OPTIMIZATION OF ENERGY CONSUMPTION AND THERMAL COMFORT IN HISTORIC BUILDINGS: CASE STUDY OF İZMİR NATIONAL LIBRARY BUILDING, TÜRKİYE

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Architecture

by
Umut ÖZSAVAŞCI

March, 2023

İZMİR

ACKNOWLEDGEMENTS

I would like to present my sincere gratitude to my advisor, Assoc. Prof. Dr. Zeynep Durmuş Arsan, for her support and correct guidance, tolerance and vast knowledge, and her invaluable efforts in research.

I would like to thank my co-advisor, Prof. Dr. Gülden Gökçen Akkurt, for excellent reviews and sharing her knowledge.

I would like to thank my dear friend Umut Çağırgan for his help.

I would like to present my gratitude to the examining committee members, Prof. Dr. Başak İpekoğlu, Prof. Dr. Türkan Göksal Özbalta and Assoc. Prof. Dr. Ayça Tokuç, for their helpful feedbacks.

I would like to express my graditutude to the The Foundation of İzmir National Library and the library staff for their assistance.

I would like to thank to İzmir Institute of Technology, Faculty of Architecture, Building Physics Laboratory for providing DesignBuilder v 7.0.0.102 student license.

I would also like to thank The Republic of Türkiye, Ministry of Culture and Tourism, İzmir Regional Board of Protection of Cultural Heritage No. I for sharing information about İzmir National Library Building.

I would like to thank Çağrı Topan who conducted his MSc thesis study in the Interdisciplinary Programme of Energy Engineering in İzmir Institute of Technology for his permission of sharing the monitored air temperature and relative humidity data of İzmir National Library Building between the periods of 01.10.2016 and 01.10.2017

Lastly, I am sincerely grateful to my parents, Mehmet Tevfik Özsavaşcı, Melek Özsavaşcı and Barış Özsavaşcı for their eternal support and encouragement. Besides, I would like to express my sincere gratitude to my fiancé, Gözde Bilir, for her continuous support and patience, unending motivation and cheeriness.

ABSTRACT

OPTIMIZATION OF ENERGY CONSUMPTION AND THERMAL COMFORT IN HISTORIC BUILDINGS: CASE STUDY OF İZMİR NATIONAL LIBRARY BUILDING, TÜRKİYE

The 'library,' as a building type, is the visiting space of researchers and storage space of wisdom of past and present thinkers. Historic libraries host unique pieces of cultural heritage such as books, manuscripts, documents, maps, artifacts, paintings, sculptures, and frescos from the previous generations.

The thesis aims to reduce energy consumption and improve occupants' comfort while paying attention to degradation risks of paper-based collections in the historic İzmir National Library Building, Türkiye. Thus, it examines building retrofit actions with different impact criteria and conducts the optimization tool to define the most optimal ones.

First, three degradation risk assessment procedures were determined for the paper-based collections of the İzmir National Library Building. Within the scope of the thesis, the library building was monitored between 01.10.2016 - 01.10.2017. According to the results of the monitoring process, mechanical, chemical and biological degradation risk analyzes were carried out. The digital simulation model of İzmir National Library was prepared in DesignBuilder v. 7.0.0.102 software and calibrated monthly for a year via hourly air temperature data. Three retrofit optimization scenarios, i.e. neutral, low and high risk impact criteria, were defined by grouping different design variables such as glazing type, exterior door material, pitched roof floor construction, exterior wall construction, heating set point and cooling set point of HVAC system. The objective of optimization was reducing energy consumption and discomfort hours at the same time.

The simulation results showed that all three retrofit actions reduced energy consumption and discomfort hours. Scenario 3 was the most successful among other scenarios, providing energy savings by 26.6% and reducing discomfort hours by 80.3%, according to the base case. Besides, there was no significant change in the degradation risk analyzes according to the base case.

ÖZET

TARİHİ BİNALARDA ENERJİ TÜKETİMİ VE ISIL KONFORUN OPTİMİZASYONU: İZMİR MİLLİ KÜTÜPHANE BİNASI ÖRNEĞİ, TÜRKİYE

Bir yapı tipi olarak 'kütüphane', araştırmacıların ziyaret ettiği ve geçmiş ve günümüz düşünürlerin bilgilerinin depolandığı bir alandır. Tarihi kütüphaneler, önceki nesillere ait kitaplar, el yazmaları, belgeler, haritalar, eserler, tablolar, heykeller ve duvar resimleri gibi kültürel mirasın eşsiz parçalarını barındırır.

Bu tez, tarihi İzmir Milli Kütüphane Binası'nda bulunan kağıt eserlerin bozulma risklerini dikkat alarak, binanın enerji tüketimini azaltmayı ve bina sakinlerinin konforunu artırmayı amaçlamaktadır. Böylece, tez bina iyileştirme tedbirlerini farklı etki kriterleri ile inceler ve en uygun olanları tanımlamak için optimizasyon aracını kullanır.

İlk olarak İzmir Milli Kütüphane Binası'ndaki kağıt eserlere üç adet bozulma risk değerlendirme yöntemi belirlenmiştir. Tez kapsamında, kütüphane binası 01.10.2016 – 01.10.2017 tarihleri arasında izlenmiştir. İzleme sürecinin sonuçlarına göre mekanik, kimyasal ve biyolojik bozunma risk analizleri yapılmıştır. İzmir Milli Kütüphanesi, DesignBuilder v. 7.0.0.102 yazılımında modellenmiş ve izleme sonuçları kullanılarak model kalibrasyonu yapılmıştır. Kalibrasyon sonrasında optimizasyonun tasarım değişkenleri olarak tanımlanan; cam tipi, dış kapı malzemesi, eğimli çatı zemin konstrüksiyonu, dış duvar konstrüksiyonu, ısıtma ayar noktası ve soğutma ayar noktası, nötr, yüksek ve düşük riskli güçlendirme etki değerlendirmesi açısından optimizasyon simülasyonu için kullanılmıştır. Optimizasyon simülasyonunun amacı, aynı anda enerji tüketimini ve konforsuz saatleri azaltmaktır.

Simüasyon sonuçları, kütüphane binasına göre, bütün güçlendirme etki değerlendirmesi optimizasyon seçeneklerinin enerji ve konforsuz saatleri azalttığını gösterdi. Senaryo 3 diğer senaryolar arasında kütüphane binasına göre enerji tasarrufunu %26.6'lık oranla ve konforsuz saatleri %80.3'lük oranla azaltarak en başarılı senaryo olmuştur. Her üç optimizasyon senaryosunda da, temel duruma göre bozulma riski analizlerinde önemli bir değişiklik olmamıştır.

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SYMBOLS AND ABBREVIATIONS

BES	Building Energy Simulation
BSM	Building Simulation Model
Clo	Clothing Insulation
CO_2	Carbon Dioxide
H_2S	Hydrogen Sulphide
HVAC	Heating, Ventilation and Air Conditioning
kWh	Kilo Watt Hour
LM	Lifetime Multiplier
M	Activity Level/Metabolic Rate
MRT	Mould Risk Factor
Na_2O	Sodium Oxide
O_3	Ozone
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
RH	Relative Humidity
SO_2	Sulphur Dioxide
T	Air Temperature
v	Air Velocity

CHAPTER 1

INTRODUCTION

1.1. Problem Statement

The 'library' is a building type that serves as a repository for the knowledge of thinkers, both past and present, and has the special duty of disseminating knowledge to all people without distinction. It is specially constructed for the collection and storage of recorded information. Human history's facts, theories, conceptions, and achievements are all preserved in the libraries (Dash, Sahoo, and Mohanty 2015). Additionally, libraries may host distinct cultural objects through their collections of old books, manuscripts, papers, maps, artifacts, paintings, sculptures, and frescoes.

Providing a proper indoor climate is a key overall design criterion to create a comfortable indoor environment for library users. Yet, the library may contain objects with cultural heritage values that require certain stable and equal indoor climate to preserve and maintain them. Tangible objects can deteriorate where they are stored or exhibited (Coşkun et al., 2017). Preservation of manuscripts and artworks are desired without any irreplaceable damage. External factors such as seepage, mechanical damage or earthquake and internal factors causing irreplaceable damages are strictly related to indoor microclimatic conditions (Litti, Audenaert and Fabbri, 2017). The indoor climate is also significant for the thermal comfort of visitors in the library.

Historic structures were built specifically to have architectural characteristics and thermal behaviour that complement the local environment. Additionally, they have a high thermal endurance, which can be both a benefit and a severe drawback, depending on the building's overall characteristics.

Many historic library buildings have free acclimatization solutions without heating and cooling systems. While this was acceptable, today, better air-conditioning can be achieved with the inclusion of HVAC technology in the historic library. From the perspective of visitors, several crucial factors must be considered including thermal comfort, and the maintenance of optimal airflow for fresh air needs. The user health in the library and the circulation of fresh air should be provided through openings and clean air ducts if necessary (Mašková et al. 2020).

Paper-based collections are mainly preserved with restorative or preventative conservation techniques (Bülow, Colston, and Watt 2002). Air temperature (T), relative humidity (RH), light, indoor air quality (gaseous and particulate pollution like carbon dioxide (CO_2), sulfur dioxide (SO_2), sodium oxide (Na_2O), ozone (O_3), hydrogen sulfide (H_2S), etc.), and microbiology should all be considered for the preventive conservation. (Dahlin, 2002). In the case of inadequate indoor conditions, chemical, mechanical and biological degradations may occur on paper-based collections. Higher T and RH levels trigger chemical degradation. The major causes of mechanical degradation are the fluctuations in T and RH. Extreme temperatures, high relative humidity, and availability of environmental substrates contribute to biological degradation (AICCM 2022), (Olesen et al. 2004).

The challenge for restoring historic library buildings is the need for a comprehensive approach. One of the biggest mistakes is to focus on solving one problem while creating other problems. The conservation of cultural heritage value of historic building itself is essential, yet the need of library users and preservation requirements of paper-based collections should also be fulfilled. In addition, the energy consumption in historic library buildings may be relatively higher due to the material choices and poor detailing. At the same time, the indoor thermal comfort for users may not be at an enough level due to the chosen heating system and cooling solutions. While energy consumption and thermal discomfort levels may be higher, the degradation risk of manuscripts is also an issue of great importance. Energy saving, proper thermal comfort conditions and preservation of paper-based collections must be resolved simultaneously without interfering with unique architectural characteristics of historic library buildings. Proposed solutions should be based on the findings obtained as a result of real-time analysis and diagnosis study conducted before any retrofit action in a historic library.

1.2. Aim of the Study

Historic buildings should be considered by their functions. Any improvement should both protect historic artifacts inside the building and provide thermal comfort of the visitors. An optimization study is required considering architectural characteristics and heritage value of building components, while carefully deciding for any improvement, i.e. building retrofit actions.

The historic libraries should adapt to today's thermal comfort expectations of users and the conservation requirements of paper-based collections defined by the standards. Any active interventions, e.g. HVAC installation and/or physical retrofits, and passive solutions, e.g. operational rescheduling, should be optimized in order not to cause excessive energy consumption and unbalanced thermal discomfort while minimizing degradation risks of paper-based collections.

This thesis aims at reducing energy consumption and improving occupants' thermal comfort while paying attention to degradation risks of paper-based collections hosted in İzmir National Library Building. It conducts a multi-objective optimization study by using DesignBuilder dynamic simulation software to define right building elements and materials. In addition, the degradation risks of paper-based collections are assessed based on proposals for reducing energy consumption and discomfort hours. The following research questions are evaluated in the scope of this thesis:

- How can the energy consumption of İzmir National Library Building be reduced?
- How can the thermal comfort in the reading room of library be increased?
- What kind of retrofit scenarios can be developed for İzmir National Library Building that reduce both energy consumption and thermally discomfort hours?
- What are the impact of these scenarios on the degradation risks of paper-based collections in İzmir National Library Building?
-

1.3. Limitations and Assumptions

In this thesis, there have been some limitations and assumptions as indicated below:

- In this thesis, the indoor monitored data of İzmir National Library Building is provided by Çağrı Topan who conducted his uncompleted MSc thesis study in the same building in the Interdisciplinary Programme of Energy Engineering in İzmir Institute of Technology (Topan 2019). The air temperature and relative humidity values monitored between 01.10.2016 and 01.10.2017 in the ground and first floors of building are evaluated in the degradation risk assessment of paper-based collections and the calibration process of DesignBuilder model. The official approval document is indicated in Appendix B, as Figures B.1, B. 2 and B.3.

- There was no available monitored data for outdoor weather conditions around İzmir National Library Building. Thus the outdoor air temperature and relative humidity data between 01.10.2016 and 01.10.2017 were obtained from the Turkish State Meteorological Service for Konak district, where İzmir National Library Building is located. The data were officially derived from the station located at the coordinates of 38.39° North and 27.08° East in the 2nd Regional Directorate of Meteorology, İzmir. The direct distance between the station and İzmir National Library Building is 4803 meters, situated to the southwest of case building.
- The ceiling of atrium, namely reading room, has covered with colorful stained glass. The attic floor over the atrium is covered with the glass Marseille tiles, permitting the sunlight penetration to the reading room. In the DesignBuilder simulation model, the colors of stained glass are not specified; it is identified as clear glass. The glass Marseille tiles are also indicated as the glass opening.
- The wrought irons in front of windows located outside of the building were not considered as building element in the simulation model.

1.4. Thesis Outline

This study consists of five chapters. In the first part, the general framework and scope on historic buildings, libraries, retrofitting and degradation risks in historic buildings were drawn. After mentioning research problems revealed with the thesis work, the aim and research questions were explained that the thesis was designed to answer. The introductory chapter is concluded by stating the existing limitations and assumptions for this thesis.

In the second part, the literature review reveals the basic terminology related to the thesis. The literature review section consists of three main titles and three sub-titles. The main titles are optimization studies in historic building, historic libraries and dynamic model of historic building. Energy efficiency in historic buildings and thermal comfort in historic building are the sub-titles of the first main title. Degradation risk factors of paper-based collections is the sub-title of the second main title. Literature about optimization studies, optimization studies for improving energy efficiency and thermal comfort are mentioned. Historic libraries and degradation risk factors of paper-based collections in historic libraries are also mentioned in literature review section. Lastly, brief explanation and examples of dynamic model of historic building is located at the end of literature section.

The materials and methods section consists of ten subsections. It starts with monitoring process of air temperature and relative humidity in İzmir National Library Building between 01.10.2016 and 01.10.2017. Then, detailed explanations of degradation risk factors are mentioned. The case of this thesis, i.e. İzmir National Library, is introduced by explaining building history, outdoor weather information of İzmir, architectural and constructional characteristics, operation schedule of HVAC system, occupants, lighting and equipment via photographs and tables. By using DesignBuilder software v. 7.0.0.102, building simulation model (BSM) were created. The building materials of the base case building and the surrounding buildings were also added to the work. Retrofit impact assessment which is five-level assessment criteria and scale of feasible retrofit levels for historic buildings are introduced by CEN EN 16883 (BSI Committee B/560, 2015) were mentioned in this chapter. Three optimization scenarios prepared according to retrofit impact assessment were also included in this section. Creation process of DesignBuilder model, calibration process of simulation model, optimization simulations and scenarios subjects were also explained in the fourth chapter.

Results and discussions were the fourth part of the thesis. This part started with presenting the monitoring results and degradation risk analysis for the base case. After that, BES model calibration results explained with tables. Ensuing subtitle was results of energy consumption and discomfort hours of base case simulation model introduced with tables. The results of multi-optimization analysis based on discomfort hours and energy consumption for each scenario were included in this section. Following part was comparison of optimization results of all scenarios and base case. In addition, mechanical, chemical and biological degradation risk analyzes for each scenario’s optimization option were also presented in this section. Degradation risk analysis of midpoint optimization options of all scenarios and base case were compared at the last part of this section.

In final section, recommendations and future studies sections are explained.

CHAPTER 2

LITERATURE REVIEW

Literature survey is performed for six main purpose of the thesis. One for optimization studies in historic building. Secondly and thirdly, energy efficiency and thermal comfort in historic building. Next one is historic libraries. Also, degradation risk factors of paper-based collections. Lastly, dynamic model of historic building.

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2.1. Optimization Studies in Historic Buildings

The benefit of 3D simulation modelling is the ability to examine the progress of the thermal features of the building worked (Martínez Molina, Tort Ausina, and Vivancos 2014). Due to the difficulties of determining how much the various restoration measures fulfill the various objectives (Kaklauska et al. 2005) the selection of the best solution and alternative comparison become more complex as the number of measures increases (Penna et al. 2014). Thus, optimization techniques are required, particularly given the inherent conflict and nonlinear interactions between the criteria. Finding the best scenario is necessary, according to certain research. The physical or operational improvements that lower the amount of energy usage is called an energy retrofit, which gives a chance to increase building energy performance. These changes might be connected to the building itself, residents' behavior, or energy-consuming equipment (Jafari, Valentin. 2017). According to global and local environmental challenges and energy legislations, numerous optimization studies have been carried out: some studies have focused on improving building envelope, heating or cooling systems, or occupants' behavior individually.

2.1.1. Energy Efficiency in Historic Building

Each part of the library should be specially designed according to the valuable paper-based heritages and occupants. In historic building, architects should ascertain how to reduce energy consumption. Energy consumption is a huge problem for libraries. These days, perhaps the biggest test of historic centers is to accomplish supportability by diminishing expenses and vitality requests without imperiling preservation and warm solace (Silva et al. 2016). Energy-efficient and sustainable library building projects could exactly meet the architectural, functional, and cosiness

Many experts and researchers are faced with the concerns of how to define the energy efficiency rating and how to evaluate the energy performance of buildings when energy conservation and efficiency issues occur. Energy efficiency is the use of less energy or the avoidance of excessive energy use without compromising the functionality and comfort of buildings. Energy performance assessment is crucial for establishing how effectively buildings use their energy, giving building owners or occupants' precise information on how much energy is consumed and how well they are performing in relation to current energy benchmarks. It gives clear information on how much energy is utilized and how performance is assessed against existing energy measures to building owners or building occupants. Any measure taken to limit energy usage will have lower operating and maintenance expenses due to building energy performance assessment (Wang, Yan, and Xiao 2012).

The definition of the term "retrofit" is "to add something to something that was not originally constructed, or to give something with a component or function that is not fitted during manufacture (Eames et al. 2014). Buildings that make adjustments to the systems inside the building and even to the structure itself at some point after initial construction and use are considered to be retrofitted (Mazzarella 2015). Retrofit refers to changing the structure of a building, such as adding insulation to walls and upgrading the glazing system, in order to boost a building's energy efficiency. In this sense, retrofit is more about the installation of new technologies. Renovation is a wide improvement process that involves repairing, renovating, and altering a building's specifications. Buildings are a good candidate for renovation. The installation of building systems and energy-saving measures are also sometimes included in renovation, which primarily focuses on aesthetics and inhabitants (Mazzarella 2015).

In the optimization process, exercised the five-level assessment criteria and scale of feasible retrofit levels for historic buildings which are introduced by CEN EN 16883 (BSI Committee B/560, 2015) (Figure 3.19). A special and comprehensive study should be adopted to retrofitting the historic buildings that have been in existence for a long time and reflect the heritage of past cultures and also have a unique architecture. When considering any retrofitting work on a historic building, it is necessary to have information about the structural condition of the building, the function of the building and its harmony with the surrounding people. Retrofitting works should be carried out to increase energy efficiency, ensure human comfort and protect the cultural heritage in the historic building correctly.

Assessment Scale				
High Risk	Low Risk	Neutral	Low Benefit	High Benefit

Figure 2. 1 The five level assessment scale for retrofit impact assessment
(Source: CEN EN 16883, 2015)

2.1.2. Thermal Comfort in Historic Buildings

Historic buildings usually have amazing and enchanting former simple technology (Martínez Molina, Tort Ausina, and Vivancos 2014). Works determined that interior microclimate in historic buildings is sorely affected by outdoor environmental conditions (Litti, Audenaert, and Fabbri 2017). Indoor climate quality of a building might be smitten either by exterior air or by interior mechanisms. Works determined that interior microclimate in historic buildings is sorely affected by outdoor environmental conditions. It is essential to work in order to prevent the indoor microclimate from being affected by the outdoor conditions in historic buildings. In addition, integrated design is needed to guarantee the conservation of objects and architecture as well as to reach high performance in energy efficiency, indoor climate and moisture safety in building physics (Napp et al. 2016). The fact is that the occupant’s well-being is affected by different features of the building, exposure to daylight and reach to views, air quality, temperature, odours, and roar (Michael and Zuraidah 2010).

Human health, productivity, and well-being are impacted by the thermal environment. The condition sine qua non for the design and operation of heating, cooling, ventilating, and air-conditioning systems when it comes to the internal environment of a building is the establishment of specific criteria that ensure human health and well-being. An energy declaration without a declaration pertaining to the indoor environment is useless, according to EU standard EN 15251 (Olesen 2015). Therefore, special criteria for the indoor climate are required for building design, energy estimates, performance, and operation.

The effect of interior physical characteristics on the thermal experience is used to measure the quality of the indoor thermal environment. The assessment of this relationship can be done using a variety of scientific methodologies, including physiological, physical, psychological engineering, and biomechanical ones. There are many indices and metrics that have been presented to measure the effect of the thermal environment on thermal perception. Over 70 indices have been presented in the past 100 years (Epstein and Moran 2006).These thermal comfort or discomfort indices can now be used to describe how thermal surroundings affect humans (Carlucci and Pagliano 2012).

In the widely used ASHRAE 55 and ISO 7730 standards for assessing indoor environments, thermal comfort is now described as "that state of mind that expresses satisfaction with the thermal environment." Engineers must first identify the thermal feeling or thermal balance occupants of an interior space may experience in conjunction with the thermal discontent experienced by occupants in order to analyze this situation. The PMV and PPD indices can be used to describe these comfort levels (Cheung et al. 2019).

2.2. Historic Libraries

A historic building is a notable structure that possesses both tangible and intangible heritage values, such as architectural and aesthetic qualities, connections to historic locales and occasions, illustrations of technical advancement, traits of social history, and relationships with other structures that also possess heritage qualities. An historic building's identity is formed by all of these values. On the other hand, unlike historic structures, historic buildings may or may not be significant historically (Akkurt et al., 2020).

Studies on historic buildings have been done extensively in the literature. There are also studies for the conservation and strengthening of the historic library building. In the study for the Tire Necip Paşa Library building (Çağırgan. 2022), the HVAC system was examined to protect the paper-based collections for long-term in the historic library building. Results of the study shows that the HVAC system, with its existing settings, will struggle to maintain a stable and balanced interior environment in 30 years and will be significantly less stable in 60 years. The cause is that further climate change will result in a more erratic and unstable indoor climate. As a result, there will be a significant danger of mechanical degradation in the future. In addition, the danger of chemical degradation will be greater than it was for 2019-2020. Therefore, in the future, HVAC settings should be adjusted as necessary to account for climatic variations.

2.2.1. Degradation Risk Factors of Paper-Based Collections

It is possible to evaluate and acquire data for different combinations of metabolic rate, insulation, temperature, airspeed, mean radiant temperature, and relative humidity that affect PMV using ASHRAE 55 and ISO standards for certain types of situations. The simulated temperature and airspeed velocity of a certain environment are utilized as inputs to compute PMV (i.e., the ASHRAE/ISO standards advice applying an adaptation for speeds exceeding 0.2m/s). The basis for calculating PMV is provided by these variables, as well as the supplied inputs for garment insulation, relative humidity, and mean radiative temperature. We can anticipate a population's thermal perception using PMV, but this does not provide a complete picture. To acquire a more complete understanding of whether and how thermal comfort may be attained, we also need to take into account the degree of happiness of the space's inhabitants. Fanger used a different calculation to link the PMV to the expected percentage of dissatisfaction (PPD) in order to account for this. The PPD, or index, which creates a quantitative forecast of the percentage of thermally unsatisfied occupants (i.e., too hot or cold), can be calculated once the PMV has been established. PPD basically indicates the proportion of persons who are expected to feel localized pain (Olesen et al. 2004).

Discomfort hours for occupants in building is related to indoor thermal comfort. Indoor thermal comfort level is not at the appropriate level occupant will feel discomfort. Discomfort hours data is based on whether the humidity ratio and the operative temperature is within the region. For these outputs the operative temperature is simplified to be the average of the air temperature and the mean radiant temperature. For summer, the 0.5 Clo level is used and, for winter, the 1.0 Clo level is used.

Indoor environment (temperature, humidity, and illumination) and indoor environmental quality (gaseous and particulate pollutants such SO2, Na_2O, O3, H_2S, acid and alkaline particles) characteristics pose the most risk to paper-based collections (Dahlin, 2002). On publication archives, degradation results in physical modifications. Tables 2.1 and 2.2 depict recommended T and RH values for paper-based collections by standards and curators (AICCM 2022).

Table 2. 1. International regulations 1 (Source: (Andretta, Coppola, and Seccia 2016))

Reference	**Material to be conserved**	**T(°C)**	**Allowable Daily Fluctuations T(°C)**	**RH (%)**	**Allowable Daily Fluctuations (%)**
ISO 11799, 2003	Paper, optimal storage	2-18	±1	30-50	±5
Standard UNI 10829,1999	Paper documents	13-18		5-60	±5
BSI 2000	Paper based collections	13-18		55-65	
Standard UNI 10586, 19978	Library heritage	14-20	±2	50-60	±5
Wilson (1995:2)	Paper documents	21 max.	±2	30-50	±3
Lull (1995:7)	Paper documents	15.5 – 23.8		40-45	
PD 5454, 2012	Storage of library and archive collections	13-20		35-60	
Bülow, 2002	Paper based collections	19-21		50	
Briggs, 1987	Paper based collections	21		40-50	

Table 2. 2. International regulations 2 (Source: (Andretta, Coppola, and Pavlovic 2015))

	For chemical and mechanical degradation				For Biological degradation			
	T(°C)	**Allowable Daily Fluctuations T(°C)**	**RH (%)**	**Allowable Daily Fluctuations (%)**	**T(°C)**	**Allowable Daily Fluctuations T(°C)**	**RH (%)**	**Allowable Daily Fluctuations (%)**
MIBACT, 2001 for books and manuscripts	19-24		50-60		<21	±3	40-55	±5
MIBACT, 2001 for paper	19-24		50-60		18-22	±1.5	40-55	±6

The factor that has the greatest influence on the composition of sheet is moisture. Paper always travels to/from environments with lower/higher RH, therefore it both collects and desorbs moisture from this kind of environments. The maximal liquid limit of the paper has a significant impact on moisture capacity. Changes in indoor RH result in buffering. Constant dampness ruins the paper. Long-term exposure to high moisture content shortens the life of the paper, and it also promotes the growth of mold. Longer durations of humidity exceeding 60% are often more detrimental than brief periods of extremely high RH levels. The majority of paper things can withstand a 25% daily drop (Michalski 1993).

As shown in Table 2.3, ASHRAE Chapter 21 (2007), appropriate indoor air temperature and relative humidity values for paper-based archives are stated there. The table defines five different climatic classifications. Class A has no danger of degradation, but classes B, C, and D have low, medium, and severe risks of degradation, respectively. The minimal indoor climatic requirements for paper-based collections are met in climate class A. Objects that are extremely prone to mechanical damage, such as manuscripts and books, are at a low risk with Class As. According to ASHRAE Chapter 21 (2007), particularly sensitive artifacts like paper-based archives ought to be preserved at historic annual value or at fixed values such as 15°C T 25°C and 50% RH.

