technology through expropriation by the Government of Cyprus. It has a building area of 3,500 m^2, renovated at the cost of 6 million euros. The basement, of 283m^2 is the data center for the entire university. The ground floor houses the electrical and PC room, with a useable area of 208m^2. The first floor, with a useable area of 284m^2 and the second floor with 285m^2 both house the labs and stores of the Electrical Engineering and Information Technology Department. The third floor has usable space of 258m^2 and houses the labs and stores of the Physics and Chemistry Department.

Fig. 4. Ttofi Kyriacou Building

The fourth floor has 144m^2 of usable space and the fifth floor has 105m^2 of useable space, both of which house the offices and stores of the Electrical Engineering and Information Technology Department.

Considerations included:

- Other than the main structure (including foundation, walls, beams and floor slabs)
- the entire building elements were replaced
- Energy efficient technologies were incorporated in the renovation

HERO'S SQUARE (Figure 5) (Multimedia department, student housing, and student café)**:**
This area of Limassol was the "red light district" and was considered an undesirable part of the city, due to the high number of brothels, cabarets, gambling shops and low quality buildings. Currently, several of the buildings have been renovated. The Roussos Plaza and Zappeio buildings are two of the buildings in Hero's Square that have been renovated. The Roussos building contains the Laboratory of the Applied Arts and Communication Department, complete with multimedia workstations, classrooms, photography labs on the ground floor, in a total space of 301m^2. The first floor of the Roussos building contains the research space, offices, meeting rooms and stores of the Laboratory of the Applied Arts and Communication Department within 176m^2. The second floor of the building has a space of 208m^2 and the third floor has a space of 192m^2, which are student accommodations complete with kitchen, toilet and shower. The Zappeio building is the student café, which is a social gathering place complete with student bar and café. It has 128m^2 of useable space on the ground floor and 10 m^2 useable space on the first floor. The total cost of renovation in this area is 3 million euros.

Fig. 5. Hero's Square

4. Preliminary Results

In this study, the life cycle assessment was conducted on Gabi software in order to provide reasonable approximations of energy efficiency in order to guide value-driven decision making for further building renovations at the Cyprus University of Technology campus. The avoided impact model was used to evaluate the case study of the Library of the Cyprus University of Cyprus.

Library of the Cyprus University of Technology. Since the Library is a historical building, the interior and exterior walls were retained. In this case, the maximum avoided impact was examined, which involves saving the envelope and as well as the structure of the building [10]. The avoided impacts can be considered to equal the effects of demolishing a structural/envelope system as well as rebuilding a comparable structural/envelope system.

Table 1 - Renovated Impact Summary

Building Component	Assembly Total area in m^2	Primary Energy per m^2	GWP per m^2 (kg)	Total Primary Energy	Total GWP (tonnes)
Intermediate Floors	84	732.15	47.62	61,501	4
Windows/Doors	68	2643.46	279.41	179,755	19
Renovation of Exterior Walls	50	3,300.04	28.00	165,002	14
Interior Wall	56	373.45	17.86	20,913	1
Roof	500	1531.59	84	765795	42
			Whole Building	**1,192,966**	**80**

Table 2 - Avoided Impact Summary

Building Component	Total Primary Energy (MJ)	Total GWP (Eq. CO2 tonnes)
Foundation	311,431	41
Columns and Beams	346,381	29
Intermediate Floors	61501	4
Exterior Walls	1315432	111
Interior Walls	150,049	7
Whole Building	**2,184,794**	**192**

The avoided Global Warming Potential (GWP) impact for new construction would have been more than double of the CO_2 emissions of renovation of this existing building. The adaptive reuse of repurposing the existing building to a library also has a social impact, as well as intangible impact which cannot be measured with LCA, but were also considered in the decision making process for renovating this existing building.

Despite that the initial construction cost of the eco-design building is higher, however, by running the life cycle assessment/costing model, during the complete life cycle (50 years), it has been found that the building with the 'eco design' is most economical effective and environmental friendly than the conventional design.

The authors concentrated at this stage in the development of a complete database for including all the basic costs for all the construction processes and materials as well all the required stages for the whole life cycle of buildings in the area of Cyprus. Prior to the application of life cycle assessment and costing for the previous case studies in the University which refer to renovation of existing infrastructure and change of their previous use, the authors present a typical common example of a recent building construction in the area of Limassol.

Table 3 - Initial Construction Cost of a Typical Building in Limassol, Cyprus

BUILDING	***CONSTRUCTION COST***
BUILT AREA	300 SQ.M
TOTAL CONSTRUCTION COST (using traditional design)	400, 000 euros
TOTAL CONSTRUCTION COST (using eco design)	550, 000 euros

Using the above example, it is apparent that the initial costs are found to be more higher in the construction stages in relation with the traditional design. The eco-design consisted some of the following basic features:

- All windows are double glazed with 'Low E' special energy efficient glass filled with inert argon gas to provide high insulation values
- The walls also have 20 cm insulation consisting of a combination of insulating blocks, mineral wool and polystyrene
- The roof is insulated with 20 cm fibreglass insulation
- Instead of the conventional sewage waste disposal system used in Cyprus, the house has its own high technology biological waste treatment plant. The sewage is completely treated and the clean water produced at the end of the process is used to water the garden and is not discarded.
- The use of 'Geothermal Energy'.

The authors also ran the life cycle model for an existing building named as 'Apothikes Sykopetriti' which has been renovated to accommodate the Mechanical Engineering Laboratories and found that the eco-design (cooling and heating etc) produce more economical effective results than the traditional design procedure. The authors are in the stages of applying the same model for the other case studies.

5. Conclusions

This work is performed in the framework of the ValPro European Project (Eracobuild VDP call). This study initially indicates that in most of the cases energy efficient renovation is a more economic solution compared to normal renovation, although it usually is higher at the investment costs. Initial costs are found to be more higher in the construction and operation stages in relation with the traditional renovation.

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