AXIOMATIC DESIGN APPROACH TO BUILDING RETROFITTING FOR ENERGY EFFICIENCY

A CASE STUDY OF AN OFFICE BUILDING IN ABU DHABI

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I. INTRODUCTION

A. *Building Energy Performance*

Every year, about 40% of the global energy produced, is being consumed in the building sector, while contributing with over 30% of the CO2 emissions [1]. In the developing countries like the UAE; the contribution of the building sector to the total national greenhouse emissions comparing to worldwide average is significantly higher, partly due to the lower level of industrial activity [2]. Most of the energy consumed in building sector is used to reach thermal comfort [1]. Growing population, rise in the demand for building services and occupants' comfort level, combined with increase in time spent inside buildings, creates an upward trend in energy demand [3]. In general, HVAC is the largest energy end-use, accounting for about half of the total energy consumption in buildings especially non-domestic buildings. It should be clear that the efforts toward increasing the energy performance of buildings should be directed toward increasing the efficiency of the HVAC system to reach a considerable reduction in energy consumption and decrease the resulting CO2 emissions.

B. *Existing Buildings retrofits*

The International Energy Agency estimates, if energy efficiency policies to be implemented immediately, the proposed actions could save as much as 7.6 gigatonnes CO2/year by 2030, the increased efficiency in the building sector will account for 25% of the reduction in CO2 emissions as illustrated in **figure 1** [4]. Buildings are long-lasting systems creating a significant environmental impact throughout their lives [5]. Since the replacement rate of existing buildings by the new buildings is only around 1.0–3.0% per annum [6], many of the buildings in 2050 are still going to be the ones that exist today, it is critical for buildings of today to continually adapt to retain an effective energy performance profile. The process of building retrofitting is focused on increasing energy performance. Nevertheless, It is required that the process follows a multi-disciplinary approach, aligned with a unified view and organized efforts by consultants, facilities mangers, contractors, architects and engineers. The decision making process includes a spectrum of possible decisions and

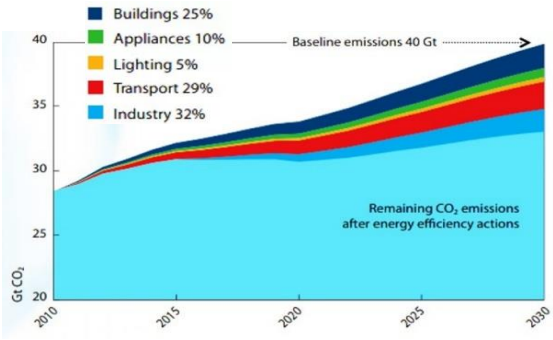

Figure 1: CO2 savings potential from energy efficiency recommendations. Source: IEA

strategies, starting with the materials as well as the mechanical system components [7]. It is required to be able to systematically list the retrofitting options, by clearly stating the hierarchy of building components and mapping the coupling between the components and their energy reduction effect. This paper will implement Axiomatic Design [AD] approach for an investigation of different retrofit options for energy reduction in an office building in Abu Dhabi.

II. AXIOMATIC DESIGN APPROACH

The conventional process used by architects is often based on previous experiences and knowledge, this knowledge is used to stimulate the early inference of possible solutions repeatedly until an adequate solution is defined [8].This conventional process is deficient in terms of providing a formal theoretical framework, which imposes both technical and finical risks [9]. Nevertheless, Retrofitting of building for energy efficiency is part of a demand side management strategy imposed by the

government [10], for that reason it is critical to avoid scheduling delays and high monetary expenses, by systematically addressing the requirements of energy performance in a time and cost effective manner. Axiomatic Design approach is used to provide a tool to effectively assesse and identify the energy related components of the building [11].

III. Modelling

Representing the system architecture of buildings using AD can differ according to the approach and the highest level requirements ought to be represented. AD was previously used as an approach to manage complexity in the first stages of sustainable building design, by offering a systematic decision making mechanism to mitigate the increasing complexity of architectural design [8]. Furthermore, AD was utilized to address the issues of temporary housing as a non-functional requirement on the housing system's lifecycle properties of modularity, reconfigurability, extensibility, and reusability. In order to fully meet the diverse range of stakeholder requirements adequately [12].

This paper employs the AD approach as a mean of representing the system architecture of an office building in the city of Abu Dhabi. The choice of the building location and type as system boundary and context will define the direction of the retrofitting procedures. Nevertheless, the baseline model is used as a case study for applying AD approach to analyses high level requirements of energy reduction retrofitting, the components included in the FR/DP dual hierarchy are focused on the goal of reaching energy efficiency, mostly through reducing cooling load and increasing the efficiency of cooling system.

IV. Conclusion

This paper proposed Axiomatic Design approach to systematically build a retrofitting scheme for an office building in the climate of Abu Dhabi. The aim of the retrofitting scheme is to reach the most energy efficient solution. The retrofitted building is treated as a large fixed system, because it includes a number of high level requirements and number of layers of decomposition necessary to generate a complete set of required retrofits, as well as, a great number of physical components. Furthermore, the components are fixed within the system, to satisfy a fixed set of requirements that do not change with time. The architecture of the system was mapped using the FR/DP dual hierarchy method of representing Axiomatic Design, the dual hierarchy is represented using Axiomatic Design Design matrix. The FR/DP dual hierarchy representation is initiated through defining the system context and boundary. Since energy efficiency is influenced by the thermal performance of the building. The climatic zone of the building acts as a system context, to provide a direction for defining the highest level requirements of the AD approach. The scale of the system is based on the case study chosen to apply the FR/DP dual hierarchy, which was a two story office building. It was demonstrated that the Axiomatic Design approach to the problem of buildings' energy efficiency provides an improved definition of the high level requirements, in addition to the corresponding design parameters. This paper demonstrated the potential of applying Axiomatic Design as a tool of creating a framework for building retrofitting scheme. The mapping of the different levels of the functional requirements with the design parameters made it easier to decide and apply the retrofits. Moreover, there is greater potential in quantifying the energy reduction of each component if the simulation was done repetitively for each separate component to examine the level of impact on the energy performance of the building.

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