Table 2. 3. Library climate guidelines (Source: ASHRAE Chapter 21, 2007; Martens, 2012)

Type	Set point or annual value	Maximum Fluctuations and Gradients in Controlled Spaces				Collection Risks and Benefits
		Class of Control		Short Fluctuations & Space gradients	Seasonal adjustments in system set point	
General Museums, Art Galleries, Libraries and Archives	50% RH Between 15-25 °C	AA		±5%RH, ±2K	RH no change, ±5K	No risk of mechanical damage to most artifacts and paintings. Some metals and minerals may degrade if 50% RH exceeds a critical relative humidity. Chemically unstable objects unusable within decades.
		A	As	±5%RH, ±2K	±10%RH, +5K, -10K	Small risk of mechanical damage to high vulnerability artifacts; no mechanical risk to most artifacts, paintings, photographs and books. Chemically unstable objects unusable within decades.
			A	±10%RH, ±2K	RH no change, +5K, -10K	
		B		±10%RH, ±5K	±10%RH, +10K but not above 30 °C, down as low as necessary to maintain RH control	Moderate risk of mechanical damage to high vulnerability artifacts; tiny risk to most paintings, most photographs, some artifacts and some books; no risk to many artifacts and most books. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods double life.
		C		Within 25% to 75% year-round Temperature rarely over 30 °C, usually below 25 °C		High risk of mechanical damage to high vulnerability artifacts; moderate risk to most paintings, most photographs, some artifacts and some books; tiny risk to many artifacts and most books. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods double life.
		D		Reliably below 75%		High risk of sudden or cumulative mechanical damage to most artifacts and paintings because of low humidity fracture; but avoids high humidity delamination and deformations, especially in veneers, paintings, paper and photographs. Mold growth and rapid corrosion avoided. Chemically unstable objects unusable within decades, less if routinely at 30°C, but cold winter periods double life.

In addition to the proactive preservation of paper-based collections, maintaining a healthy interior atmosphere in historic libraries depends on the thermal comfort of visitors (Turhan, Arsan, and Akkurt 2019). Thermal comfort is defined by ASHRAE 55 (2011) as a subjective experience that depends on two individual characteristics, clothing value (clo) and metabolic rate, as well as four environmental elements, including indoor T and RH, mean radiant temperature (MRT), and air velocity (v) (met). In older libraries, visitors' thermal comfort should also be examined. The most widely used international standard for thermal comfort is ASHRAE 55 (2010). According to ASHRAE, "thermal comfort" is "the state of mind in which happiness with the thermal environment is conveyed" (ASHRAE 55, 2010). Thermal comfort is effected by personal differences in mood, culture and other individual, organizational and social factors and is generally evaluated with physical, physiological and psychological factors. Thermal performance is often measured using physical, biological, and psychological variables and is influenced by individual variances in emotion, lifestyle, and other personal, institutional, and societal factors.

2.3. Dynamic Model of Historic Buildings

Computer programs are used to correct or improve energy consumption, comfort, natural ventilation, etc. problems in historic buildings. These studies are available in the literature. Using the DesignBuilder software, two historic buildings in Malta; In Auberge de France, Birgu and Casa Rocca Piccola, Valletta, studies have been conducted on how much energy it can consume with real energy consumption and new studies (Mallia, Prizeman. 2018). In addition, the testing of suitable conditioning mechanisms to protect manuscripts in libraries from degradation was also done in these computer programs. The air conditioning system recommended for the protection of manuscripts in the historic Necip Paşa Library from chemical, mechanical and biological degradation was made using the DesignBuilder software. In another study for the Historic Necip Pasha Library, the study of how many years the manuscripts in the historic library building can be preserved with the current air conditioning and how long they can be preserved with the suggestions of air conditioning systems was done using the same program (Çağırgan. 2022). Another study using dynamic modeling was conducted to find the impact of low-energy strategies that could be applied to improve the indoor thermal environment and cooling energy consumption of library buildings in hot and humid cities such as (Nanning, China) (Li, He. 2021). It is observed in the literature that the studies to be carried out using dynamic modeling are tested before the studies to retrofit the historic buildings.

CHAPTER 3

MATERIALS AND METHODS

Objectives of the Thesis;

- Determine whether if degradation risks exist on the paper-based collection and studying to reduce degradation risks.
- Determining discomfort hours and increasing comfortable hours for visitors and staff with optimization work.
- Using the optimization exercise to reduce energy consumption by taking into account the unique architecture of the historic building.

As explained in the literature review section, the risks of degradations of manuscripts are investigated by measuring the indoor climate and using the measurement results with various risk analysis methods. Monitoring processes are conducted for at least one year in order to collect the necessary measurement data. Using monitoring results, degradation risk analysis were done. Then, creation of simulation model in DesignBuilder v. 7.0.0.102 software was started. Additionally, measurement data is used to calibrate BES models, which check the model's validity; so that accurate results can be obtained through simulations. After that, calibrated model was used to investigate annual energy consumption and discomfort hours. Then, for optimization, the design variables were determined and the optimization process was carried out. According to the results of the optimization study, optimum scenarios were selected. Finally, selected scenarios'' determined degradation risk analysis were made.

The methodology of the thesis consists of consecutive studies (Figure 3.1). The studies lay the groundwork for the next step to begin. Some of the studies aim to prove themselves by comparing them with each other.

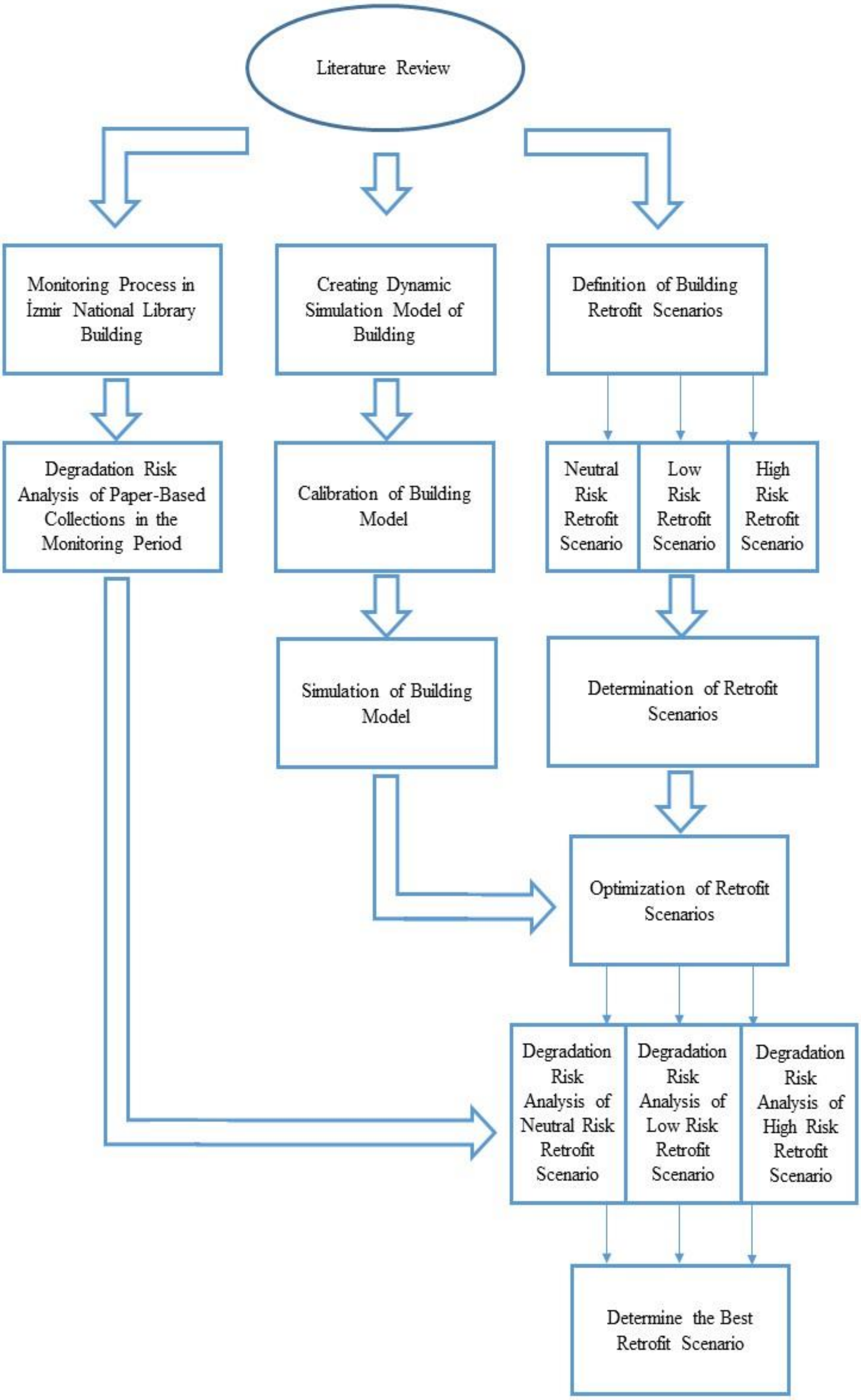


Figure 3. 1. Methodology flowchart

3.1. Monitoring Process

Degradation risk for paper-based collections are evaluated by the data obtained from T and RH measurements that conducted for one year from 01.10.2016 to 01.10.2017. The measurements were taken from two different zones of the library: ground floor and first floor.

For calibration and paper-based collections degradation risk are evaluated by the data obtained from T and RH measurements that conducted for one year from November 2016 to November 2017. The locations and the types of the data loggers are given in Figure 3.2. The T and RH measurements were taken every ten minutes by 7 mini data loggers that located in the book shelve on study room, study room on the ground floor and first floor. Furthermore, outside of the weather data was taken from Turkish State Meteorological Service for Konak district. All data loggers located 1.5 m above from the ground level. List of the data loggers are given in Table 3.1.

The monitoring process for İzmir National Library Building was carried out by Çağrı Topan who had conducted the uncompleted MSc Thesis in İzmir National Library Building in the Interdisciplinary Programme of Energy Engineering in İzmir Institute of Technology by 2019 (Topan 2019). The name of the thesis was ‘Comfort Based Investigation on Historic Libraries for User Satisfaction and Preservation of Paper-Based Collections. Case Study: İzmir National Library, Konak, İzmir, Türkiye’. The monitored data specific for the period of between 01.10.2016 and 01.10.2017 was used in this thesis by the permission of Çağrı Topan and the team members of the bilateral project namely ‘Energy Analysis and Comfort Study in İzmir National Library’ between İzmir Institute of Technology and Foundation of İzmir National Library in 2017. The official approval report is attached in Appendix B (Figures B.1, B.2 and B.3).

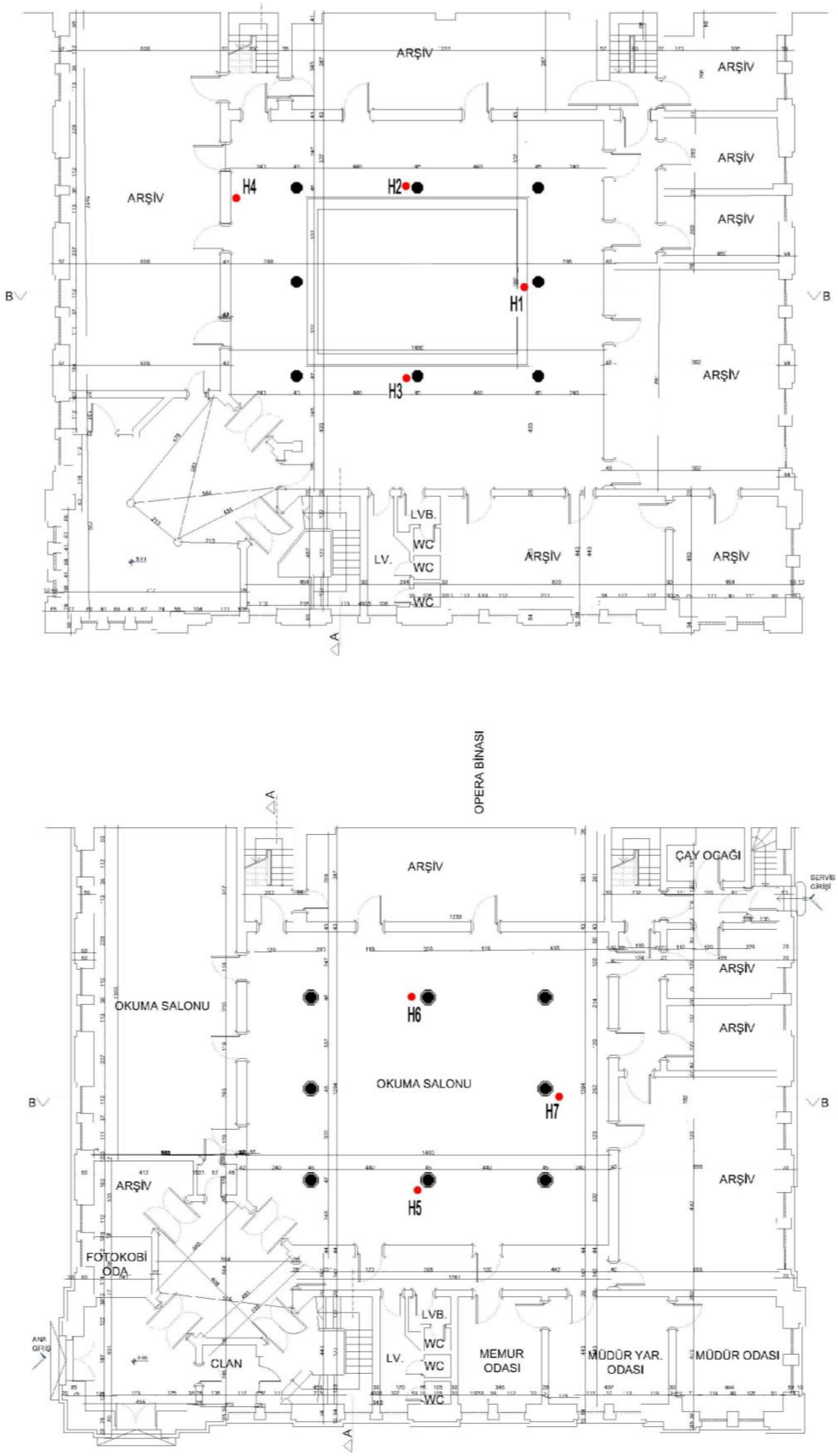


Figure 3. 2. Location of data loggers on the study hall and first floor

Table 3. 1. List of the data loggers (Air Quality Monitoring | Onset Data Loggers)

Items	Description
H1, H2, H3, H4, H5, H6, H7	HOBO U12-012 T/RH

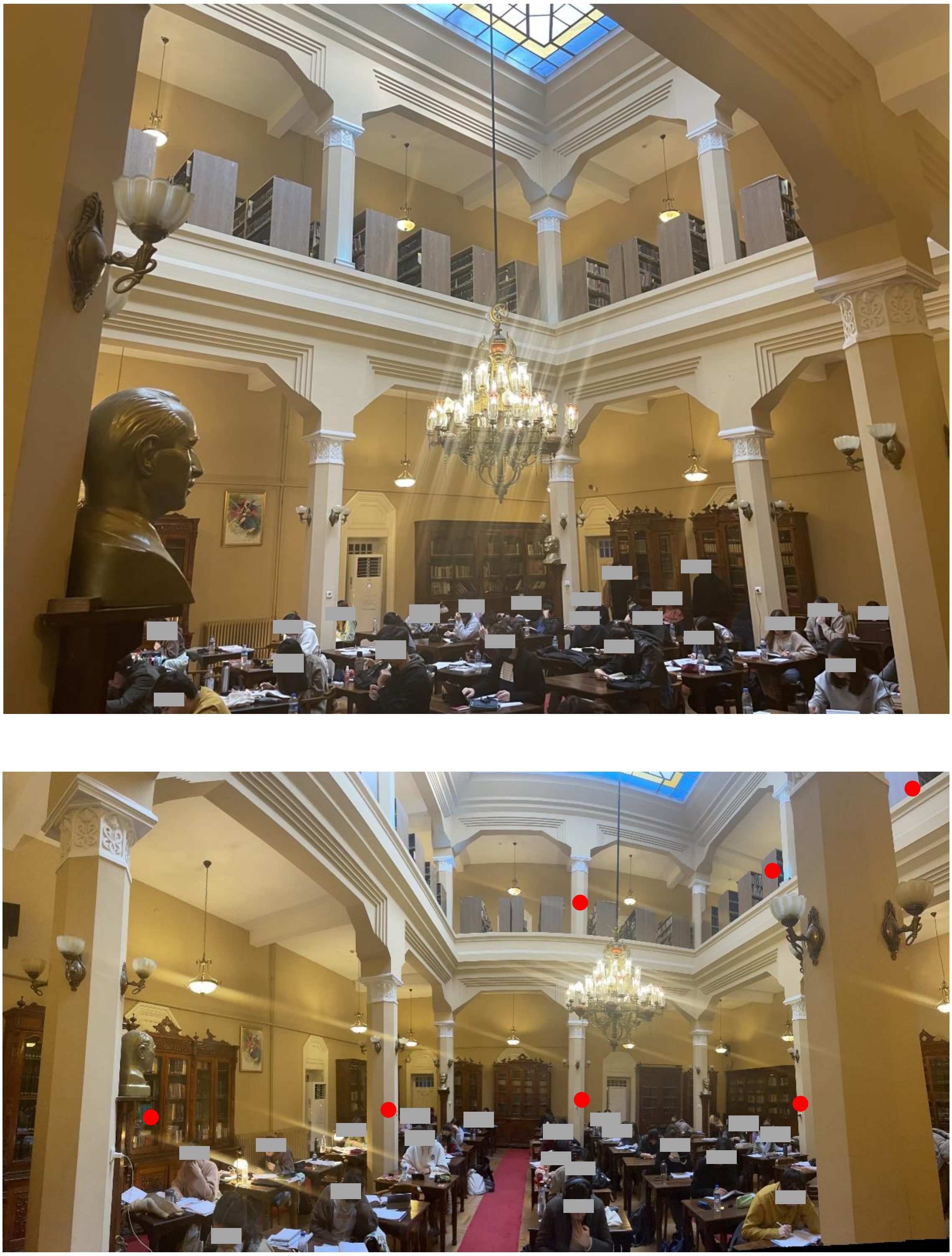


Figure 3. 2 Study hall, first floor and book shelves (Source: Umut Özsavaşcı, 2022)

3.2. Degradation Risk Factors

3.2.1. Chemical Degradation

The universal gas constant and the cellulose activation energy are 100 kJ/mol and 8.314 J/mol.K, respectively. Equation 3.1 states that a change of 1 °C and 5% RH results in the same outcome (Michalski 2002). The objects' lifetimes are duplicated by a 5K decrease at 20 °C (Derluyn et al. 2007). The object's lifespan doubles when the relative humidity falls to %59 of the value.

Table 3.2 displays the LM values and accompanying risk values. Lower LM values below 0.75 are indicative of increased chemical danger. Between 0.75 and 1.0, the LM value denotes a possible chemical concern.

Chemical degradation is evaluated by LM method as given in Equation 3.1.

$$LM_X = (\frac{50\%}{RH_x})^{1.3} \times e^{\frac{E_a}{R}(\frac{1}{T_x+273.15} - \frac{1}{293.15})} \qquad (3.1)$$

Table 3. 2. Critical LM values (Silva and Henriques, 2015)

	Ideal	**Good**	**Some Risk**	**Potential Risk**	**High Risk**
LM	>2.2	[1.7-2.2]	[1-1.7]	[0.75-1.0]	<0.75

3.2.2. Mechanical Degradation

The primary causes of mechanical degradation are short-term RH changes and externally applied stresses (Erhardt and Mecklenburg 1994). (Sahin et al. 2017). The properties of the material are altered by variations in humidity equilibrium, which can result in ripping, swelling, and embrittlement. When RH exceeds 80%, animal glues start to weaken and lose their adhesive power (Bülow, Colston, and Watt 2002). If the strain is greater than the yield point strain, humidity changes that last longer than an object's reaction time result in mechanical degradation. Mechanical degradation happens at RH values between 25% and 65%. Warping, cracking, embrittlement, and delamination are seen at low RH levels, but excessive moisture content combined with stress results in relaxation and permanent deformation (Bülow, 2002; Dahin et al., 2017). According to ASHRAE, small period variations are permitted for paper-based collections at a maximum of 5% RH and 2°C. Calculating the estimated daily Temperature and relative humidity variations, if 90% of the T or RH measurements are less than 2°C and 5% RH, mechanical degradation is not anticipated (Grygierek, 2014).

3.2.3. Biological Degradation

There are four substrate classes according to (Silva and Henriques 2014) (Table 3.3.), categorization. In Substrate Class II, where spore germination is to be avoided, paper-based collections are conducted. Biological degradation, as shown by mold growth on a material's surface, is determined by mold risk factor (MRF) (Table 3.4.).

Table 3. 3. Substrate classes (Source: Silva and Henriques, 2014)

Substrate Class 0	**Substrate Class I**	**Substrate Class II**	**Substrate Class III**
Optimal culture medium	Biologically recyclable building materials	Biologically adverse building materials	Building materials that are neither degradable nor contain any nutrients

Table 3. 4. Degree of risk according to MRF (Source: Silva and Henriques, 2014)

MRF	**Class 5**	**Class 4**	**Class 3**	**Class 2**	**Class 1**
	Ideal	Less demanding	Some risk	Potential Risk	High Risk
	0	<0.5	0.5≤MRF<1	1	>1

Table 3. 5. Description of mold index values (Source:(Vereecken, Saelens, and Roels 2011))

Index	Description
0	No mold growth
1	Some growth visible under microscope
2	Moderate growth visible under microscope, coverage less than 10%
3	Some growth detected visually, 10-30%
4	Visual coverage 30-70%
5	Coverage more than 70%
6	Tight coverage, 100%

3.3. Case Study: İzmir National Library

İzmir National Library is located in the city center, Konak, in İzmir in Türkiye with the coordinate's 38° 24' 52.1208" North and 27° 8' 38.8428" East.

Figure 3. 3 Location of İzmir National Library (Source: Umut Özsavaşcı 2022)

Exterior view of the library is shown on figure 4.2. Library is open to visitors from 08.30 till 17.30, 6 days a week except Sunday. 52 visitor seats are located at the study hall.

İzmir National Library Building was taken under The Republic of Türkiye, Ministry of Culture and Tourism, İzmir Regional Board of Protection of Cultural Heritage No. I. Because it is not only historic building but also it has unique architecture. As the report says, this building, which is designed for neo-classically, has an important place for the city of İzmir and it is quite normal to be protected (Figures A.1 and A.2).

Figure 3. 4 Exterior view of the library (Source: Umut Özsavaşcı, 2022)

3.4. History of the Building

The İzmir National Library Building first welcomed visitors on July 6, 1912, in a rented structure. On May 14, 1915, work on the most current library building began. To help the library raise money, a movie theater was also built at the same time. After the First World War, from May 15, 1919, until September 9, 1922, when building was halted, İzmir was occupied by the Greek army. Construction resumed after the establishment of the Turkish Republic on October 29, 1923. A library fund was created in 1925. The movie hall, which is on the left side of the library, was finished in 1926. On October 31, 1933, the library's brand-new, modern structure officially opened to the public. Tahsin Sermet Bey was the architect. The library fund had received a 50% transfer of the movie hall's revenue. Since 1934, the library has been home to all of the magazines. At the end of 1996, the overall inventory included 290606 books, 3792 manuscripts, and 44 stone mold prints, and 9058 hardcover newspapers, 950 newspapers without covers, 16238 hardcover journals, and 4473 journals without covers. The library has a collection of 4,000 Arabic, Persian, and Turkish manuscripts that were written throughout the Seljuk and Ottoman Empires. These collections contained 72 priceless Qurans as well as Dusturname that Enveri had authored in 1464–1465.

Figure 3. 5 Old picture of the library (Source: (2022 İzmir National Building Official Web Site)

3.5. Local Weather Data

İzmir is in Csa region, as per Köppen-Geiger Climate Classification, Mediterranean climate, temperature is warm, summer is dry and hot.

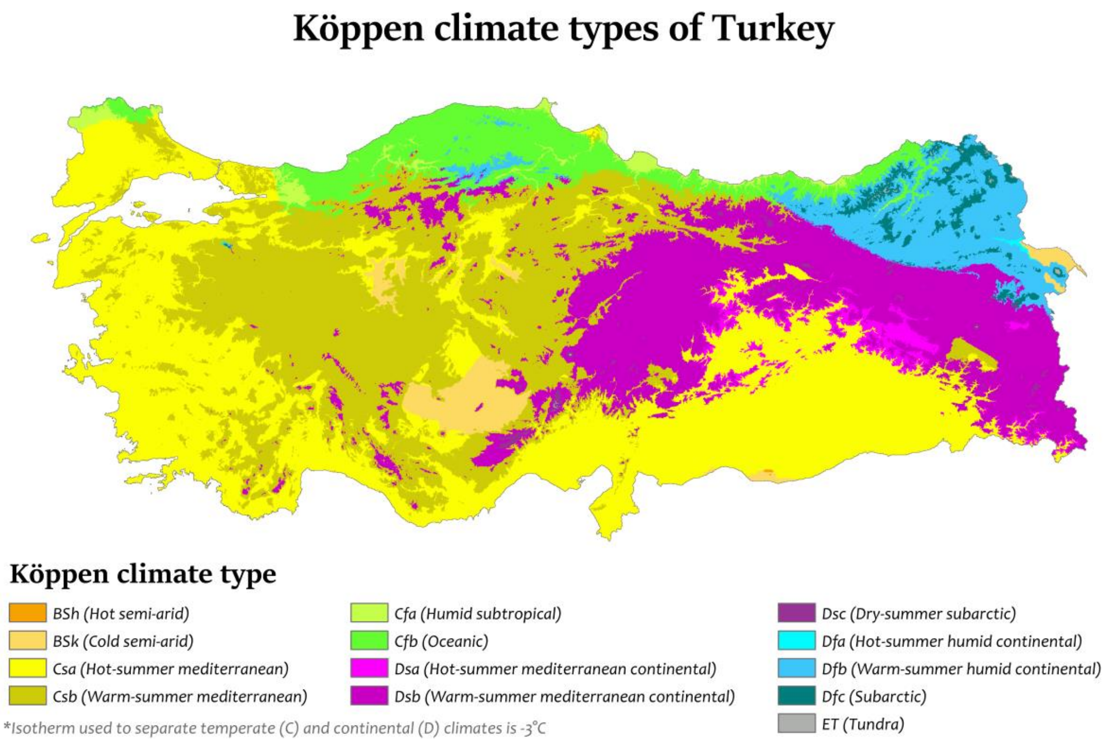


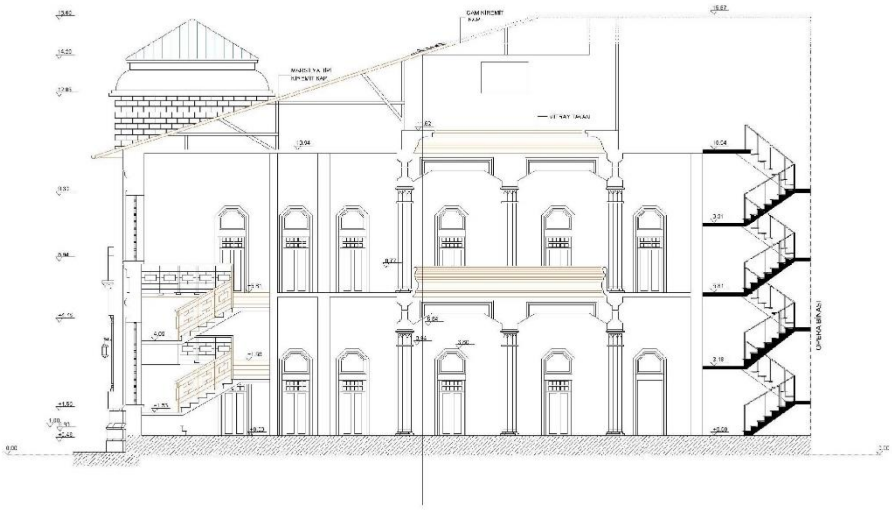
Figure 3. 6 World map of Köppen-Geiger Climate Classification (Source: Rubel and Kottek 2010)

Table 3. 6. Maximum and minimum temperatures for İzmir, Konak

	Winter (December, January, February)	Summer (June, July, August)
1938-2016 Maximum temperatures (°C)	25.2, 22.4, 23.8	41.3, 42.6, 43.0
1938-2016 Minimum temperatures (°C)	-2.7, -4.0 ,-5.0	10.0, 16.1, 15.6

3.6. Structure of the Library

Library is two storey building, ground floor is open to the first floor. Closed shelves are at the study hall on the ground floor, open shelves are at the first floor. Study hall is 195 m^2 and surrounded by achieve rooms. Because of security of collections, visitors cannot reach to the first floor and achieve rooms.



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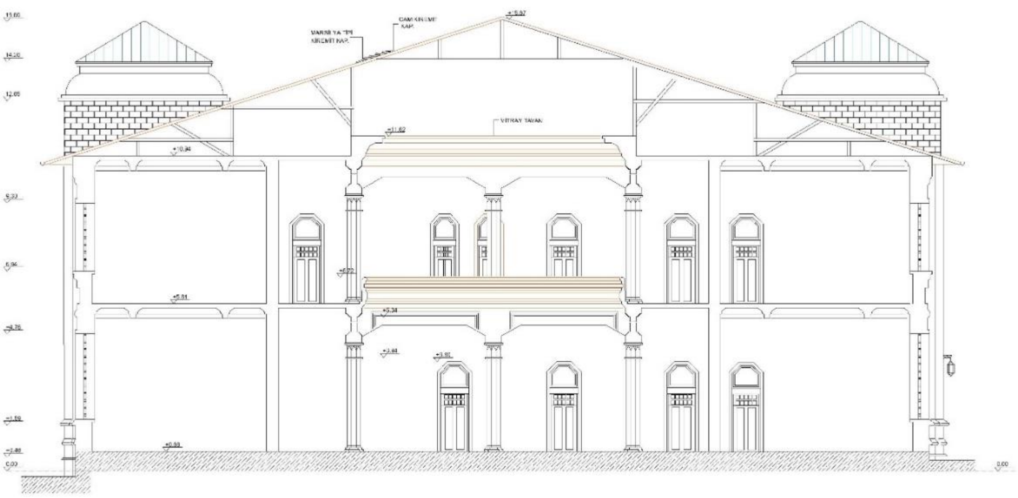

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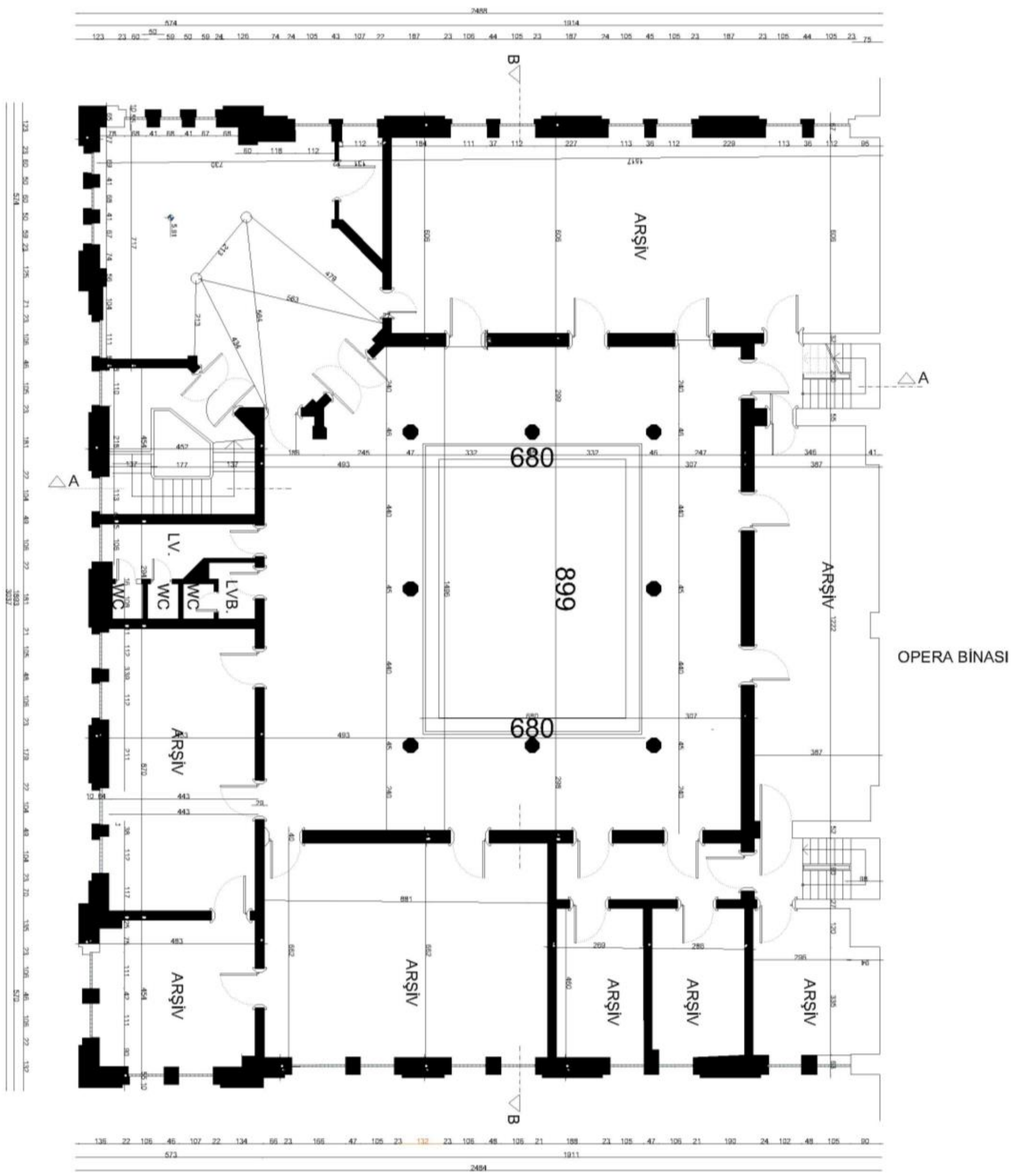
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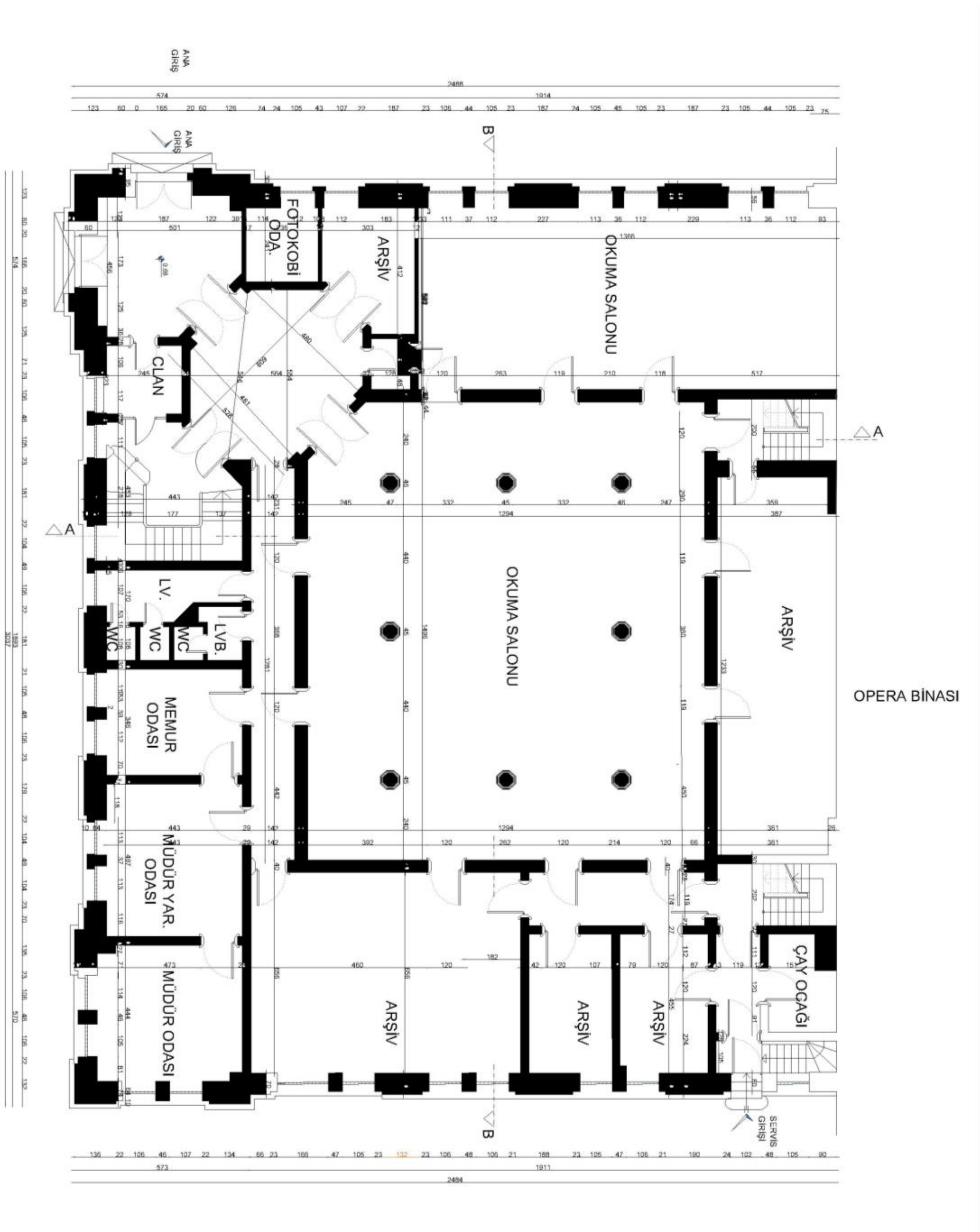
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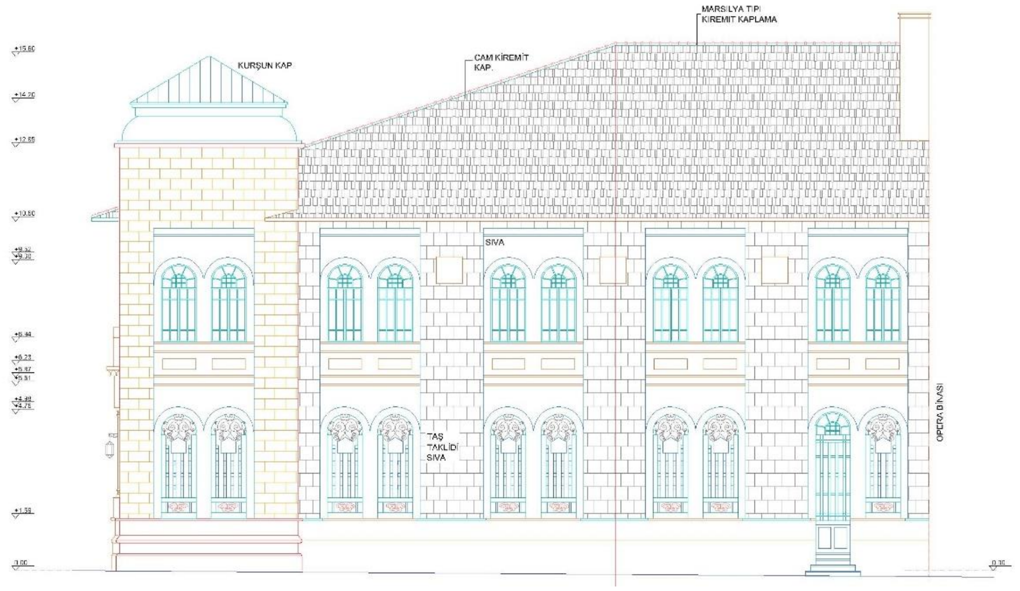
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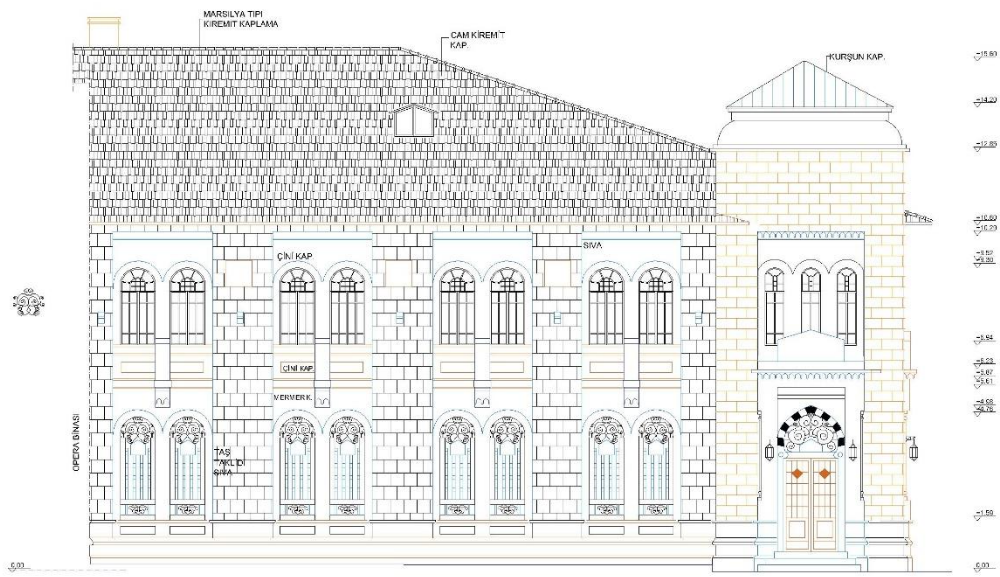
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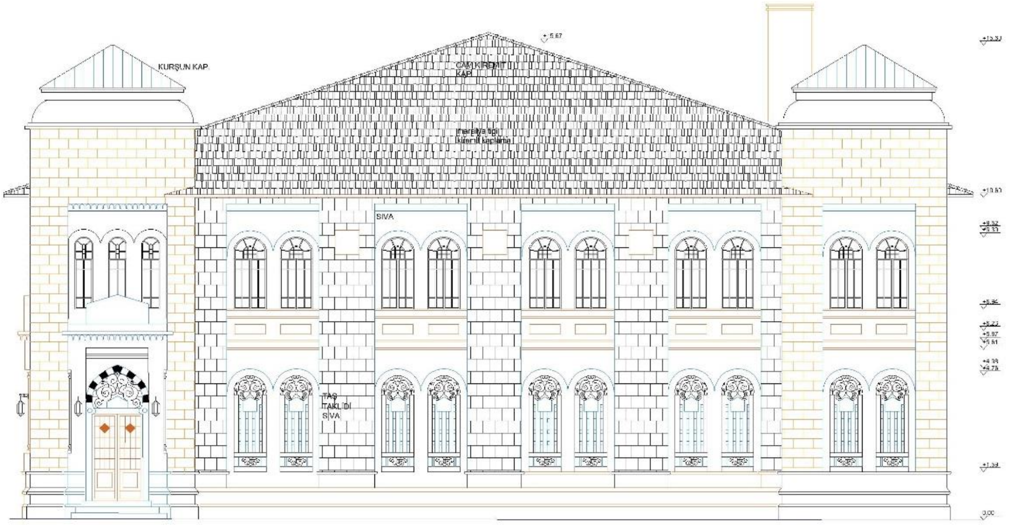


(g)

Figure 3. 7 Section A-A (a) section B-B (b) plan of the ground floor (c) plan of the first floor (d) east elevation (e) west elevation (f) south elevation (g)

3.6.1. Walls

Exterior wall thickness varies between 60 and 80 cm for all the facades. Exterior wall material is masonry andesite. Building's carriers are made up of concrete, rubble and brick was also used (Şimşek Özel 2015).

Figure 3. 8 Exterior walls of the library (Source: Umut Özsavaşcı, 2022)

3.6.2. Roof

Stained glass at the roof of the library is providing natural light to the study hall. Pitched roof of the building is covered with Marseille type tile, stained glass is covered with glass tile. Domes at the corners were covered with lead (Şimşek Özel 2015).

Figure 3. 9 Roof of the building in interior view (Source: Umut Özsavaşcı, 2022)

3.6.3. Doors and Windows

All the exterior windows are single glazed and interior doors are wooden framed doors. In building, there are two exterior door which made of steel.

Figure 3. 10 Doors and windows of the library (Source: Umut Özsavaşcı, 2022)

Table 3. 7. Components and U values of the Windows

Window components	Material	U (W/(m2K)
Glazing	Glass (3 mm)	5.894
Frame	Wood	3.633

Table 3. 8. Components and U values of the doors

Door components	**Material**	**U (W/(m2K)**
Glazing	Glass (3 mm)	5.894
Frame	Wood	3.633

3.6.4. Schedules

In order to support the data and equations, some schedules should be recorded. Occupancy schedule, HVAC schedule, Operation Schedule of the equipment and lighting are the main schedules.

3.6.5. Occupancy Schedule

Library is open 6 days a week. Library is closed only on Sundays. Minimum staff is always available at the study hall information desk. Study hall has 52 visitor desks and seats. Working hours are between 08.30 and 17.30. Visitors are not allowed to study hall achieve rooms or to first floor.

3.6.6. Heating, Cooling and Ventilating Schedule

Two wall-mounted 47000 btu/h cooling capacity ACs are located inside the study hall and one split type AC is located at the entrance. During hot season air conditioners are operated only during working hours. There is no indoor climate monitoring and control system installed in the library and no definite set temperature policy. Library staff always gives priority to the thermal comfort of the visitors. During the working hours, study hall and the shelf inside the study hall is effected by the cooling of the AC system. There is no AC system for the first floor book shelves. Library has an HVAC system which is operated only at working hours of the library.

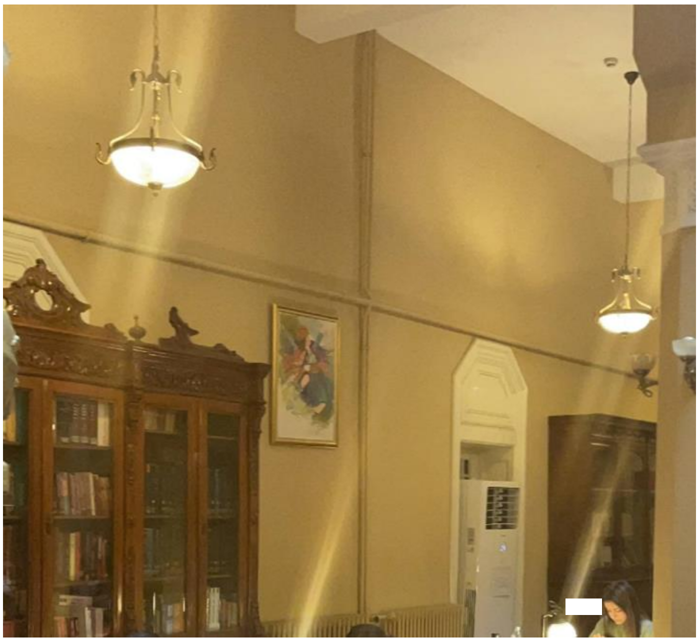


Figure 3. 11 Split air conditioners and radiators (Source: Umut Özsavaşcı, 2022)

There are five each 85cm length radiators located on the study hall walls. 4 x100 kW boilers are installed at the basement, two natural gas heaters serve for library and two natural gas heaters serve for cinema building. During cold season natural gas heaters are operated only during working hours. There is no definite set temperature policy. All of the study hall, shelf in the study hall and the first floor are equipped with radiators

3.6.7. Operation Schedule of Equipment

At the entrance hall of the library, 5 desktop computers are available for searching the inventory of the books and manuscripts on a round table. Also, in office area several computers are located.

3.6.8. Lighting

On the study hall roof, there is a big roof window which supplies most of the light for the library. Also there are two different lamp types available in the main hall. 40 Watt energy saving led bulbs and 80 Watt energy saving led bulbs are in use. According to

(Hanus and Hanusová 2013), desired light intensity for the libraries and storage areas is 200 lux. Figure 3.14 shows the types of electrical light at the study hall.

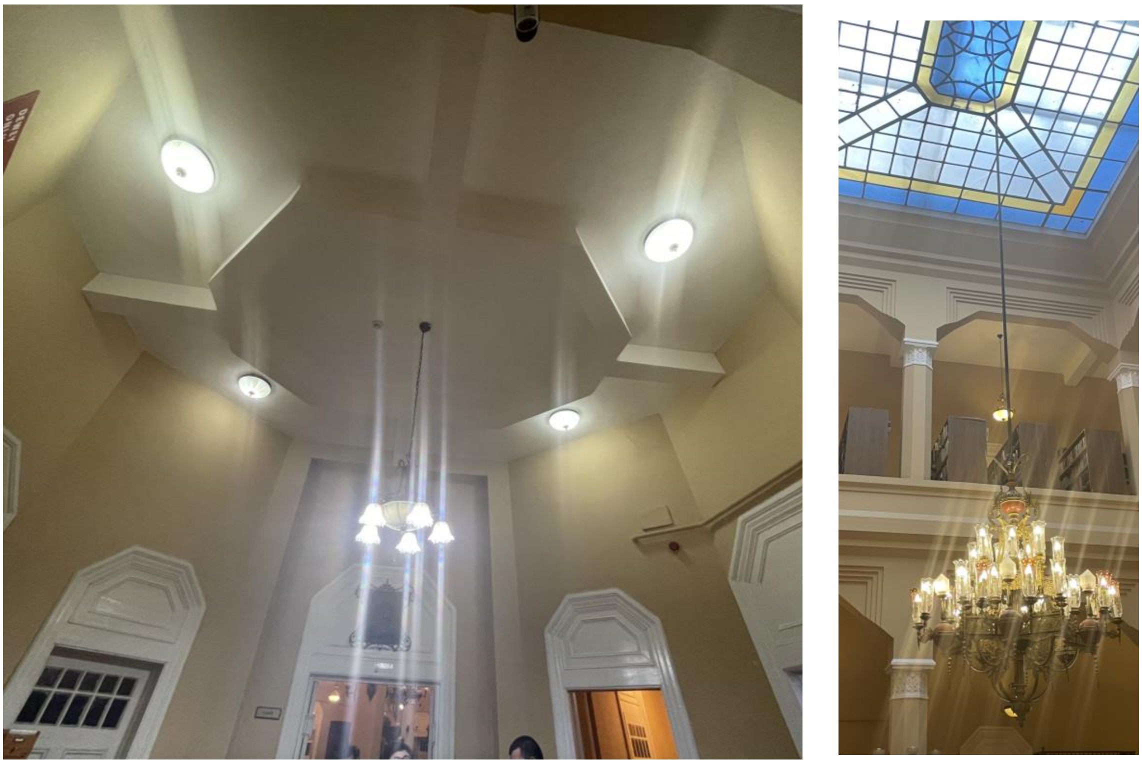
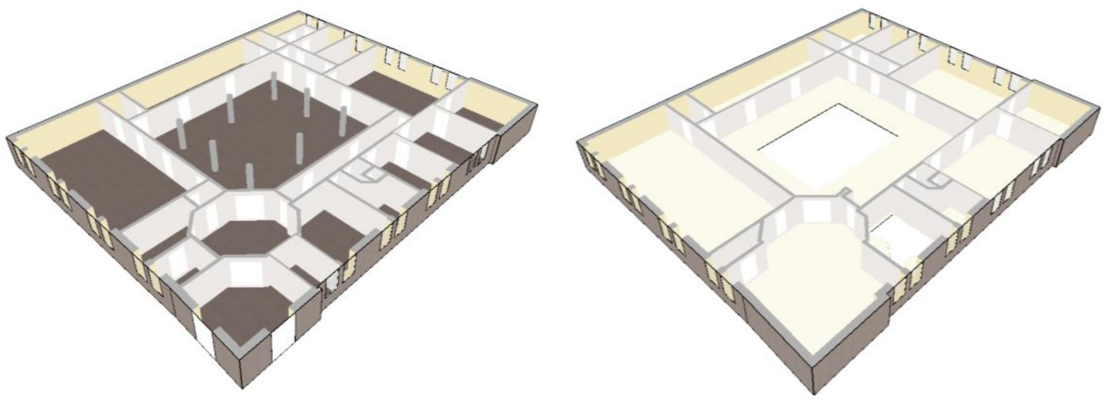


Figure 3. 12 Lightings in the Library (artificial lighting) (Source: Umut Özsavaşcı, 2022)

3.7. BES Model

Plans, sections and elevations of the case building were provided as JPEG files from The Republic of Türkiye, Ministry of Culture and Tourism, İzmir Regional Board of Protection of Cultural Heritage No. (See Appendix C, Figures C.1., C.2 and C.3) and Çağrı Topan (Topan 2019). After that, plans, sections and elevations were drawn in AutoCAD programme. Then for creating the BES model in DesignBuilder v. 7.0.0.102 software, .dxf file was imported to DesignBuilder simulation software. Because of the dxf files, a model was created based on the floor plans. The study room, archive rooms, employees' rooms, circulation areas and toilets are modeled. After modeling the study room and the first floor as seen in Figure 3.17, the gallery in the building was designed and a hole was defined in a part of the ceiling of the study room. The glass part of the roof, which corresponds to the gallery space, is modeled and it is ensured that it is a whole with the roof. When all the opening were modelled, creation of modelling process was done.

After the library building model was completed, Figure 3.18 shows that the surrounding buildings and roads were created. Material information provided from site investigations and Çağrı Topan (Topan 2019). According to information gathered by library manager, schedules of occupancy, lighting, equipment and HVAC system were appointed. All different blocks which roads and surrounding buildings were defined in DesignBuilder v. 7.0.0.102 software as component blocks. Their maximum transmittance was set 0.00.



(a) (b)

Figure 3. 13 Ground Floor View (a) First Floor View (b) of Library's Model

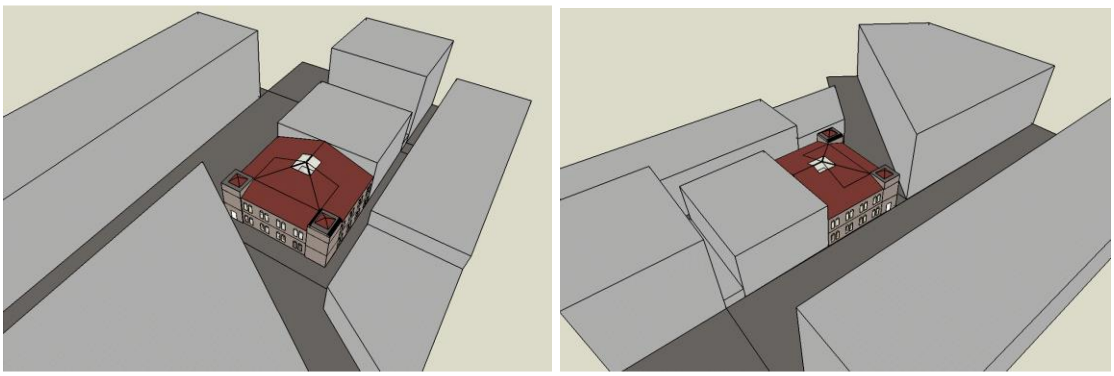


Figure 3. 14 Exterior View of BES Model

3.7.1 Walls

Thickness of external walls of the library building varies between 60 and 80 cm for all the facades. In BES model, thickness of external walls are accepted to be 70 cm. Table 3.9. shows the materials of exterior and internal walls. The material of the exterior wall is masonry andesite with paint.

Table 3. 9. Information of wall materials (Source: DesignBuilder, 2022)

COMPONENT	U-VALUE W/M²-K	MATERIAL	CONDUCTIVITY W/m-K	SPESIFIC HEAT J/kg-K	DENSITY Kg/m³	THICKNESS (m)
External Wall	1,892	Cement/plaster/mortar – plaster	0,7200	840,00	1860,00	0,030
		Gypsum plaster	0,2300	840,00	720,00	0,0150
		Masonary andesite,	1,4000	840,00	2200,00	0,4500
Internal Wall	1.777	Gypsum plasterboard	0,2500	1000,00	900,00	0,0150
		Masonary andesite,	1,4000	840,00	2200,00	0,2000
		Gypsum plasterboard	0,2500	1000,00	900,00	0,0150

3.7.2. Floors and Roof

Table 3.10. shows which materials are used in ground floor, internal floor and pitched roof. In ground floor, reinforced concreate, cement mortar and ceramic floor tiles are used. Also same materials used in internal floor. For pitched roof, wooden material which is oak, bitumen and clay tile for roofing is determined.

Table 3. 10. Information of ground floor, internal floor and pitched roof (Source: DesignBuilder, 2022)

COMPONENT	U-VALUE W/M²-K	MATERIAL	CONDUCTIVITY W/m-K	SPESIFIC HEAT J/kg-K	DENSITY Kg/m³	THICKNESS (m)
Ground Floor	1.209	Concreate Reinforced (with 1% steel)	2,300	1000,00	2300	0,1000
		Cement/plaster/mortar-cement mortar	0,7200	920,00	1650,00	0,0040
		Ceremic clay tiles – ceramic floor tiles dry	0,800	850,00	1700,00	0,0030
Pitched Roof	0.666	Clay tile roofing	1,00	800,00	2000,00	0,0250
		Bitumen	0,2300	1000,00	1100,00	0,0050
		Oak (radial)	0,1900	2390,00	700,00	0,0250
Internal Floor	2,601	Ceremic clay tiles – ceramic floor tiles dry	0,800	850,00	1700,00	0,030
		Cement/plaster/mortar-cement mortar	0,7200	920,00	1650,00	0,0100
		Concreate Reinforced (with 1% steel)	2,300	1000,00	2300	0,1000
		Gypsum plaster	0,5100	960,00	1120,00	0,0100

3.7.3. Windows and Doors

In the building, there are 48 windows in the building. In Table 3.11 shows that all the windows' glazing type in building is 3mm single clear and its U-Value is 5.894 (W/m²-K).

In building there are 2 external door which made of steel. Interior doors materials are wood. Specifications are given in Table 3.12.

Table 3. 11. Information of glazing type (Source: DesignBuilder, 2022)

	Options	**Total Solar Transmission**	**Light Transmission**	**U-Value (W/m^2-K)**
Glazing type	3mm single clear	0.861	0.898	5.894

Table 3. 12. Information of door materials (Source: DesignBuilder, 2022)

	Options	**Conductivity (WW/m-K)**	**Specific Heat (J/kg-K)**	**Density (kg/m^3)**	**U value (W/ m^2-K)**
Interior door	Wooden Door	0.1900	2390	700	2.823
Exterior door	Steel Door	50	450	7800	3.124

3.7.4. Occupancy Schedule

Library is open 6 days a week. Library is closed only on Sundays. Minimum staff is always available at the study hall information desk. Study hall has 52 visitor desks and seats. Working hours are between 08.30 and 17.30. Visitors are not allowed to study hall achieve rooms or to first floor. Hence, at 08.00-08.30 only two or three people works in library. Between 08.30 and 12.00, generally there are few people come to work. Afterwards, the number of people visiting the building increases later in the day.

3.7.5. Heating and Cooling Schedule

Employees determine the operation of the heating and cooling system in office areas. Radiator is to be used in winter. In summer, cooling is done with air conditioning.

In the study room, cooling and heating mechanisms are used in autumn and spring, upon the request of most of the visitors.

3.7.6 Equipment Schedules and Lighting

At the entrance hall of the library, 5 desktop computers are available for searching the inventory of the books and manuscripts on a round table. Although it is not possible to predict when these computers will be used, they are not preferred much according to the library staff. Also, in office area several computers are located.

On the study hall roof, there is a big roof window which supplies most of the light for the library. Hence, generally in cloudy day and in the evening study hall lighting equipment is on. Also, in office areas, lighting usage is change depends on staff.

3.8. Calibration

The simulation model of İzmir National Library is calibrated against the error detection equations of ASHRAE Guide 14, RMSE (3.2) and MBE (3.3). While the monitored and simulated hourly indoor temperature and relative humidity are compared via these equations; an annual RMSE result below ±30% and a MBE result below ±10% is targeted.

$$RMSE\ (\%) = (100/T_{ma}) * [1 / N * (S(T_s - T_m)^2)]^{1/2} \qquad (3.2)$$

$$MBE\ (\%) = (100/T_{ma}) * [S(T_s - T_m)] / N \qquad (3.3)$$

For the calibration simulations, study area zone were chosen. Since the work area has a gallery, the average of the hobo data in the gallery area and the hobo data on the upper floor of the study area was taken. Monitoring period for calibration process is between 01.10.2016 to 01.10.2017. For base case building four iterations were done. Because, iteration should be done until the necessary results are achieved to calibrate the building in the model with the actual building.

3.9. Retrofit Impact Assessment for Historic Buildings

While providing thermal comfort, exterior insulation of the walls can be preferred in order to reduce hygrothermal risks, moisture damage and heat entrance risks. If there is air leakage from exterior walls, the building surrounding will be more hermetic with insulation. It is also important to usage of insulating materials that authorize moisture to move through the building surrounding. Albeit, making insulation of exterior walls can have an adverse effect on the facade in terms of the unique architectural content of historic buildings (Ståhl 2011).

Insulation of the attic floor reduces heat loss. Relative humidity after insulation will be high in winter due to humidity and this level will increase gradually in autumn and spring. To solve this problem, it is necessary to prevent air leakage from the attic, insulate the attic passage and ventilate the attic (Ståhl, 2011). While insulating the attic from the bottom does not have a negative impact on the historic significance in general, adding insulation from the top is a more preferred option as it does not change the interior appearance of the buildings (Ståhl 2011).

High risk level assessment means making retrofit work by interfering with the elements, materials and structure of the building. This process, which is generally applied in buildings with poor structural condition, has wrongful results when it is not done by competent people. Low risk level assesment means changing the building materials but without affecting the unique architectural structure of the building and the experience of the users when retrofitting it. Neutral risk level assessment is the strengthening work done without changing any material or structure of the building, only by changing the air conditioning or room usage functions.

In this thesis, three scenarios were designed to find most proper retrofit strategy for İzmir National Library Building. These three scenarios were prepared according to the five level assessment scale for retrofit impact assessment (Figure 2.1.). These were determined as scenario 1, scenario 2 and scenario 3. The scenarios represent neutral, low and high risk retrofit impact assessment, respectively. For scenario 1, retrofit interventions were not made in the structure, elements or HVAC system of the building. Only the cooling setpoint and heating setpoint have been changed. In scenario 2, in addition to the change of cooling set point and heating set point, there were new proposals for the building's external door, pitched roof floor construction and glazing type. For scenario 3, in addition to the suggestions of the second scenario, sustainable materials with a lower U-Value than the basecase were selected for the structure of the exterior wall.

3.10. Optimization in DesignBuilder Model

Multi-objective optimization is a process where many simulations are run automatically under the control of an optimizer which favors design options that best meet design criteria and iteratively tests and re-tests new generations of these until the very best set of options have been identified. Optimization is a technique for efficient searching for and identifying design options that best meet key design performance objectives. The technique for analyzing how design performance varies with changes in the building configuration through use of design curves. In multi-objective optimization, where there are conflicting constraints between the objectives, the notion of optimality is different. This is represented by an Edgeworth-Pareto relationship, known as the Pareto optimum. The Pareto optimum is indicated by the red dot in the optimization analysis tables. Figure 3.17. shows process of the optimization simulations.

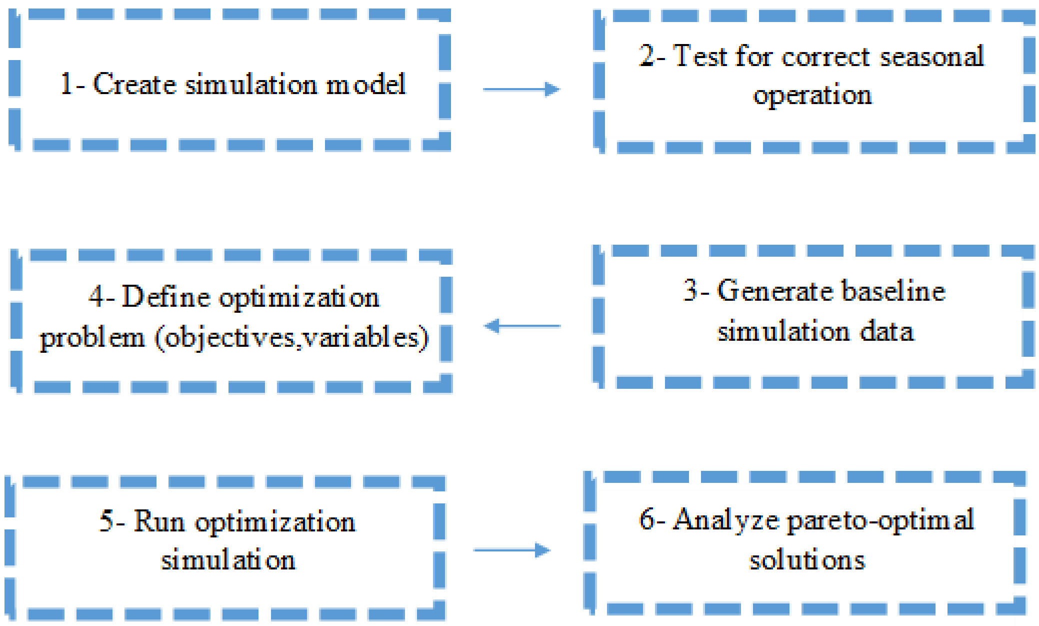


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Figure 3. 15. Flowchart of the optimization process

To achieve the best design criteria, the optimization analysis process should consist of many iterations. Many different things can be specified as a design option. For example, building materials, glazing design and HVAC mechanisms. The most accurate design options for the specified design criteria are obtained with the most accurate combinations of design options. To increase combinations, it is necessary to increase the range of design options. In the light of this situation, the high number of iterations in the optimization analysis process ensures that the optimization analysis reaches the most accurate result. In this study, 200 iterations were selected for optimization analysis. The 200 iterations were selected according to the performance of the computer on which the optimization analysis was made, this number can be increased for future studies.

It is a solution whose optimum value in the optimization analysis results is optimal (maximum or minimum) within the set of solutions. The point where the design variables are most suitable for the desired design criteria is called the optimum point. When the most optimum point of the design variables changes for the design criteria, the most optimal point of the design variables selected considering all the criteria is the midpoint optimal.

CHAPTER 4

RESULTS AND DISCUSSIONS

There are multi objectives of this thesis to be succeeded at the same time for İzmir National Library:

- Preservation of paper based collections,
- Increasing thermal comfort of the visitors,
- Reduction energy consumption,

This chapter presents the results of analyses conducted for these objectives. In this chapter some analysis were done which are monitoring, mechanical degradation risk, chemical degradation risk, biological degradation risk and optimization. All these analysis were made to find best retrofit solution for base case building.

4.1. Monitoring Results

The air temperature and relative humidity data of outdoor, ground floor and the first floor in İzmir National Library recorded for a total of 365 days between 01.10.2016 and 01.10.2017 are indicated in (Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6).

Recorded ground floor and first floor air temperature data were averaged. In this instance, for the outdoor, the maximum recorded air temperature is 40.5°C (01.07.2017, 01.00 pm), while the maximum air temperature for the ground floor is 31°C(16.07.2017, 03.00 pm) and the first floor one is 33.4°C (10.08.2017, 10.00 am). The minimum air temperatures for the outdoor, ground floor and first floor are -2.6°C (07.01.2017, 02.00 am), 16.9°C (02.01.2017, 04.00 am) and 17.2°C (02.01.2017, 04.00 am), respectively. Besides, the annual average of outdoor air temperature is 18.3°C, for the ground floor is 24.9°C and for the first floor is 25.9°C.

The maximum recorded relative humidity in outdoor, ground floor and the first floor are 96%, 59.8% and 57.6%, respectively. The minimum relative humidity recorded in the outdoor is 12%, while the minimum ground floor relative humidity is 20.1% and the first floor one is 24.9%. In addition, the annual average of outdoor relative humidity is 56.2%, for the ground floor is 42.3% and in the first floor one is 40.5%.

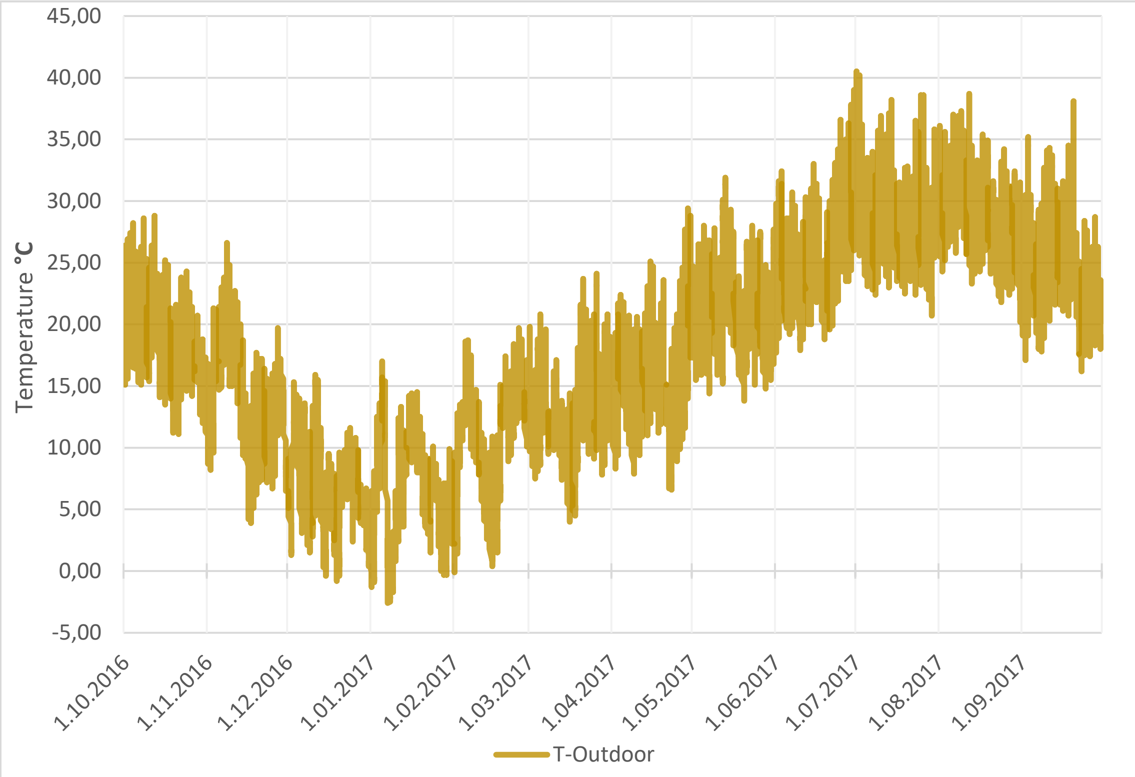


Figure 4. 1. Outdoor air temperature results (01.10.2016-01.10.2017)

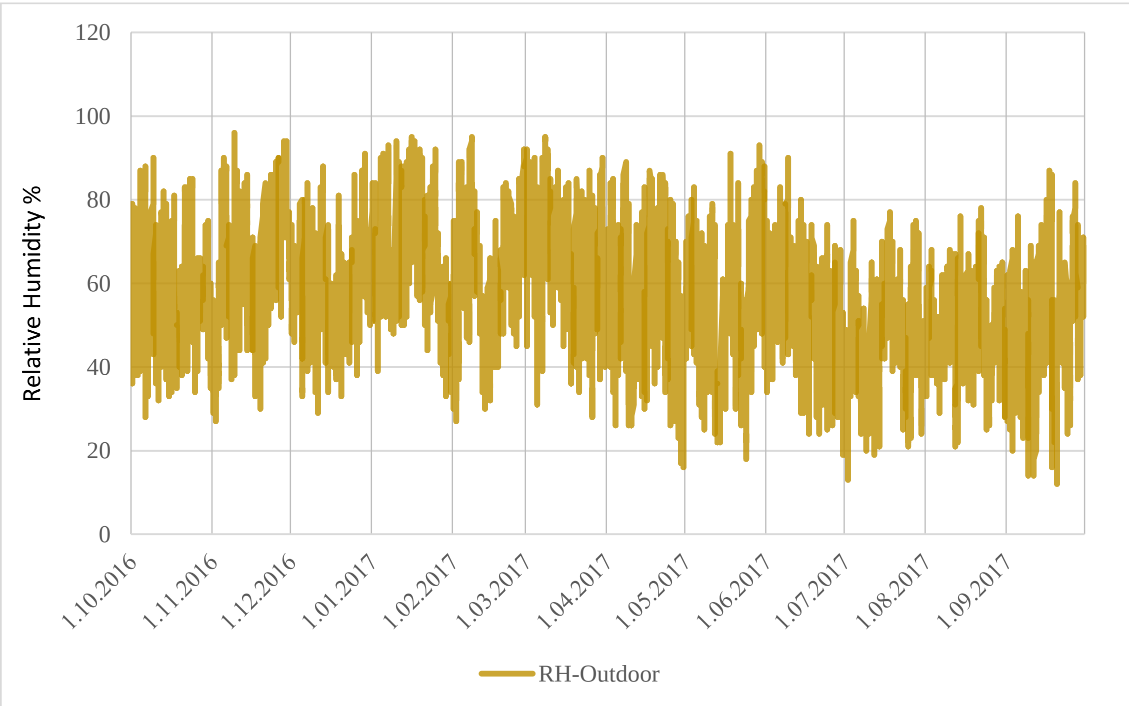


Figure 4. 2. Outdoor relative humidity results (01.10.2016-01.10.2017)

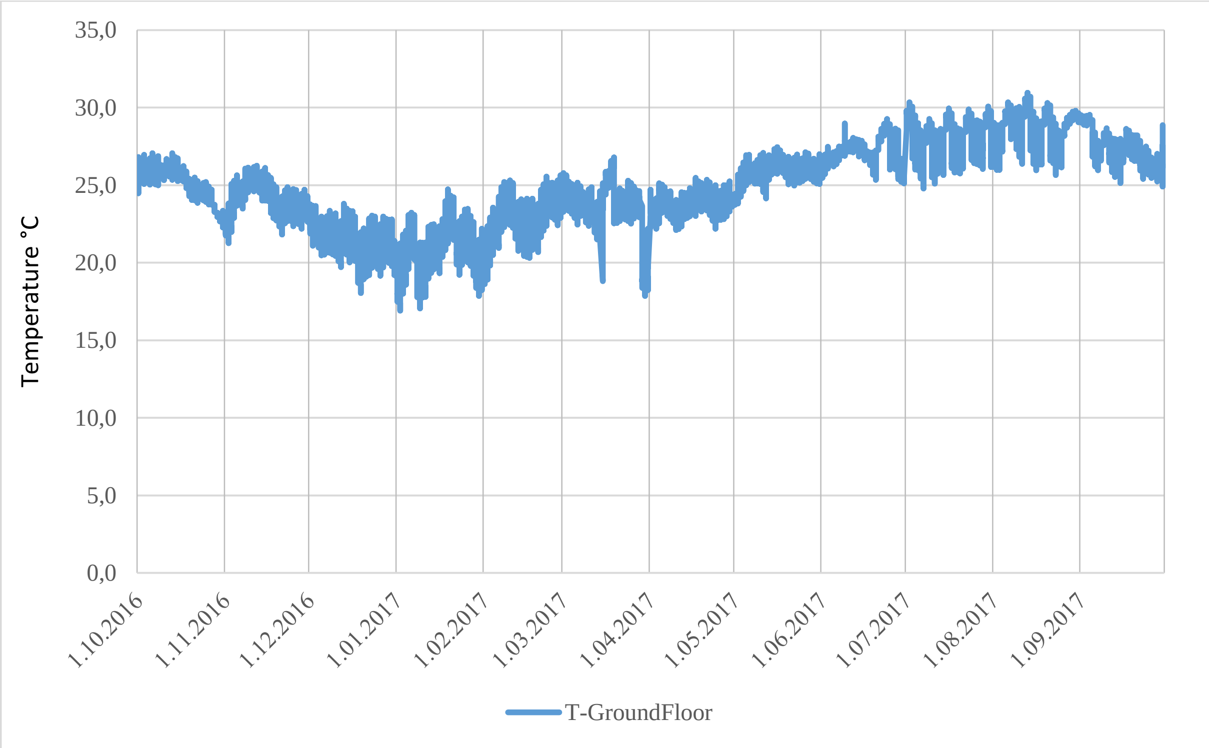


Figure 4. 3. Air temperature results of ground floor (01.10.2016-01.10.2017)

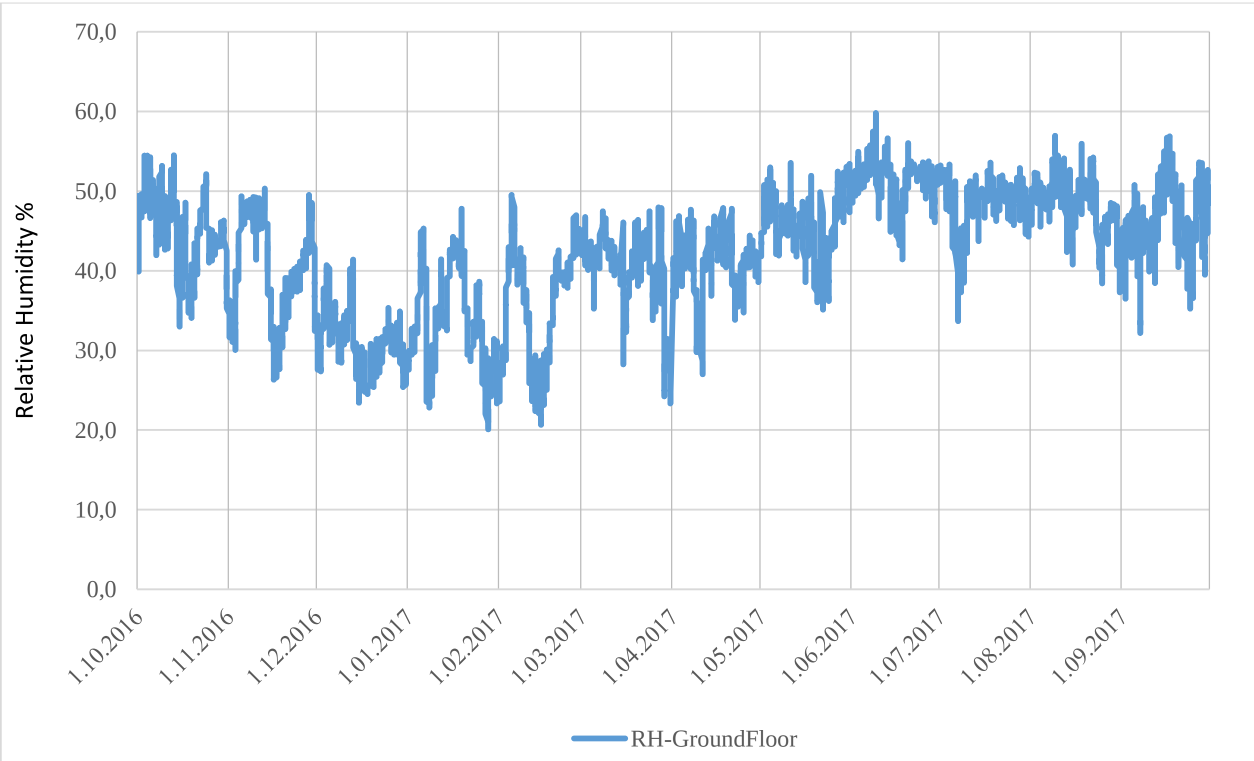


Figure 4. 4. Relative humidity results of ground floor (01.10.2016-01.10.2017)

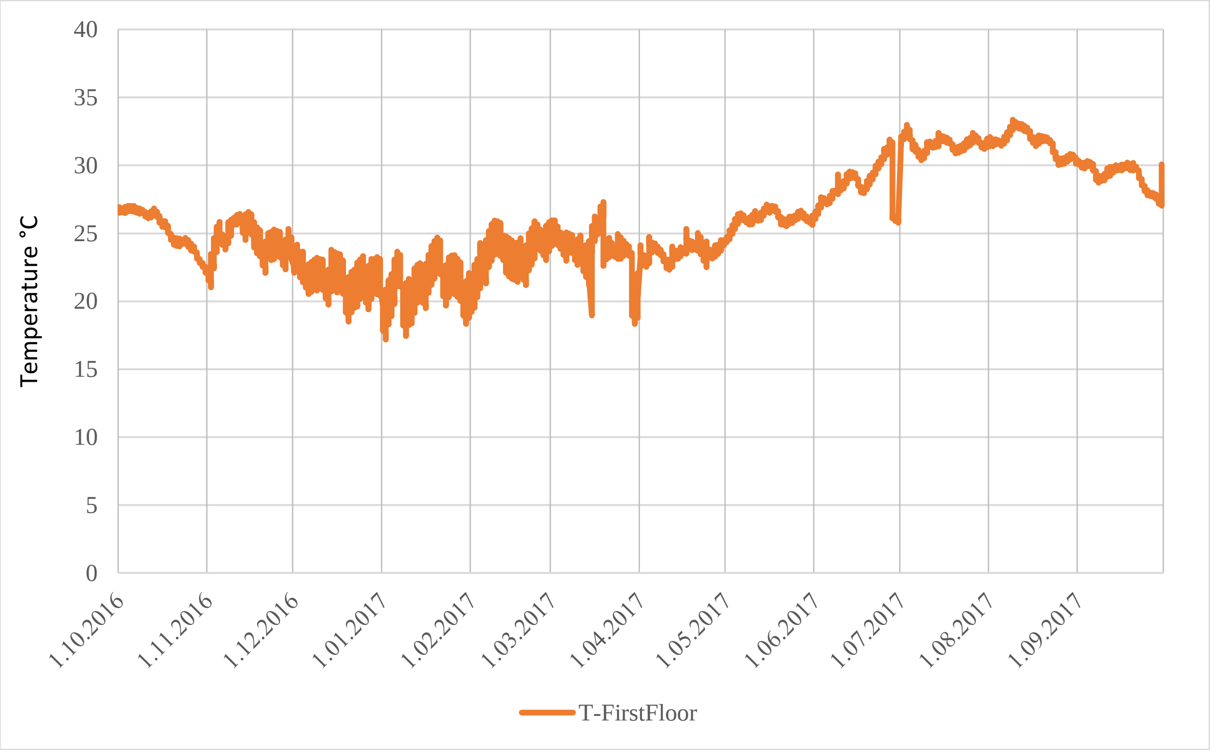


Figure 4. 5. Air temperature results of first floor (01.10.2016-01.10.2017)

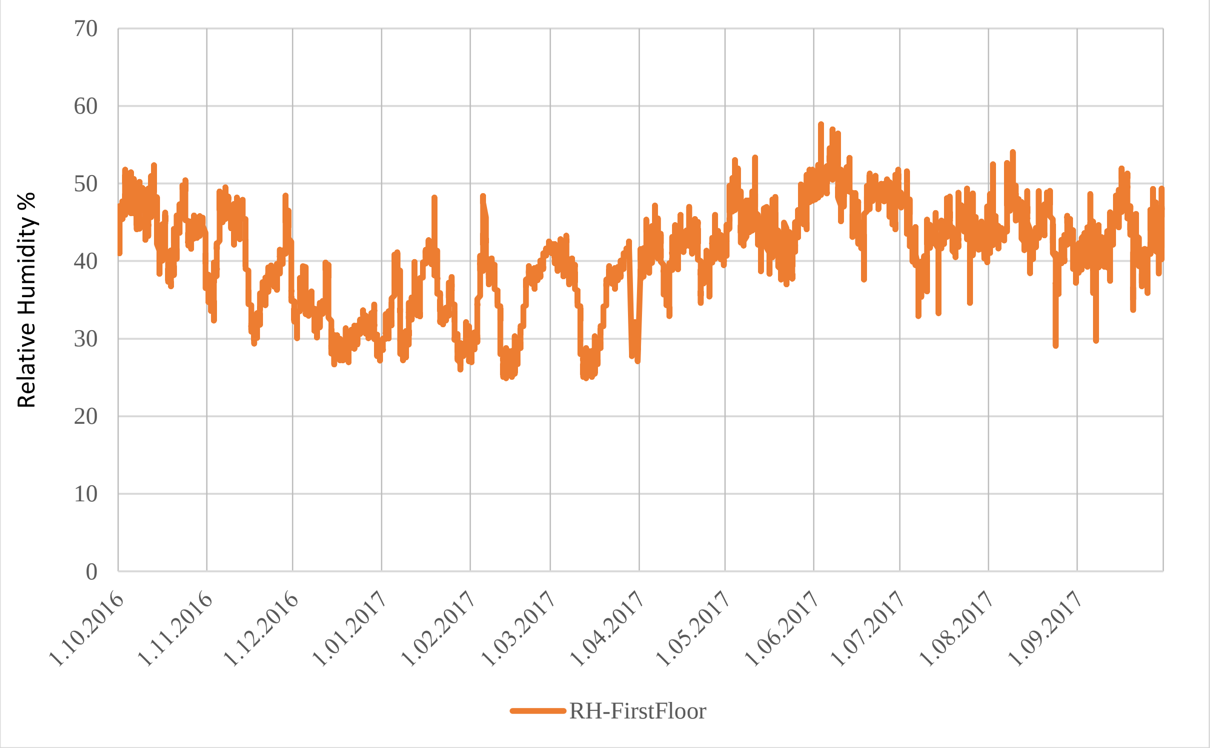


Figure 4. 6. Relative humidity results of first floor (01.10.2016-01.10.2017)

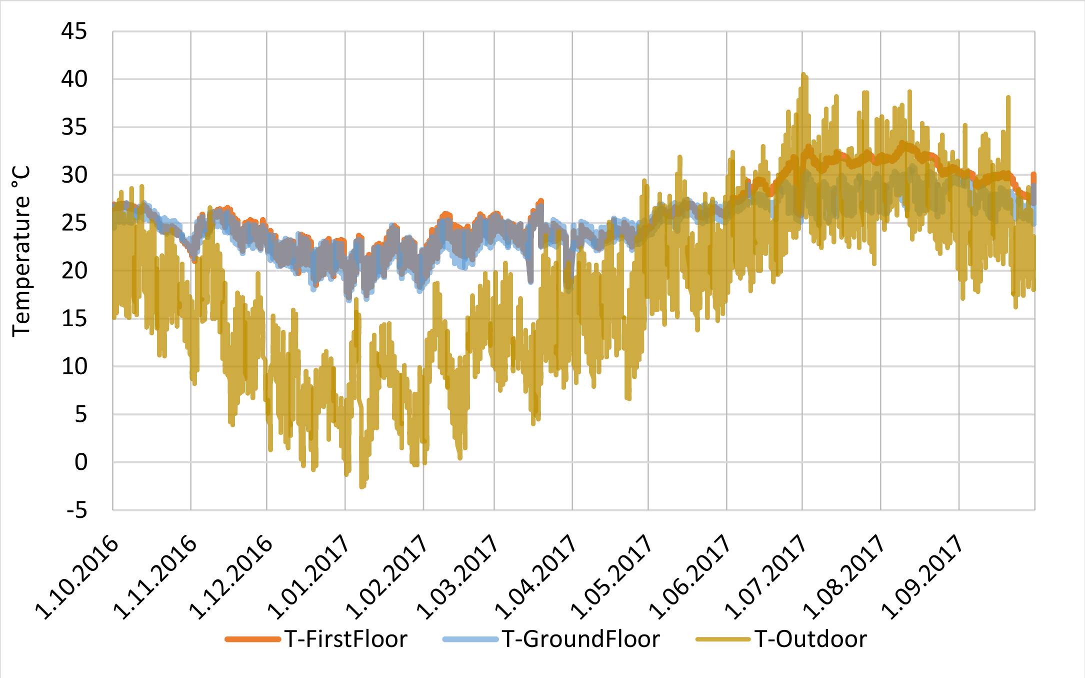


Figure 4. 7. Comparison of air temperature values between ground floor, first floor and outdoor

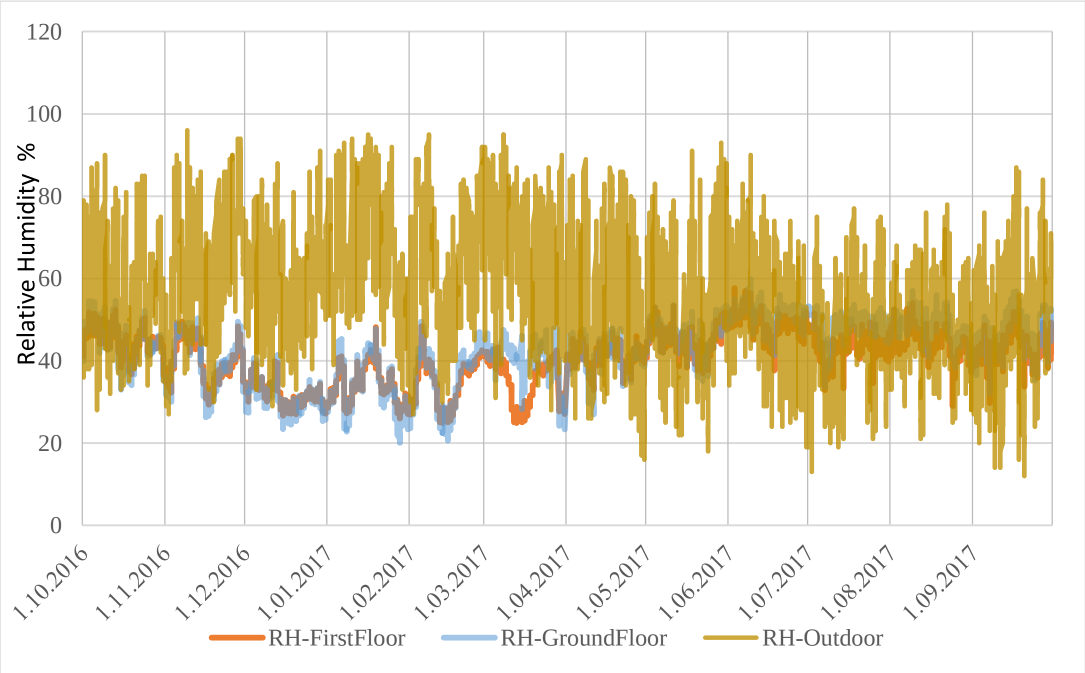


Figure 4. 8. Comparison of relative humidity between ground floor, first floor and outdoor

Considering the air temperature and relative humidity measurements of the ground and first floors, it is seen that both floors experience almost the same effects. Trend in air temperature was observed almost the same in some months for both floors, but the first floor was measured to be slightly warmer than the ground floor. The reason for this is that the stained glass on the ceiling of the gallery space allows more sunlight to affect the first floor. However, first floor is warmer than ground floor (Figure 4.7). In additionally, especially in winter season, the ground floor and the first floor is not affected much by the outdoor temperature. This might be due to the existing of a gallery space in the measurement area and also the fact that the HVAC system is left on all the time.

According to the air temperature measured during a year, the maximum and minimum air temperature difference of the ground floor was analyzed as 14.1°C and that of the first floor as 16.2°C (Figure 4.7). According to this situation, it has been revealed that the air temperature change of the first floor during a year is higher than the ground floor. This is because the HVAC system on the ground floor provides a more stable air temperature to the floor. The reason for the small difference between the floors is the air corridor provided by the gallery space.

According to the measured relative humidity, the maximum and minimum relative humidity difference of the ground floor was calculated as 32.8% and that of the first floor as 35.7% (Figure 4.8). According to the results, the presence of air conditioners on the ground floor, as in the air temperature, makes the ground floor more stable in relative humidity changes.

As a comparison of the outside air temperature with the indoor air temperature, the maximum and minimum air temperature difference of the interior was analyzed as 15.2°C and for outdoor was 43.1°C (Figure 4.7). Indoor relative humidity difference was analyzed as 34.3% and for outside was 84% (Figure 4.8). As expected, the interior is more stable than the exterior, as it has a closed area and HVAC system. In addition, since the HVAC system is fully open in winter and adjusted according to human comfort in summer, the difference between indoor air temperature relative humidity were very small compared to outside.

4.2. Degradation Risk Analysis of the Base Case

Historic buildings such as the İzmir National Library Building might be at risk of degradation. Degradation types are mechanical, chemical and biological. Mechanical degradation risk analysis based on short-term charges of relative humidity and air temperature. Chemical degradation risk analysis are made by using LM parameter (Equation 3.1). Biological degradation risk factors calculated by using MRF. According to the results of the analysis, it is determined whether there is a risk or not, and then appropriate ways are sought to solve these risks. In this section works are based on the İzmir National Library Building. Degradation risk analyzes are the same as the dates in the motoring process and the analysis dates are between 01.10.2016 and 01.10.2017. Hence, thanks to monitoring process, all temperature and relative humidity data used in degradation risk analysis are correct.

4.2.1. Mechanical Degradation Risk Assessment

The short fluctuations should be separately examined in accordance with the ASHRAE Chapter 23 climate control classes' short fluctuation limitations in order to determine the risk of mechanical degradation. The largest daily T and RH differences that were observed in ground floor is shown in Figures 4.9 and 4.10. When examined, more than half of the recorded daily T changes fell below the ±2 K but relative humidity changes stay on top ±5% limitations. As can be seen in Figure 4.9, In terms of mechanical degradation of ground floor air temperature, it can be seen that between December and April, July and September risk was increased. On the other hand, for mechanical degradation of ground floor relative humidity fluctuations more sharply and frequently in all months.

The cumulative frequencies of the highest daily T and RH variations in ground floor are shown in Figure 4.11. The cumulative frequency calculations revealed that 42.11% of the RH differences were below the ±5% RH limit and that 54.49% of the ground floor T changes were below the ±2 K limit.

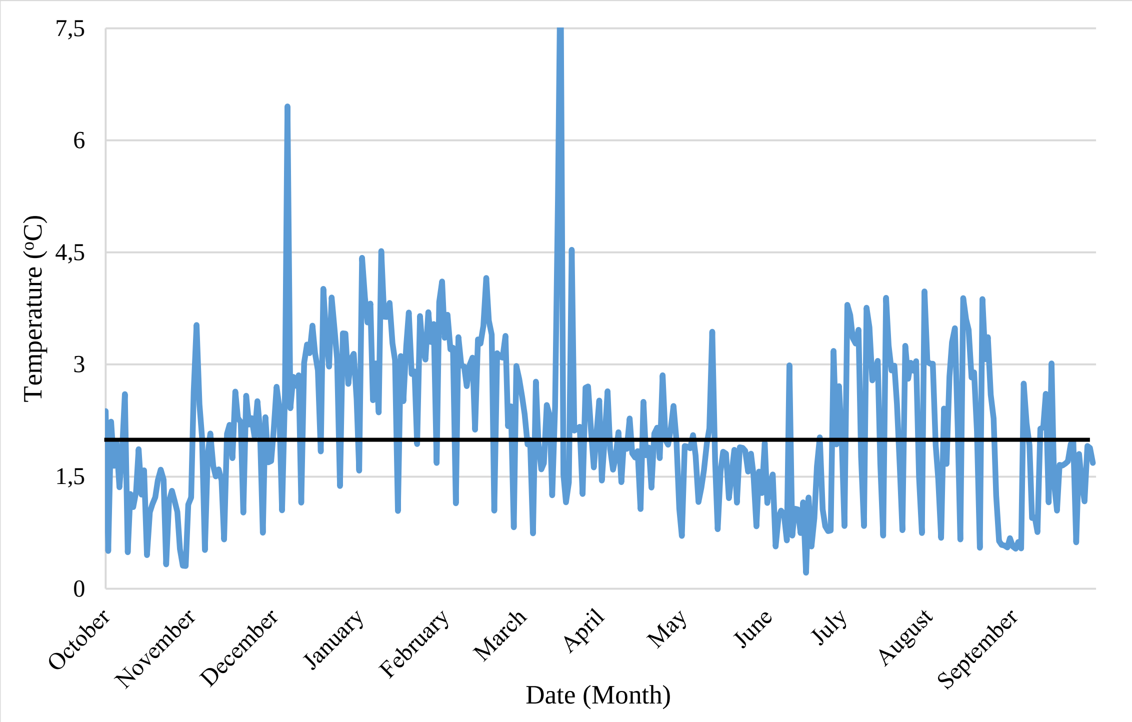


Figure 4. 9. Daily air temperature (Daily T) fluctuation in the ground floor

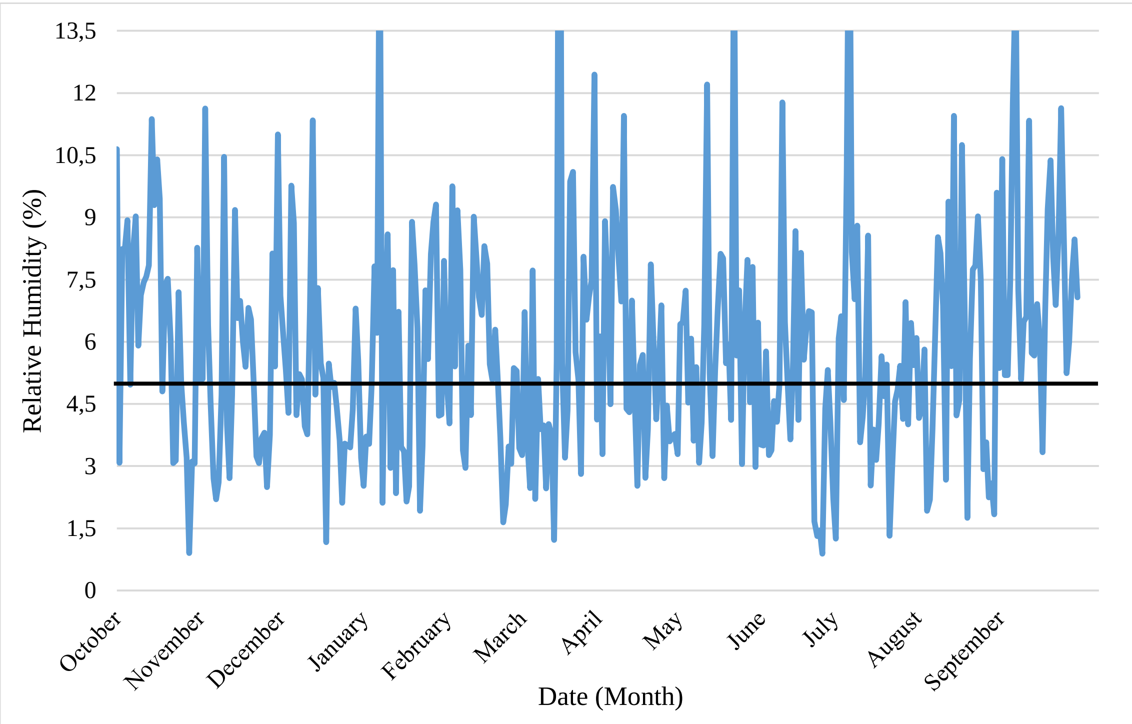


Figure 4. 10. Daily relative humidity (Daily RH) fluctuation in the ground floor

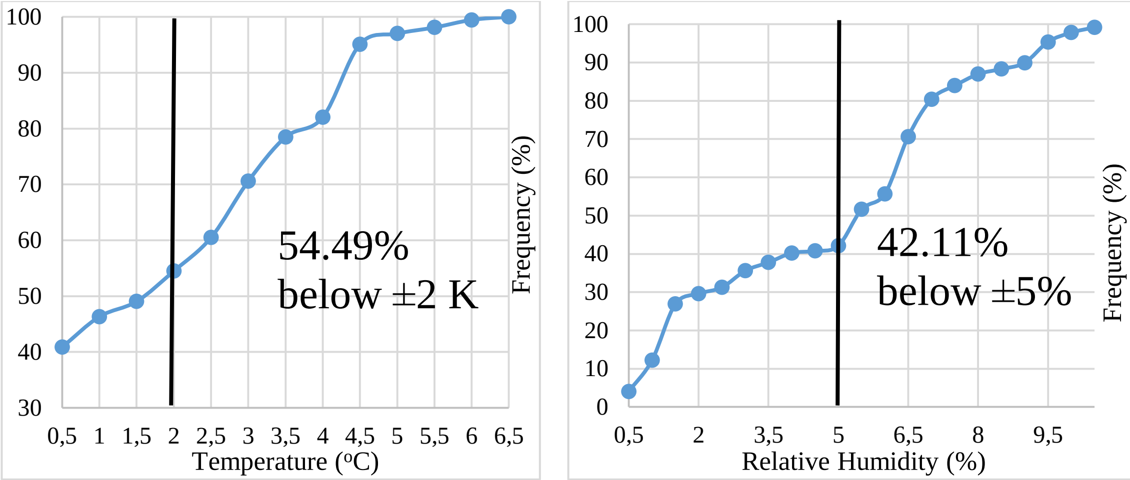


Figure 4. 11. Cumulative frequencies of T (left) and RH (right) differences in ground floor

Figure 4.12 and Figure 4.13 show the maximum hourly T and RH differences which were monitored in first floor. While more than half of the monitored hourly T fluctuations were below the limit ±2 K and RH fluctuations were below the ±5% limit. Figure 4.14 shows the cumulative frequencies of respectively maximum daily T and RH differences. According to cumulative frequency calculations 68.03% of the first floor T differences were below ±2 K limit, while 70.49% of the RH differences were below ±5% RH limit. Generally, between December and April period increased risk of mechanical degradation. It can be said that T and RH fluctuations of the building satisfied the requirements of all control classes in terms of mechanical degradation. Also, according to the results, it could be understand that first floor results are better than ground floor results.

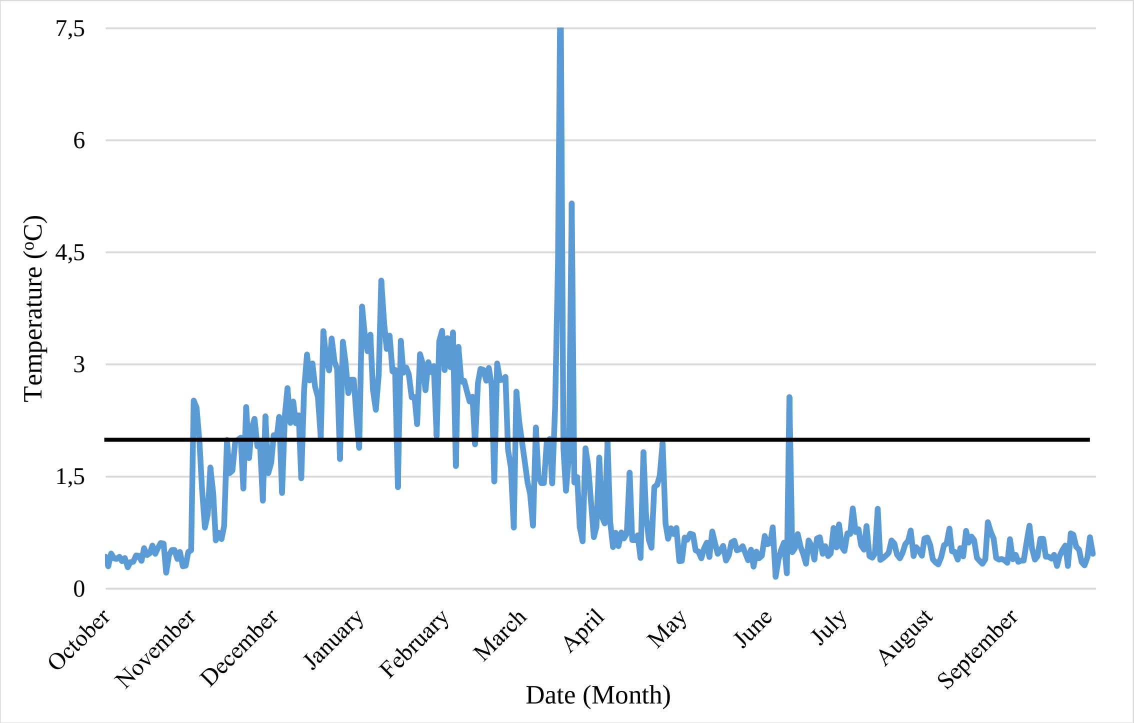


Figure 4. 12. Daily air temperature (Daily T) fluctuation in the first floor

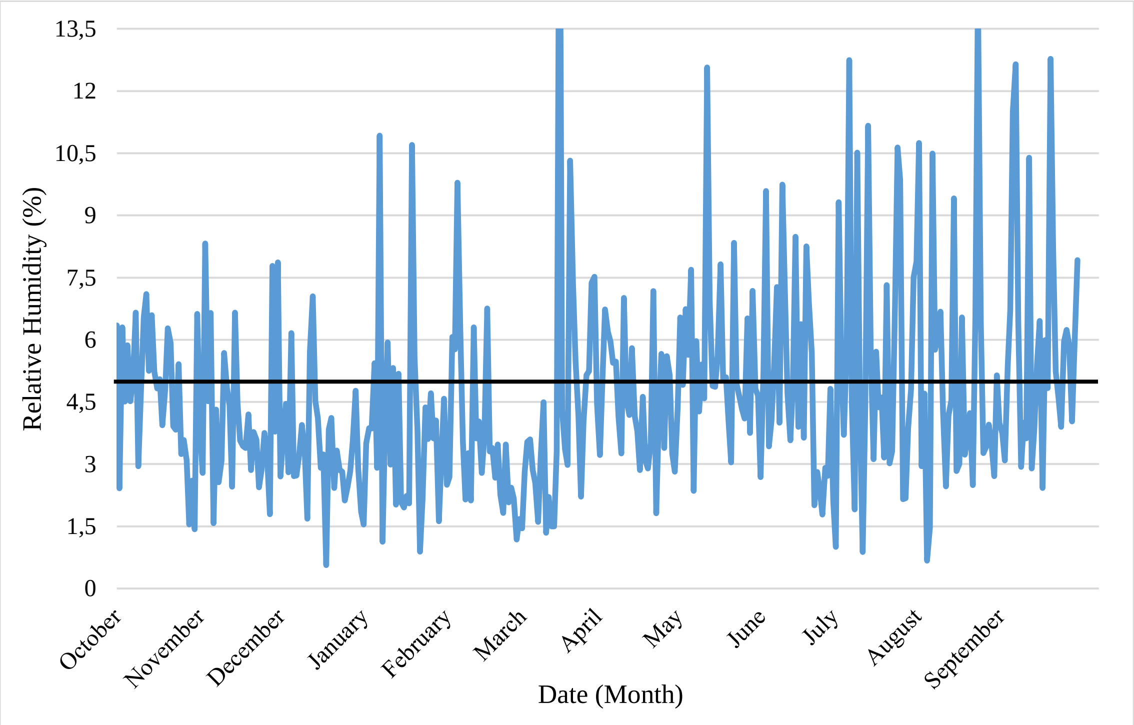


Figure 4. 13. Daily relative humidity (Daily RH) fluctuation in the ground floor

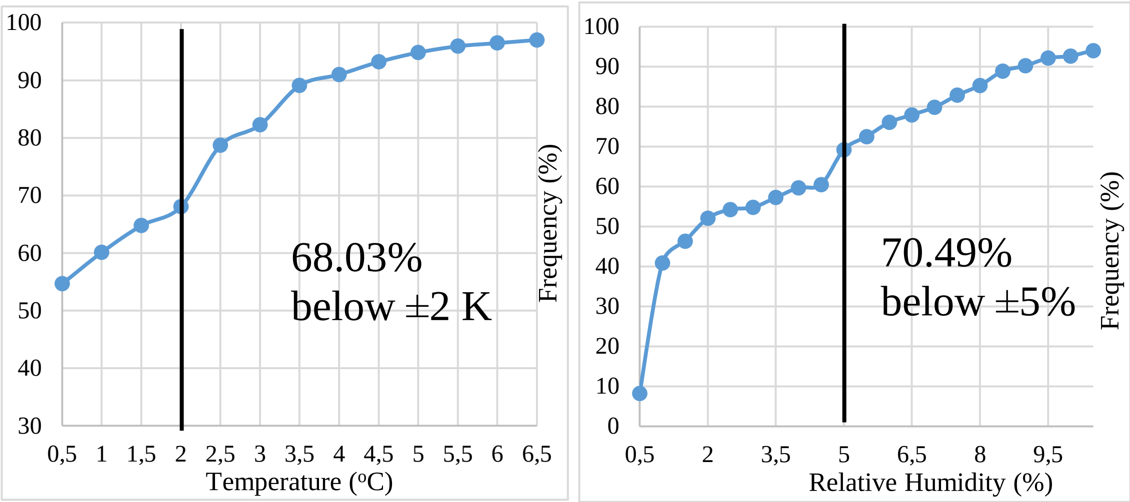


Figure 4. 14. Cumulative frequencies of T (left) and RH (right) differences in first floor

4.2.2. Chemical Degradation Risk Assessment

The results of the chemical degradation risk assessment for ground floor and first floor monitored T and RH data in terms of LM can be found in Figure 4.15 and Figure 4.16. According to the ground floor results, the manuscripts were under low risk of chemical degradation in December, January and February. Between May to October, manuscripts in high risk in terms of chemical degradation. The lowest calculated LM value was 0.224 in August, while the highest was 3.818 in December.

According to the first floor results, as same as ground floor result, the manuscripts were under low risk of chemical degradation in December, January and February. Between May to October, manuscripts in high risk in terms of chemical degradation. The lowest calculated LM value was 0.150 in August, while the highest was 3.058 in January.

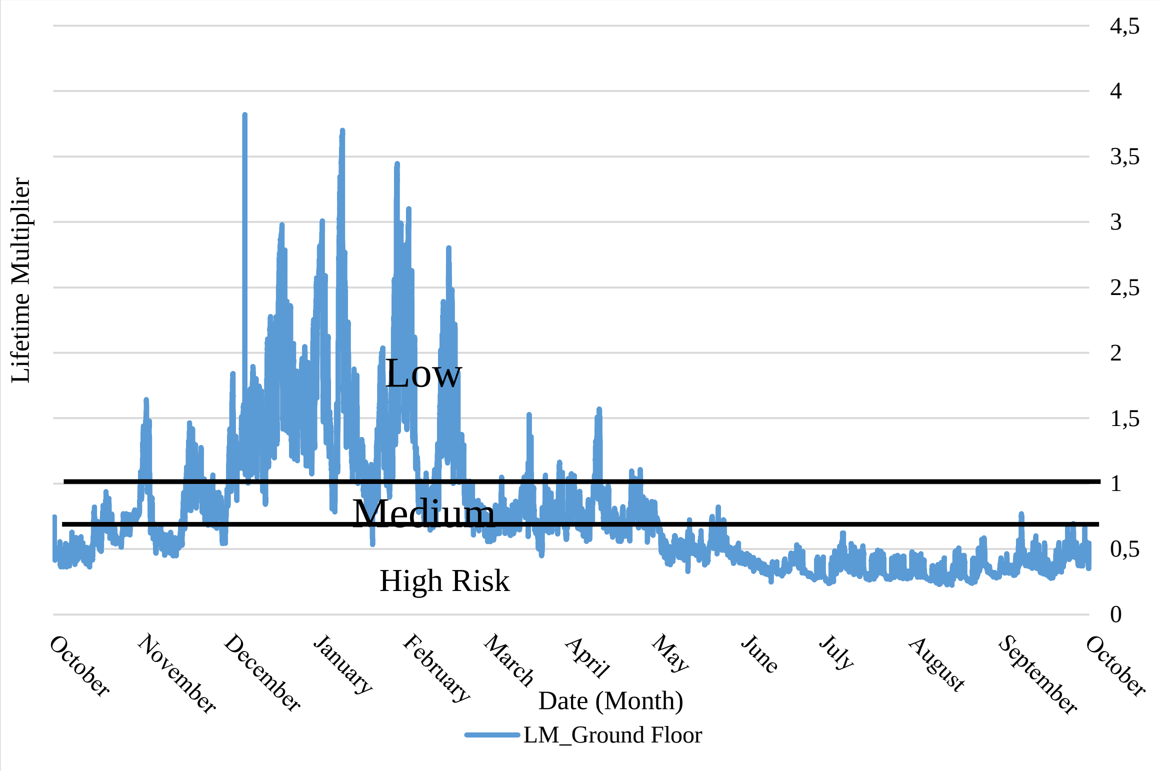


Figure 4. 15. LM values of ground floor

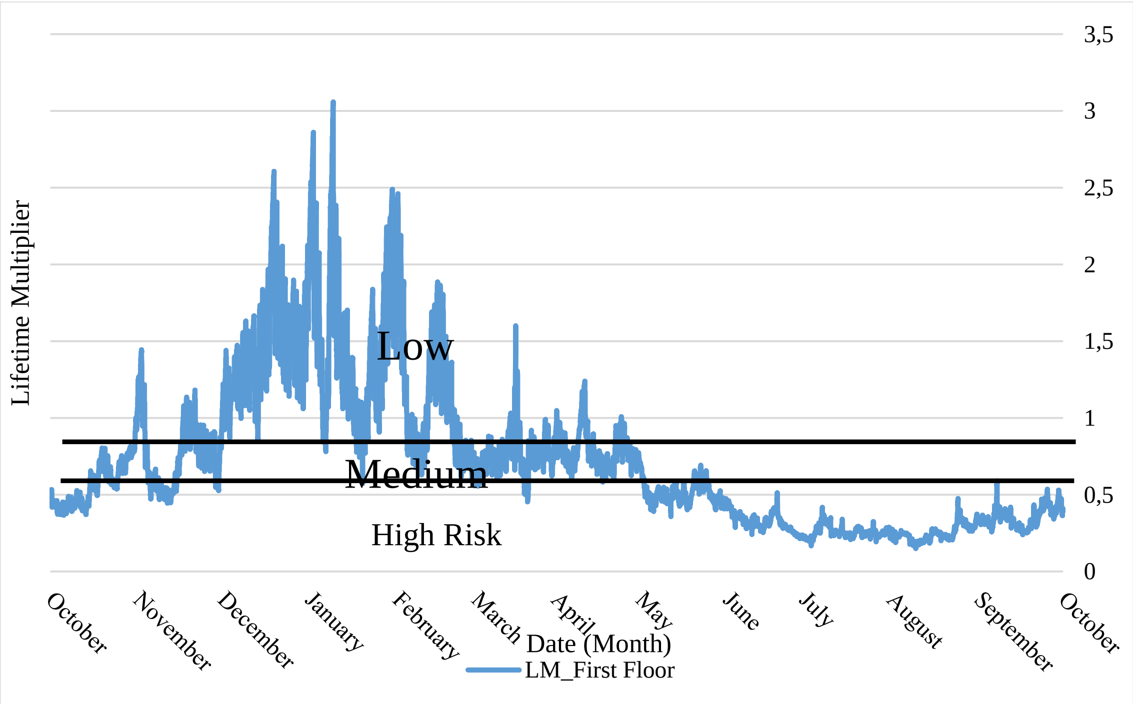


Figure 4. 16. LM values of first floor

4.2.3. Biological Degradation Risk Assessment

Using isopleths and superimposing the measured indoor T and RH data for these periods to the limit curves, the biological degradation risk assessment for the ground floor and first floor periods was carried out. The findings of this evaluation are depicted in Figures 4.17 and 4.18. Equation 3.3 is used to construct the blue limit curve at these figures, which is for porous materials, whereas Equation 3.4 is used to make the green limit curve, which is for woody materials.

Figure 4.22 and 4.23 show that manuscripts were under no risk of biological degradation during both ground and first floors. Ground floor graph is nearly the same with first floor graph. Bookshelves are located in both ground and first floors. Hence, according to this situation, the historic building can be considered successful in terms of risk of biological degradation.

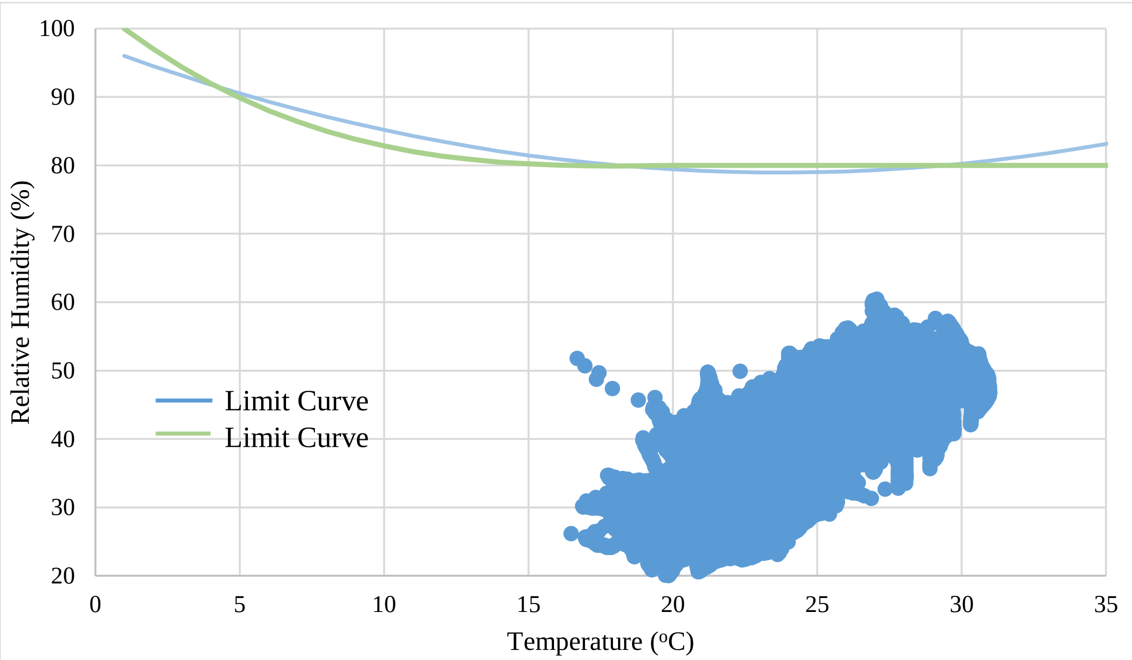


Figure 4. 17. Biological degradation risk in ground floor

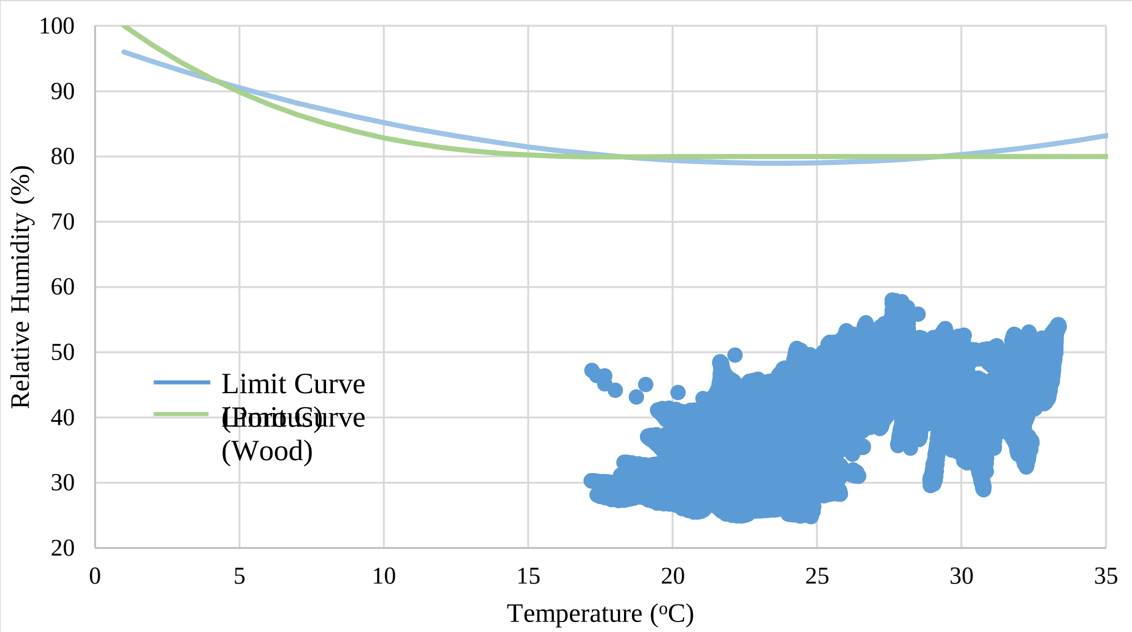


Figure 4. 18. Biological degradation risk first floor

4.3. BES Model Calibration Results

Modeling the structure, material properties and charts of the library building according to the information received from the library manager and staff, calibration simulations were performed to optimize the temperature and relative humidity settings of the HVAC system. HVAC system settings provided in Table 4.1. In order to complete the calibration process successfully, the cooling and heating degrees have been changed. The values of this process, which was successful as a result of the fourth trial, are given below.

Table 4. 1. HVAC values for calibration simulation

Options	Calibration Model
Heating	24.00
Heating Setback	22.00
Cooling	29.00
Cooling Setback	30.00
RH Humidification Setback	50.00
RH Dehumidification Setback	60.00
Humidification	On
Dehumidification	On

Yearly RMSE is 8.73% and annual MBE is -2.36. Hence, according the results, calibration simulation yearly results are within ASHRAE Guideline 14's limits.

When the results are analyzed monthly, RMSE and MBE results for all months are still within the ASHRAE Guideline 14's limits. It is observed that the winter season is higher in fluctuation than the summer season. This difference may be due to the HVAC used according to these two seasons.

Table 4. 2. RMSE and MBE results for simulation

	RMSE %	**MBE %**
October	7.87	-5.39
November	6.78	-4.14
December	8.75	6.78
January	12.58	9.74
February	6.63	-0.50
March	9.06	-2.19
April	6.64	-0.64
May	8.24	-2.33
June	8.22	-3.01
July	8.65	-6.58
August	9.33	-7.62
September	9.73	-6.32
Annual	8.73	-2.36

4.4. Energy Consumption and Discomfort Hours Results for Base Case Building

The annual energy consumption result for base case scenario is shown in Table 4.3. The annual amount of energy consumed in this building is 382952.57 kWh. According to the results, energy spent on the cooling process is almost twice the energy spent on the heating process. As can be seen from the results, it can be explained by the use of natural gas for the heating process and the use of electricity for the cooling process. At the same time, this situation may have occurred due to climatic conditions.

Table 4. 3.Total energy consumption and amount of energy per square meter

	Total (kWh)	The amount of energy per square meter (kWh) Total m² 1508
Heating (kWh)	96110.10	63.73
Cooling (kWh)	184240.32	122.17
Lighting equipment and interior equipment (kWh)	102602.15	68.03
Annual Energy Consumption (kWh)	382952.57	253.94

Annual discomfort hours in working period determined as 1152.42. This corresponds to a period of slightly more than 48 days.

4.5. Annual Energy Consumption and Discomfort Hours Results of Optimization Option

4.5.1 Scenario 1 Optimization Analysis

The aim of this optimization study is to reduce energy consumption and discomfort hours without changing anything in the building. This study helps to find proper degree of cooling set point and heating set point. Only cooling and heating set point are chosen as design variables. As seen in Table 4.4, cooling set point is set minimum 24°C, maximum 27.50°C. Heating set point is set minimum 20°C, maximum 23°C.

According to result of the optimization process, the lowest energy consumption is 312274.54 kWh when cooling set point temperature is 27.2°C and heating set point is 21°C. In optimal design for discomfort hours, discomfort hours in work-hour determined as 599.12 and cooling set point temperature is 24.1°C and heating set point is 23°C. In results of the midpoint of the optimization option, annual energy consumption found as

319136,51 kWh and discomfort hours determined as 1147.45 when cooling set point temperature is 25.4°C and heating set point is 23.4°C.

Table 4. 4. Design variables of scenario 1 optimization option

Design Variables	Maximum	Minimum
Cooling Set Point	27.50 °C	24 °C
Heating Set Point	20 °C	23 °C

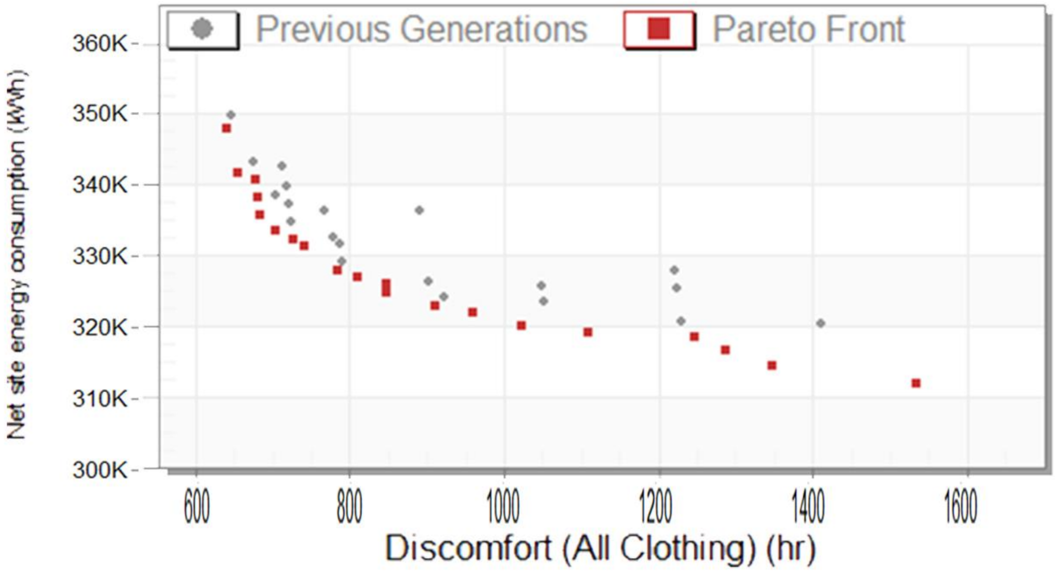


Figure 4. 19 Optimization results of scenario 1

Table 4. 5. Optimal designs of scenario 1 for energy consumption and discomfort hours

Optimal Design	**Discomfort hours in work-hour(All Clothing) (hr)**	**Net site energy consumption (kWh)**	**Cooling set point temperature (°C)**	**Heating set point temperature (°C)**
Optimal Design for Energy Consumption	1548.63	312274.54	27.2	21
Optimal Designs for Discomfort Hours	599.12	347984.23	24.1	23
Midpoint of the Optimal Designs	1147.45	319136,51	25.4	21.4

4.5.2 Scenario 2 Optimization Analysis

The objective of this optimization study is to find best proper materials to reduce energy consumption and discomfort hours without changing any structural materials. For this objective, five design variables are selected. These are cooling set point temperature, heating set point temperature, glazing type, exterior door construction and pitched roof floor construction. Cooling set point is set minimum 24°C, maximum 27.50°C. Heating set point is set minimum 20°C, maximum 23°C.

External door, pitched roof floor construction and glazing type design variables are shown in Table 4.6 and Table 4.7.

Table 4. 6. Design variables of scenario 2 optimization option

Design Variables	**Options**		**Conductivity (WW/m-K)**	**Specific Heat (J/kg-K)**	**Density (kg/m³)**	**U value (W/ m²-K)**
Exterior door	Wooden Door		0.1900	2390	700	2.823
	Steel Door		50	450	7800	3.124
	Metal Door with Board Insulation	Metal	45.28	500	7824	3.820
		Board	0.0360	840	160	
Pitched roof floor construction	Glass Wool 50mm		0.0360	840	20	0.603
	Glass Wool 100mm		0.0360	840	20	0.328
	Stone Wool 50mm		0.0350	840	150	0.589

Table 4. 7. Glazing type variables of scenario 2 optimization option

Design Variable	Options	Total Solar Transmission	Light Transmission	U-Value (W/m²-K)
Glazing type	3mm single clear	0.861	0.898	5.894
	Double clear 3mm/ 6mm air	0.762	0.812	3.159
	Double clear 3mm/ 13mm air	0.764	0.812	2.716
	Double loE (e2= 1) 3mm/ 6mm air	0.600	0.769	2.470
	Double loE (e2= 2) 3mm/ 13mm air	0.691	0.744	2.597

Result of the optimization study, the best options are selected for energy saving and reducing discomfort hours Table 4.8. In optimal design for reducing energy consumption; cooling set point temperature is 27.4°C, heating set point temperature is 21°C, glazing type is double loE (e2= 2) 3mm/ 13mm air, exterior door construction is wooden door and pitched roof construction floor is glass wool 100mm. In optimal design for increasing comfortable hours; cooling set point temperature is 24°C, heating set point temperature is 22.8°C, glazing type is double loE (e2= 1) 3mm/ 6mm air, external door construction is metal door and pitched roof construction floor is glass wool 100mm. In addition, the midpoint of optimal designs is the point where energy use and discomfort hours can be minimized together. For the midpoint of optimal designs options; cooling set point temperature is 25.4°C, heating set point temperature is 21.4°C, glazing type is double loE (e2= 1) 3mm/ 6mm air, exterior door construction is metal door and pitched roof construction floor is glass wool 100mm.

According to results, glass wool 100mm is the best option for pitched roof floor construction because all the optimal designs are selected this material. For the external door design variable, wooden door is selected for reducing energy because of its U-Value, wooden door is selected for reducing discomfort hours. Double loE glazing type is selected for all optimal designs. Double loE (e2= 2) 3mm/ 13mm air glazing type selected for optimal design for energy consumption because of its total solar transmission.

In optimal design for energy consumption, cooling set point is higher than optimal design for discomfort hours. Also, optimal design for energy consumption heating set point is lower than optimal design for discomfort hours. Set points are selected in this way because higher cooling set point consumes less energy and lower heating set point consumes higher energy. According to results, all the optimal designs succeeded in reducing discomfort hours.

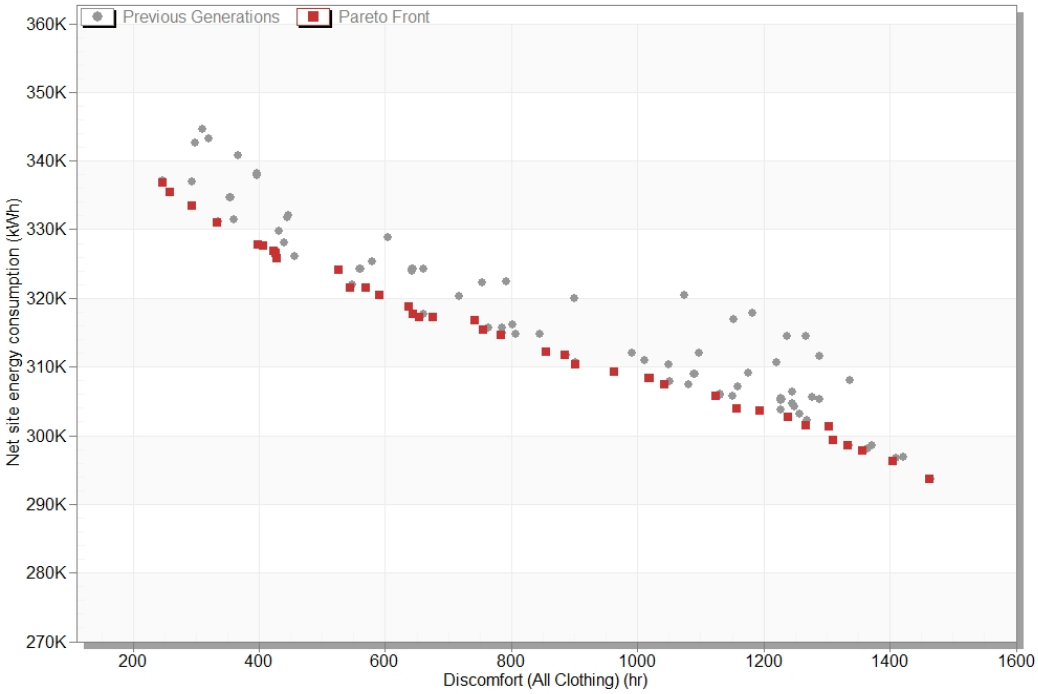


Figure 4. 20. Optimization results of scenario 2

Table 4. 8. Optimal designs of scenario 2 for energy consumption and discomfort hours

Optimal Design	**Discomfort hours in work-hour(All Clothing) (hr)**	**Net site energy consumption (kWh)**	**Cooling set point temperature (°C)**	**Heating set point temperature (°C)**	**Glazing type**	**Exterior door construction**	**Pitched roof floor construction**
Optimal Design for Energy Consumption	1461.30	293644.85	27.4	21	Double loE (e2=2) 3mm/13mm air	Wooden door	Glass Wool 100mm
Optimal Designs for Discomfort Hours	241.73	336809.23	24	22.8	Double loE (e2=1) 3mm/6mm air	Metal door	Glass Wool 100mm
Midpoint of the Optimal Designs	780.97	314673,51	25.4	21.4	Double loE (e2=1) 3mm/6mm air	Metal door	Glass Wool 100mm

4.5.3. Scenario 3 Optimization Analysis

The objective of this optimization study is to find best proper materials to reduce energy consumption and discomfort hours with changing some structural materials. For this objective, five design variables are selected. These are cooling set point temperature, heating set point temperature, glazing type, exterior door construction and pitched roof floor construction. Cooling set point is set minimum 24°C, minimum 27.50°C. Heating set point is set minimum 20°C, minimum 23°C. Exterior door, pitched roof floor construction, glazing type and exterior wall design variables are shown in Table 4.9. and Table 4.10.

Table 4. 9. Design variables of scenario 3 optimization option

Design Variables	Options		Conductivity (W/m-K)	Specific Heat (J/kg-K)	Density (kg/m³)	U value (W/ m²-K)
Exterior door	Wooden Door		0.1900	2390	700	2.823
	Steel Door		50	450	7800	3.124
	Metal Door with Board Insulation	Metal	45.28	500	7824	3.820
		Board	0.0360	840	160	
Pitched roof floor construction	Glass Wool 50mm		0.0360	840	20	0.603
	Glass Wool 100mm		0.0360	840	20	0.328
	Stone Wool 50mm		0.0350	840	150	0.589
Exterior wall	Exterior Wall					1.892
	Exterior Wall with Flax					1.263
	Exterior Wall with wool					1.228

Table 4. 10. Glazing type variables of scenario 3 optimization option

Design Variable	Options	Total Solar Transmission	Light Transmission	U-Value (W/m²-K)
Glazing type	3mm single clear	0.861	0.898	5.894
	Double clear 3mm/ 6mm air	0.762	0.812	3.159
	Double clear 3mm/ 13mm air	0.764	0.812	2.716
	Double loE (e2= 1) 3mm/ 6mm air	0.600	0.769	2.470
	Double loE (e2= 2) 3mm/ 13mm air	0.691	0.744	2.597

Result of the optimization process, the most accurate options are selected for reducing energy consumption and increasing comfortable hours in Table 4.11. In optimal design for increasing saving energy; cooling set point temperature is 27.4°C, heating set point temperature is 21.6°C, glazing type is double loE (e2= 2) 3mm/ 13mm air, exterior door construction is wooden door, pitched roof construction floor is glass wool 100mm and exterior wall construction is exterior wall with wool.

In optimal design for reducing discomfort hours; cooling set point temperature is 24°C, heating set point temperature is 23°C, glazing type is double loE (e2= 1) 3mm/ 6mm air, exterior door construction is metal door, pitched roof construction floor is glass wool 100mm and exterior wall construction is exterior wall with wool.

In addition, the midpoint of optimal designs is the point where energy use and discomfort hours can be minimized together. For the midpoint of optimal designs options; cooling set point temperature is 25.4°C, heating set point temperature is 21.4°C, glazing type is double loE (e2= 1) 3mm/ 6mm air, exterior door construction is metal door, pitched roof construction floor is glass wool 100mm and exterior wall construction is exterior wall with wool.

According to results, all selected design variables are the nearly same with scenario 2 in optimization study. Glass wool 100mm is the best option again for pitched roof floor construction because of its U-Value. For the exterior door design variable, wooden door is selected for reducing energy because wooden door has the lowers U-Value. Double loE glazing type has lower U-Value that other materials thus double loE glazing type is selected for all optimal designs. Because of its total solar transmission, Double loE (e2= 2) 3mm/ 13mm air glazing type is selected for optimal design for energy consumption. For the exterior wall construction, there are two different options apart from the base case option. Exterior wall with wool and exterior wall with flax. These two design variables are selected because of their organic structure. Hence, while proposing a new design variable to be used in the historic building, it is aimed to use a sustainable material. All the optimal options are selected exterior wall with wool design variables because it has lowest U-Value.

When the optimal designs results of two optimization options are compared, the design variables for the optimal designs in scenario 2 and scenario 3 are almost the same. Only cooling set point design variable and heating set point design variable are changed a few degrees. The conclusion drawn from this situation is that the design variables selected in scenario 2 in optimization study do not show any change in the case of adding the exterior wall construction design variable. All the optimal designs reduced discomfort hours. Furthermore, optimal designs for discomfort hours in scenario 3 is more successful than optimal designs for discomfort hours and reducing energy consumption in scenario 1 and scenario 2.

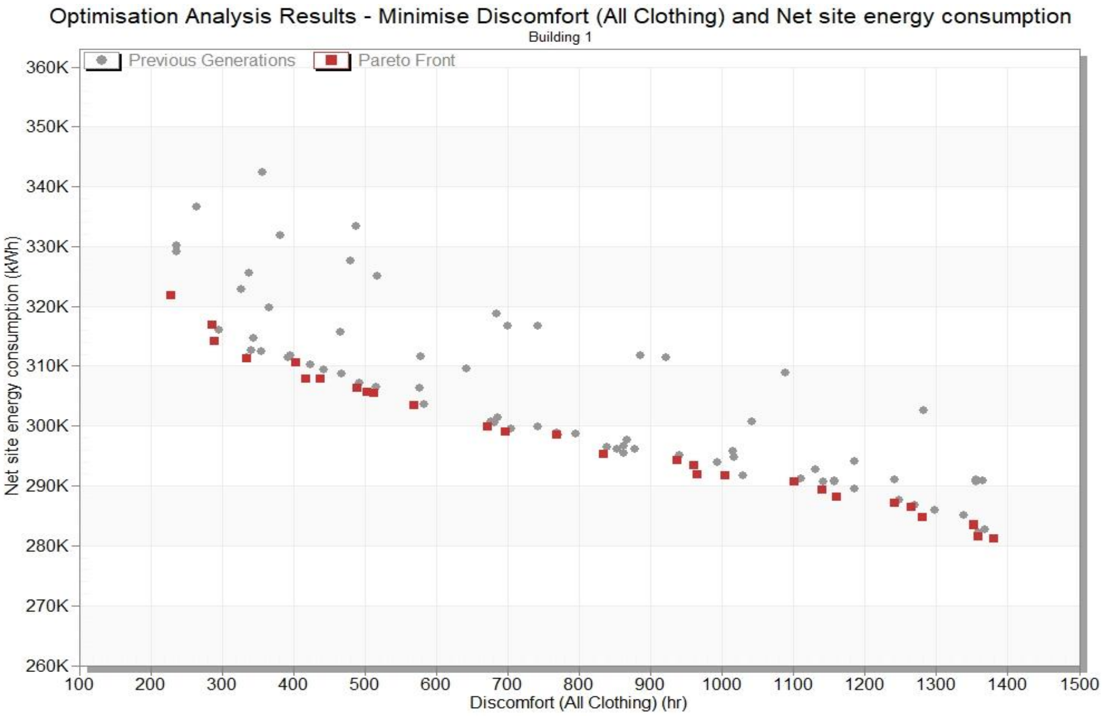


Figure 4. 21. Optimization results of scenario 3

Table 4. 11. Energy consumption and discomfort hours for scenario 3

Optimal Design	**Discomfort hours in work-hour(All Clothing) (hr)**	**Net site energy consumption (kWh)**	**Cooling set point temperature (°C)**	**Heating set point temperature (°C)**	**Glazing type**	**Exterior door construction**	**Pitched roof floor construction**	**Exterior wall construction**
Optimal Design for Energy Consumption	1375.52	281219,21	27.4	21,6	Double loE (e2= 2) 3mm/ 13mm air	Wooden door	Glass Wool 100mm	Exterior Wall with wool
Optimal Designs for Discomfort Hours	227.26	321810,18	24	23	Double loE (e2= 1) 3mm/ 6mm air	Metal door	Glass Wool 100mm	Exterior Wall with wool
Midpoint of the Optimal Designs	718.11	304284.41	25.4	21.4	Double loE (e2= 1) 3mm/ 6mm air	Metal door	Glass Wool 100mm	Exterior Wall with wool

4.6 Energy Consumption and Discomfort Hours Comparison of Base Case and Scenarios' Optimization Option

Comparison between base case and best option of scenario 1 optimization shows that, decreasing in energy consumption and discomfort hours was revealed according to the base case. As a result of the optimization with the lowest energy consumption, a decrease of 18,50% was observed compared to the base case. This means a decrease of 70678,03 kWh. There is also a decrease in discomfort hours. As a result of the optimization with the lowest discomfort hours, a decrease of 48.10% was observed compared to the base case. This decrease is quite small but beneficial in terms of occupants' comfort.

According to the results, it has been seen that the optimization study has resulted in a successful way in Table 4.12. When base case and best scenarios of scenario 2 optimization option, decreasing in energy consumption and discomfort hours was revealed according to the base case. As a result of the optimization with the lowest energy consumption, a decrease of 23.4% was observed compared to the base case. This means a decrease of 2553492.10 kWh. At the same time, there is also a decrease in discomfort hours. As a result of the optimization with the lowest discomfort hours, a decrease of 79.10% was observed compared to the base case. This means, decreasing level is 910.69 hours. This decrease is extremely beneficial in terms of human comfort.

When comparison between base case and best scenarios of scenario 3 optimization option, decreasing in energy consumption and discomfort hours was revealed according to the base case. As a result of the optimization with the lowest energy consumption, a decrease of 26.6% was observed compared to the base case. This means a decrease of 101733.36 kWh. There is also a decrease in discomfort hours. As a result of the optimization with the lowest discomfort hours, a decrease of 80.30% was observed compared to the base case. This decrease is exceedingly beneficial in terms of occupants' comfort.

Comparison of scenario 1, scenario 2 and scenario3 optimization option is shown that scenario 3 optimization option results are more satisfying than scenario 1 and scenario 2 optimization option. As a result of the optimization with the lowest energy consumption option, a decrease of 4.3% was observed compared to scenario 2 optimization option. This means a decrease of 12425.64 kWh. There is also a decrease in discomfort hours, a decrease of 5.9% was observed compared to the scenario 2 optimization option. Hence, scenario 3 optimization option offers more comfortable hours than scenario 2 optimization option.

Table 4. 12. Comparison between base case and scenarios' optimization midpoint option in terms of energy consumption and discomfort hours

	Energy Consumption (kWh)	Energy Consumption According to Base case	Discomfort Hours	Discomfort Hours According to Base case (%)
Base Case	382952.57		1152.42	
Scenario 1 Optimization Option	312274.54	- 18.50 %	599.12	- 48.10%
Scenario 2 Optimization Option	293644.85	- 23.40 %	241.73	- 79.10 %
Scenario 3 Optimization Option	281219,21	- 26.60 %	227.26	- 80.30%

In Table 4.13., Table 4.14 and Table 4.15, it is shown that comparison of base case and all scenarios' optimization midpoint option in terms of energy consumption and discomfort hours. According to results of scenario 1 optimization midpoint option, scenario 2 optimization midpoint option and scenario 3 optimization midpoint option, decreasing in energy consumption and discomfort hours was revealed according to the base case.

Base case and scenario 1 optimization midpoint option comparation shows that, decreasing in energy consumption and discomfort hours was determined according to the base case. As a result of the midpoint optimization option for energy consumption, a decrease of 16.7% was observed compared to the base case. This means a decrease of 63816.06 kWh. There is also a decrease in discomfort hours. As a result of the midpoint optimization option for discomfort hours, a decrease of 5% was observed compared to the base case.

When comparation of base case and scenario 2 midpoint option, decreasing in energy consumption and discomfort hours was revealed according to the base case. As a result of the midpoint optimization option, a decrease of 17.9% was observed compared to the base case in temrs of energy usage. This means a decrease of 68279.06 kWh. At the same time, there is also a decrease in discomfort hours. As a result of the optimization with the lowest discomfort hours, a decrease of 32.3% was observed compared to the base case. This means a decrease of 368.88 hours. This decrease, which corresponds to 6 days.

When comparation of base case and scenario 3 midpoint option, decreasing in energy consumption and discomfort hours was revealed according to the base case. As a result of the midpoint optimization option for energy consumption, a decrease of 20.6% was observed compared to the base case. This means a decrease of 78668.16 kWh. There is also a decrease in discomfort hours. As a result of the midpoint optimization option for discomfort hours, a decrease of 37.7% was observed compared to the base case. This decrease, which corresponds to little more than 7 days.

Comparison of scenario1, scenario 2 and scenario 3 optimization midpoint option is shown that scenario 3 midpoint optimization option results are more satisfying than other scenarios’ optimization midpoint option. As a result of scenario 3 midpoint option for energy consumption option, a decrease of 3.4% was observed compared to scenario 2 optimization option. This means a decrease of 10389.10 kWh. There is also a decrease in discomfort hours, a decrease of 7.9 % was observed compared to the scenario 2 optimization midpoint option. This means a decrease of 61.43 hours. Hence, scenario 3 optimization midpoint option offers more comfortable hours than scenario1 and scenario 2 optimization midpoint option.

Table 4. 13. Comparison between base case and all scenarios' optimization midpoint option in terms of energy consumption and discomfort hours

	Energy Consumption (kWh)	Energy Consumption According to Base case	Discomfort Hours in work-hours (hr)	Discomfort Hours According to Base case
Base Case	382952.57		1152.42	
Midpoint of Scenario 1 Optimization	319136.51	- 16.7 %	1147.45	- 5 %
Midpoint of Scenario 2 Optimization	314673.51	- 17.9 %	780.97	- 32.3 %
Midpoint of Scenario 3 Optimization	304284.41	- 20.6 %	718.11	- 37.7 %

Table 4. 14. Energy consumption comparison of optimal designs for all scenarios and base case

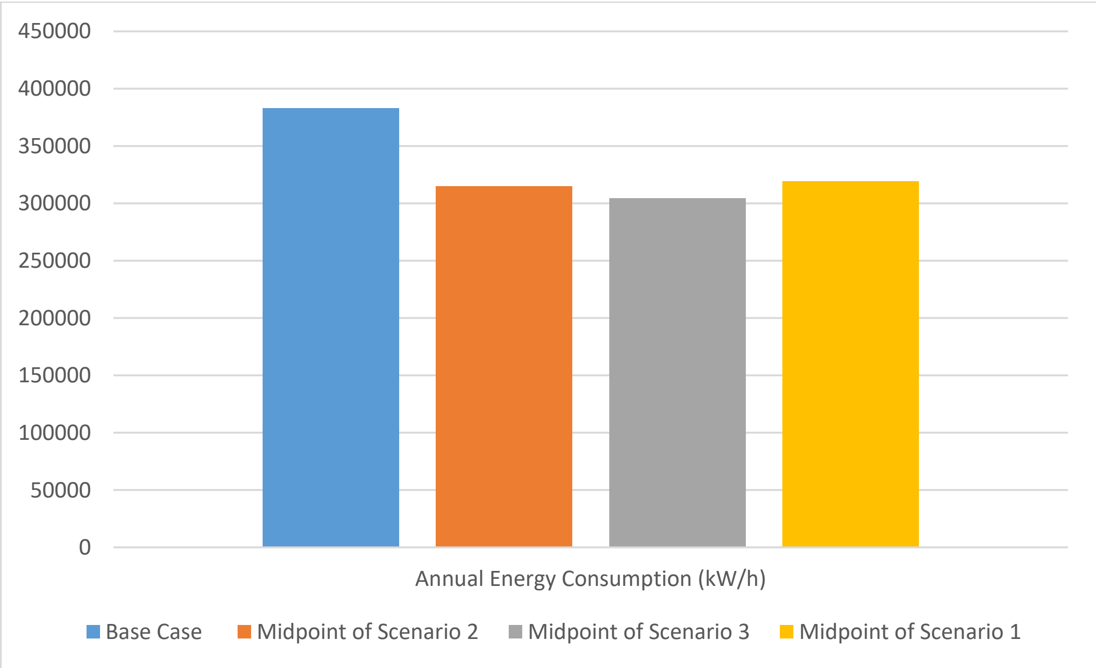
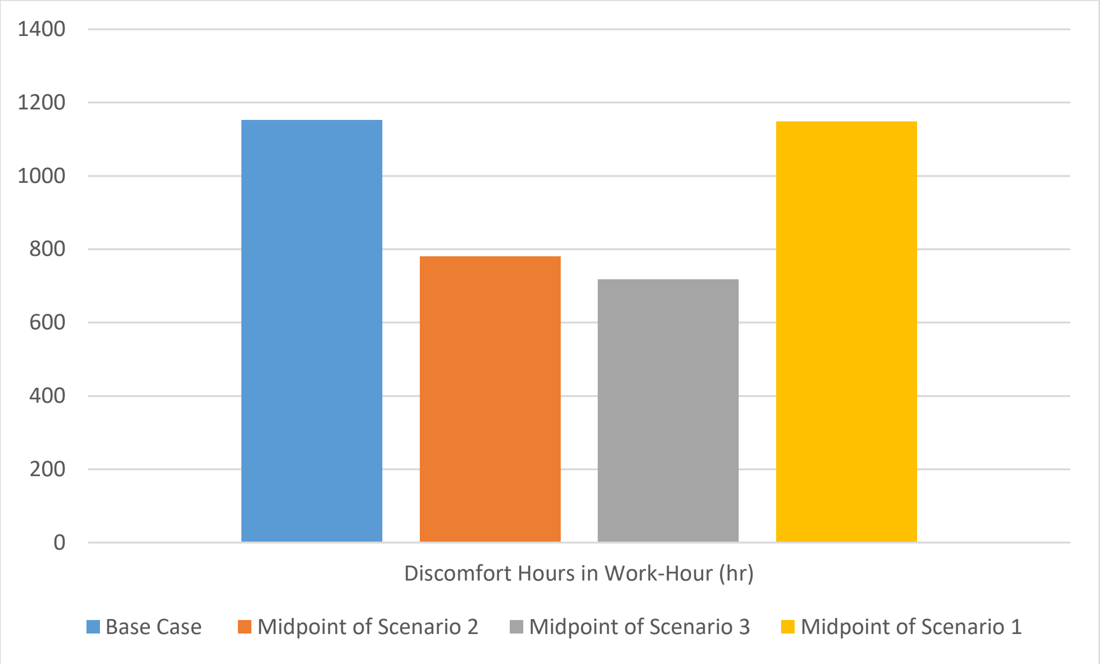


Table 4. 15. Discomfort hours comparison of optimal designs for all scenarios and base case



4.7. Degradation Analysis of Midpoint of Optimization Processes

4.7.1. Degradation Results of Scenario 1 Optimization Midpoint Option

4.7.1.1. Mechanical Degradation Risk Assessment for Scenario 1 Optimization Midpoint Option

Based on degradation results, comparison of midpoint option and base case results, base case mechanical degradation risk a little bit less than midpoint option. The cumulative frequency calculations revealed that 28.7% of the RH differences were below the 5% RH limit and that 6.22% of the ground floor T changes were below the 2 K limit (Figure 4.24.). Changes to the design variables have increased the risk of mechanical degradation in terms of base case.

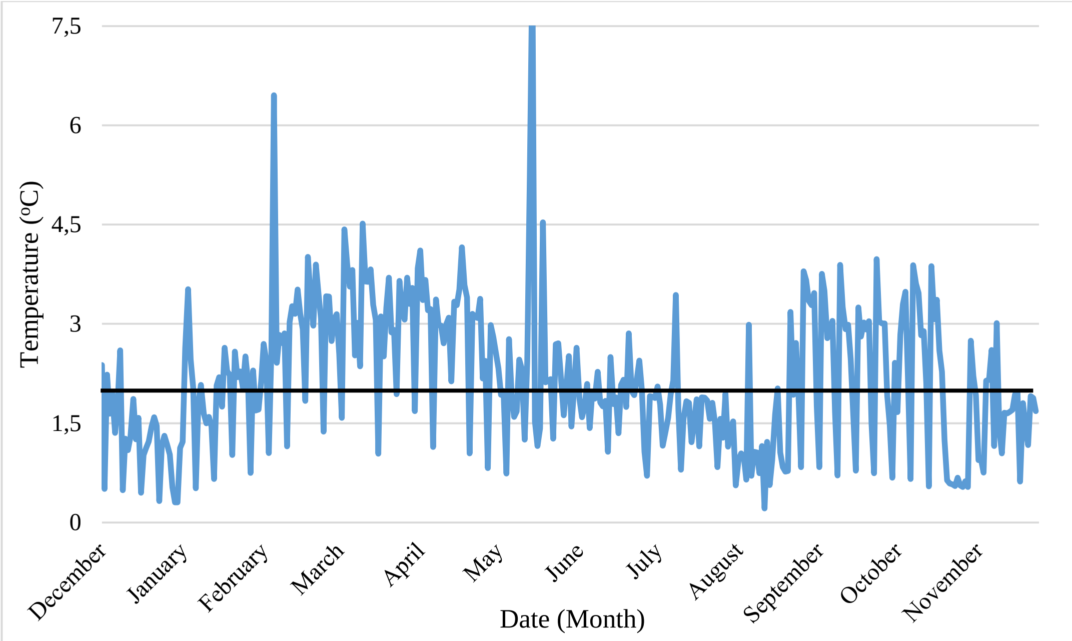


Figure 4. 22 Daily air temperature (Daily T) fluctuation in the ground floor scenario 1 midpoint option

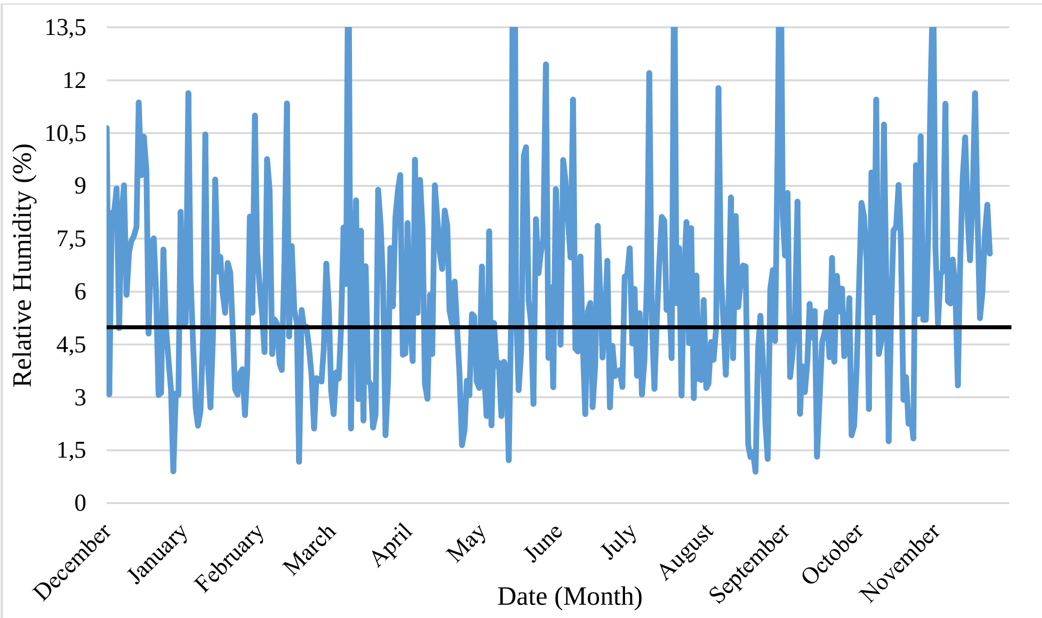


Figure 4. 23 Daily relative humidity (Daily RH) fluctuation in the ground floor of scenario 1 midpoint option

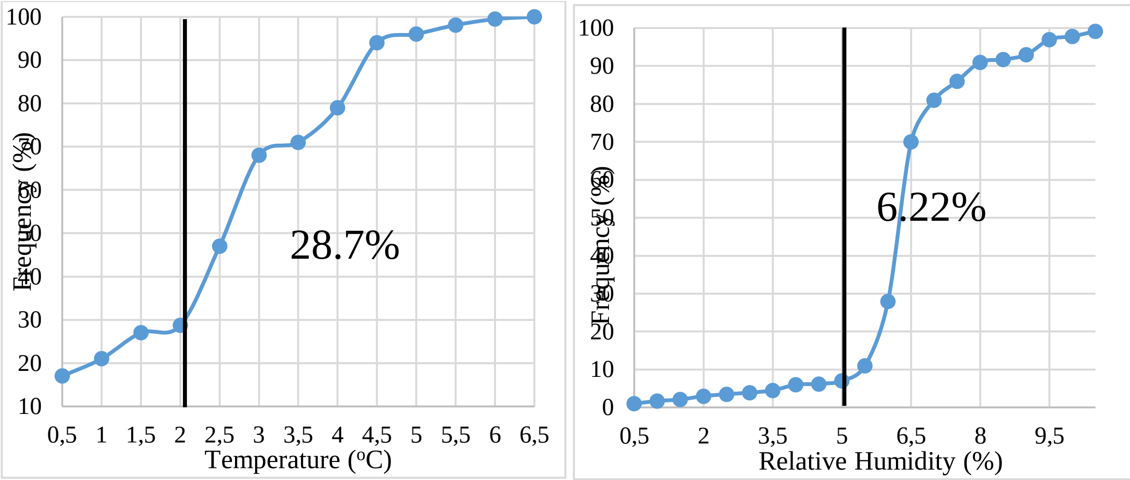


Figure 4. 24 Cumulative frequencies of T (left) and RH (right) differences in ground floor scenario 1 midpoint option

4.7.1.2. Chemical Degradation Risk Assessment for Scenario 1 Optimization Midpoint Option

According to figure 4.25, there is a difference between base case and scenario 1 optimization midpoint option from the point of chemical degradation risk. High risk area has more points than base case. Hence, as no material has been changed, chemical degradation is higher level.

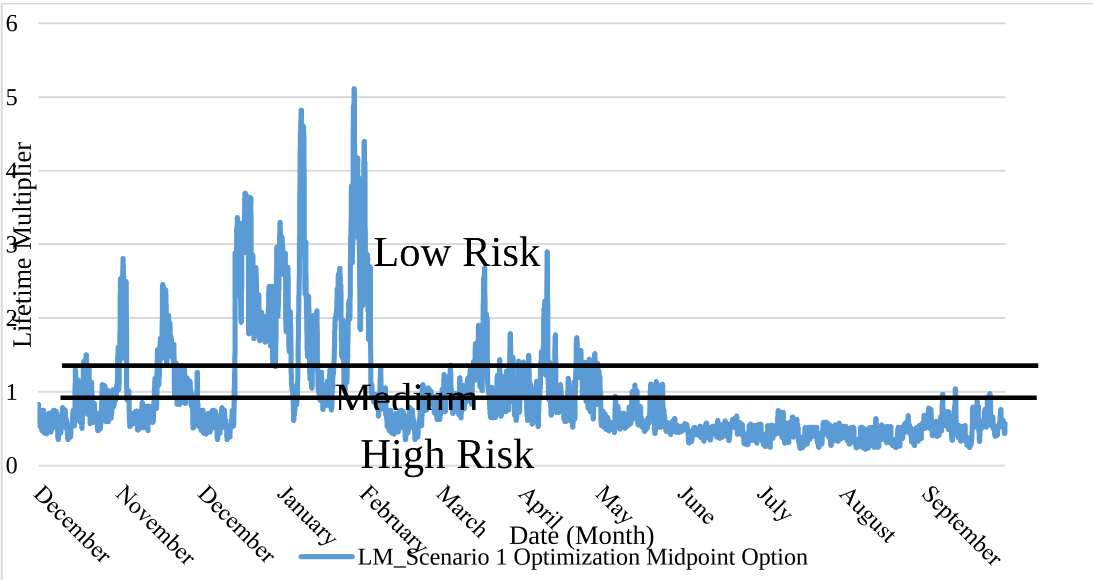


Figure 4. 25 LM values of scenario 1 midpoint option

4.7.1.3. Biological Degradation Risk Assessment for Scenario 1 Optimization Midpoint Option

Figure 4.26 show that manuscripts were under no risk of biological degradation for midpoint optimization option. Like in base case, scenario 2 optimization midpoint option, the midpoint option has no condition to cause biological degradation.

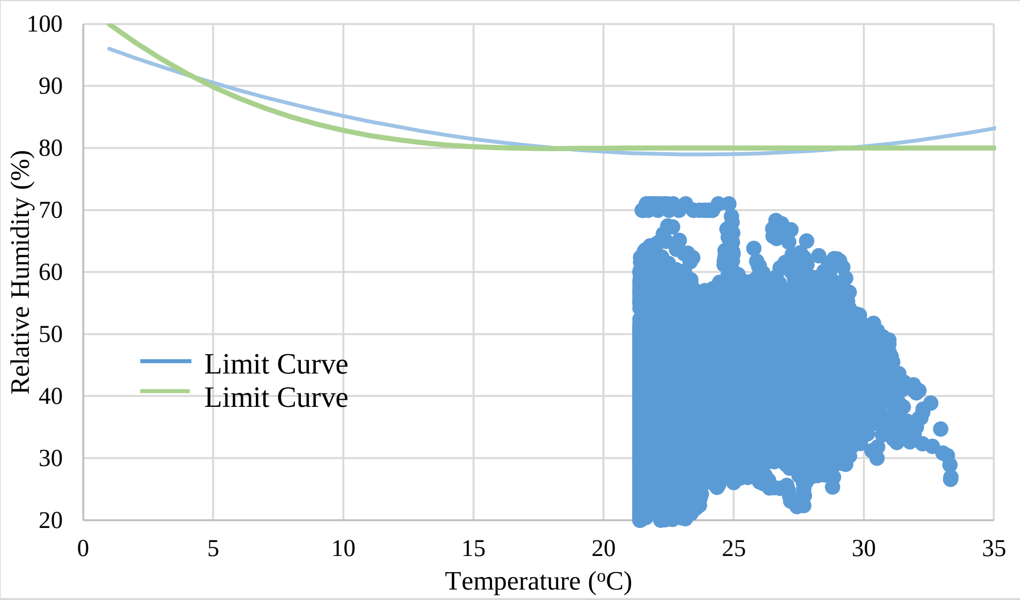


Figure 4. 26 Scenario 1 midpoint option biological degradation risk

4.7.2. Degradation Results of Scenario 2 Optimization Midpoint Option

4.7.2.1. Mechanical Degradation Risk Assessment for Scenario 2 Optimization Midpoint Option

Comparison of midpoint option and base case results, in midpoint option, mechanical degradation risk is higher than base case building. While in base case building more than half of the recorded daily T and RH changes fell below the 2 K and 5% limitations, fulfilling the requirements for all control classes, respectively, in midpoint option less than half of the recorded daily T and RH changes fell below the 2% K and 5% limitations. The cumulative frequency calculations revealed that 49.04% of the RH differences were below the 5% RH limit and that 07.33% of the ground floor T changes were below the 2 K limit (Figure 4.29). Changes to the design variables have increased the risk of mechanical degradation.

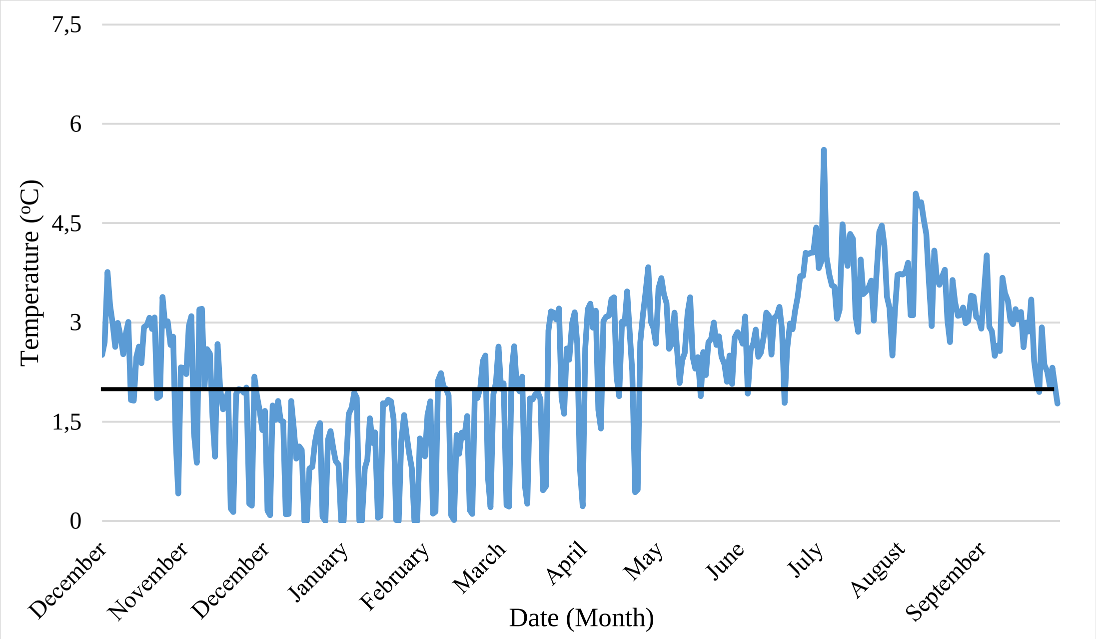


Figure 4. 27. Daily air temperature (Daily T) fluctuation in the ground floor of scenario 2 midpoint option

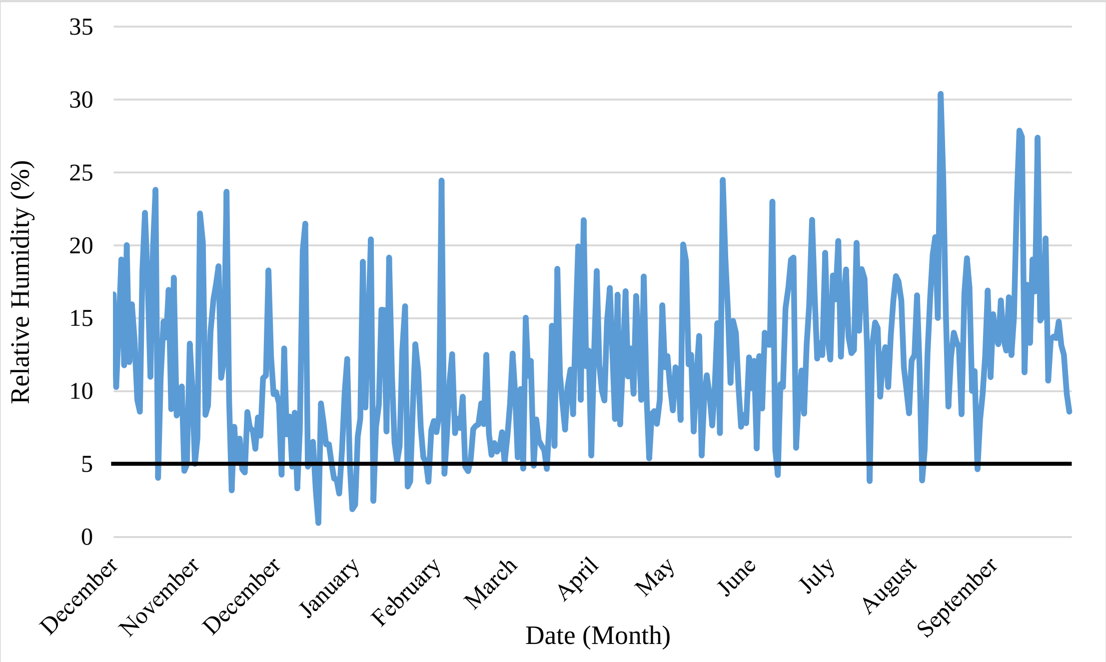


Figure 4. 28. Daily relative humidity (Daily RH) fluctuation in the ground floor of scenario 2 midpoint option

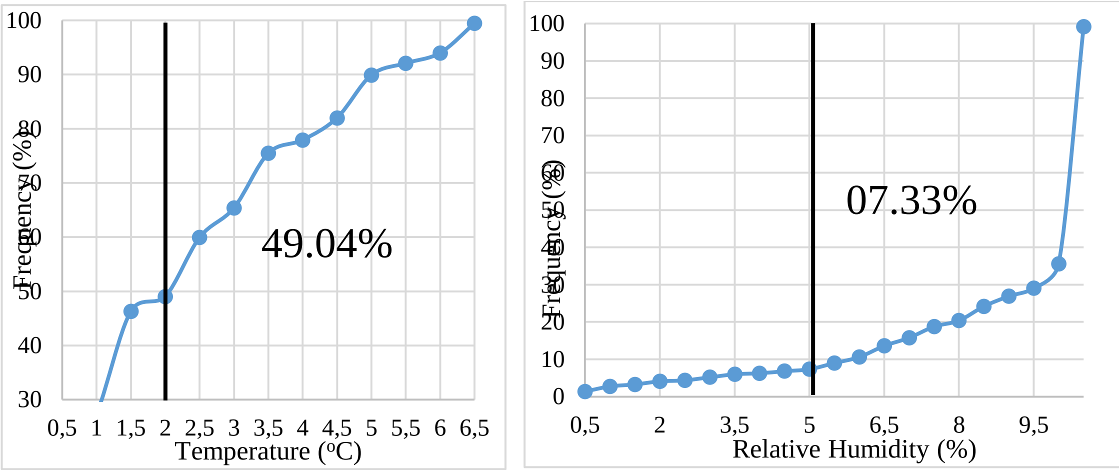


Figure 4. 29. Cumulative frequencies of T (left) and RH (right) differences in ground floor of scenario 2 midpoint option

4.7.2.2. Chemical Degradation Risk Assessment for Scenario 2 Optimization Midpoint Option

The results of the chemical degradation risk assessment for midpoint option monitored T and RH data in terms of LM can be found in Figure 4.30. According to the results, the manuscripts were under low risk of chemical degradation in December, January and February. Between May to October, manuscripts in high risk in terms of chemical degradation. The lowest calculated LM value was 0.225 in August, while the highest was 3.818 in January.

Actually, the results of chemical degradation of midpoint nearly as same as base case results. Changes to the design did not affect the risk of chemical degradation to any major extent. It can be said that, changing of glazing type, exterior wall material, pitch roof floor material, cooling set point and heating set point have no great effect against chemical degradation in this historic building.

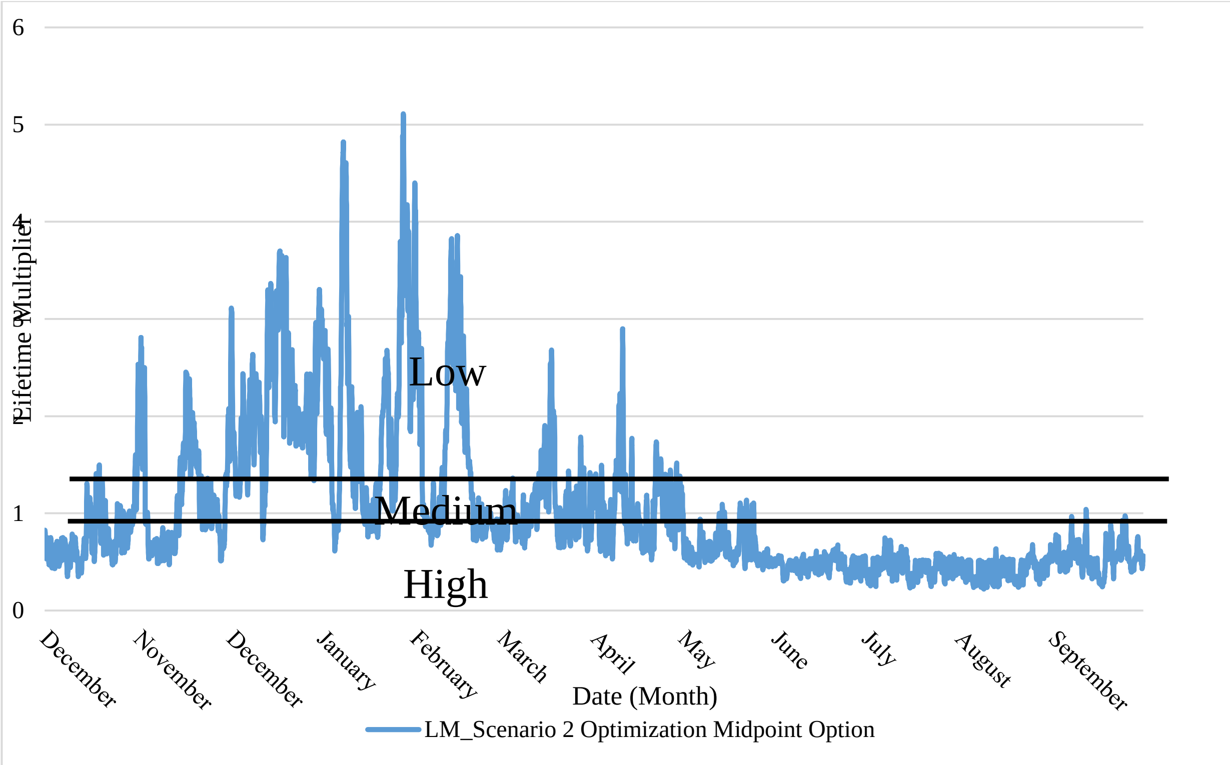


Figure 4. 30. LM values of Scenario 2 midpoint option

4.7.2.3. Biological Degradation Risk Assessment for Scenario 2 Optimization Midpoint Option

Figure 4.31. show that manuscripts were under no risk of biological degradation for midpoint optimization option. Like in base case scenario, the midpoint option has no condition to cause biological degradation. Therefore, according to results, the modified design elements did not increase the risk of biodegradation.

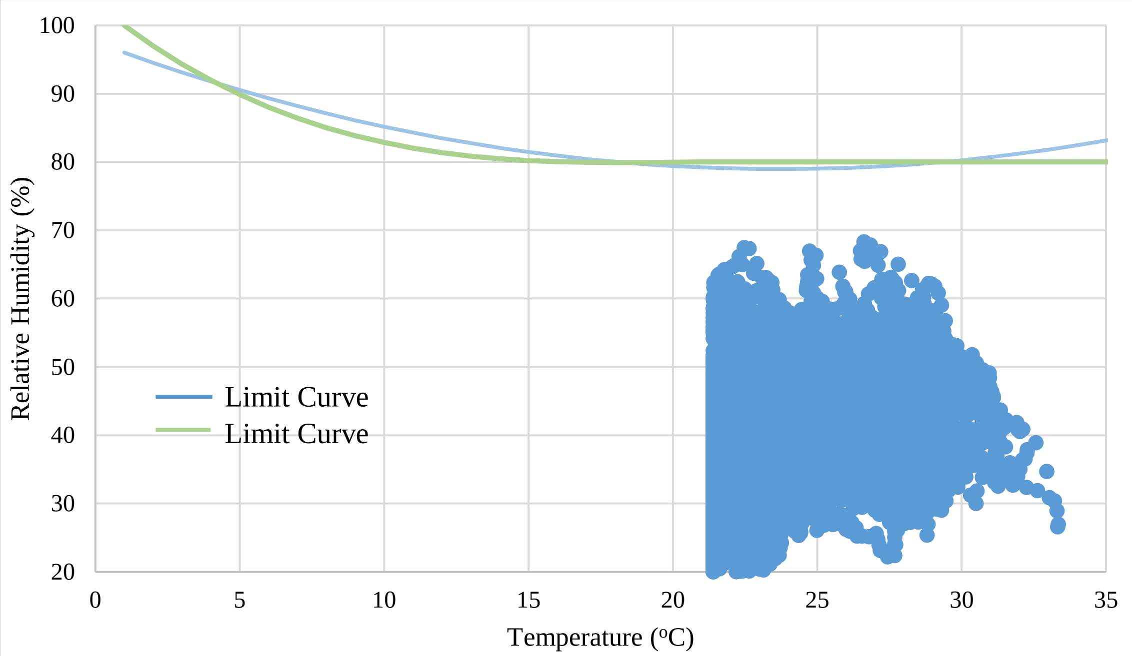


Figure 4. 31. Scenario 2 midpoint option biological degradation risk

4.7.3. Degradation Results of Scenario 3 Optimization Midpoint Option

4.7.3.1. Mechanical Degradation Risk Assessment for Scenario 3 Optimization Midpoint Option

According to results, there is almost no difference between scenario 3 optimization midpoint option and scenario 2 optimization midpoint option in terms of mechanical degradation risk. Comparison of midpoint option and base case results, base case mechanical degradation risk less than midpoint option The cumulative frequency calculations revealed that 49.67% of the RH differences were below the 5% RH limit and that 07.88% of the ground floor T changes were below the 2 K limit (Figure 4.34). Changes to the design variables have decreased the risk of mechanical degradation in terms of scenario 2 midpoint option.

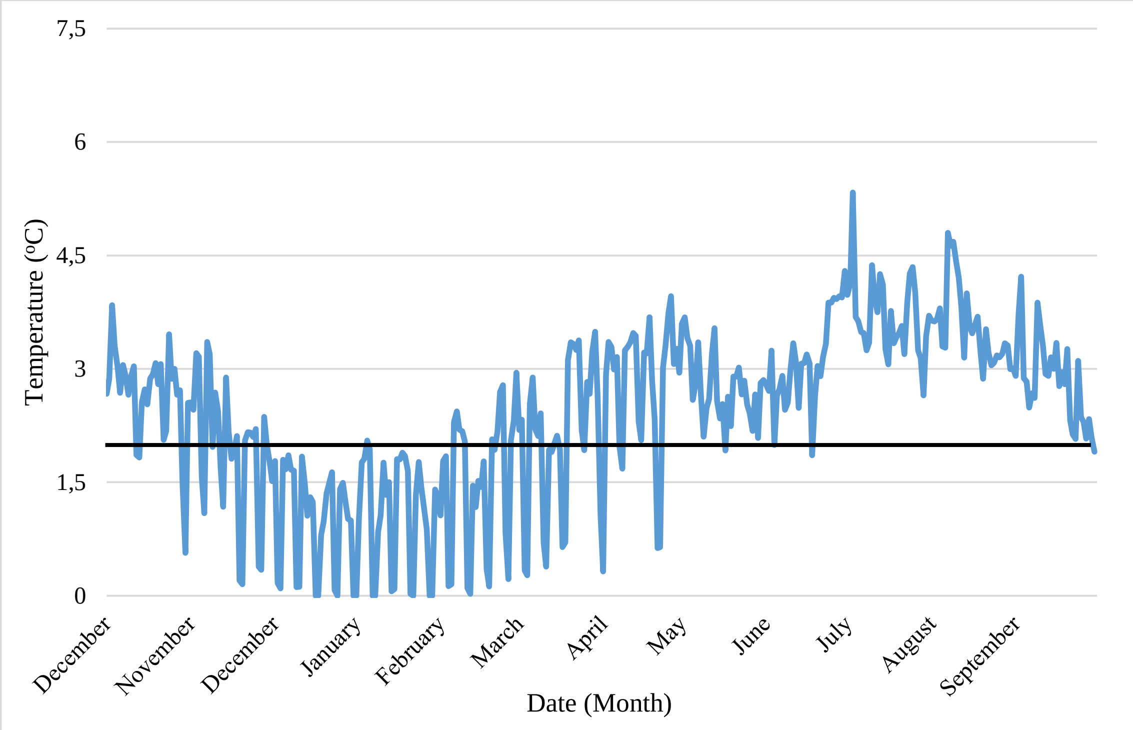


Figure 4. 32. Daily air temperature (Daily T) fluctuation in the ground floor of scenario 3 midpoint option

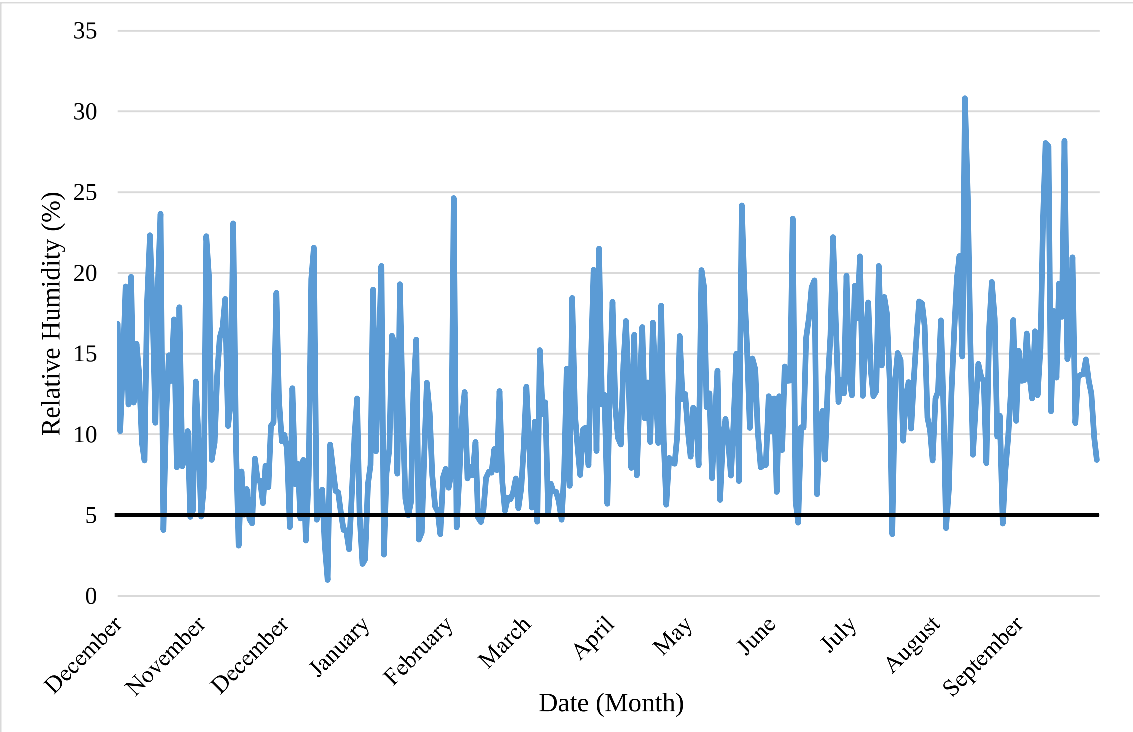


Figure 4. 33. Daily relative humidity (Daily RH) fluctuation in the ground floor of scenario 3 midpoint option

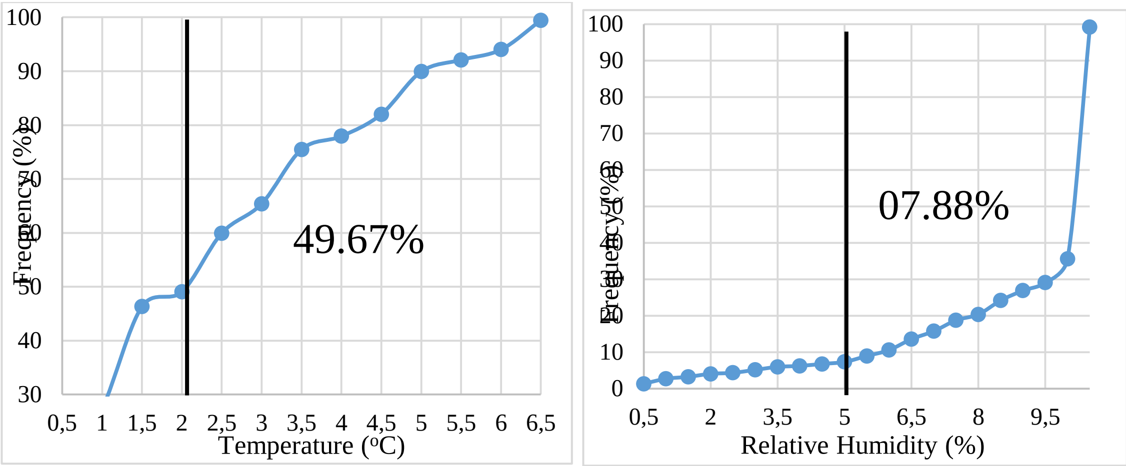


Figure 4. 34. Cumulative frequencies of T (left) and RH (right) differences in ground floor of scenario 3 midpoint option

4.7.3.2. Chemical Degradation Risk Assessment for Scenario 3 Optimization Midpoint Option

According to figure 4.35., there is no visible difference between scenario 3 in optimization midpoint option and scenario 2 retrofit optimization midpoint option from the point of chemical degradation risk. Although it is not reflected on the chart, scenario 3 midpoint option's high-risk area is less than scenario 2 midpoint option numerically. The conclusion that can be drawn from this is that changing the exterior wall construction reduces the risk of chemical degradation to a very low extent.

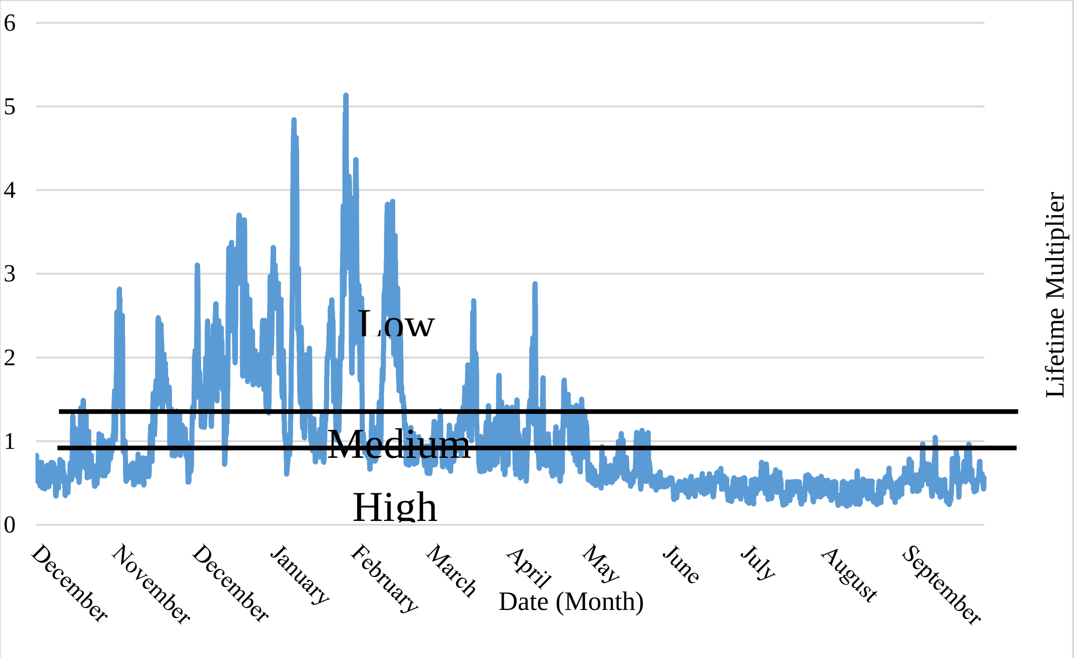


Figure 4. 35. LM values of scenario 3 midpoint option

4.7.3.3. Biological Degradation Risk Assessment for Scenario 3 Optimization Midpoint Option

Figure 4.36 show that manuscripts were under no risk of biological degradation for midpoint optimization option. Like in base case scenario and scenario 2 optimization midpoint option, the midpoint option has no condition to cause biological degradation. Furthermore, according to results, the modified design element which is exterior wall construction did not increase the risk of biological degradation.

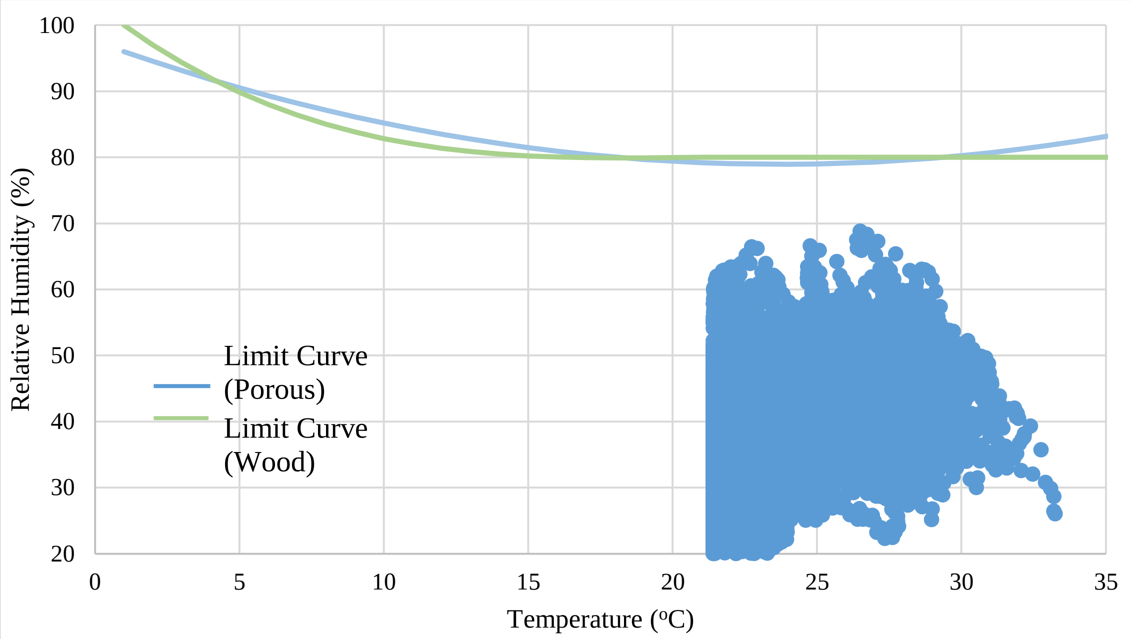


Figure 4. 36. Scenario 3 midpoint option biological degradation risk

4.7.4. Discussion of Optimizations and Base Case Degradation Risks Analysis

For the optimization studies, the degradation risk analysis was performed as for the base case. According to the results, the risks of degradation of the midpoints of the optimization results are higher than the risks of degradation of the base case. All optimization suggestions, which are almost the same in terms of mechanical degradation risk were observed to be higher than the base case mechanical degradation risk (Figure 4.37). In addition, although it is seen in the graphs that the risk of chemical degradation was decreased, there are more result of low risk and medium risk area (Figure 4.38). It has been observed that the three optimization studies for biological degradation risk are almost identical (Figure 4.39). Although the risk has increased according to base case, it has been observed that it still gives results below the risk limit.

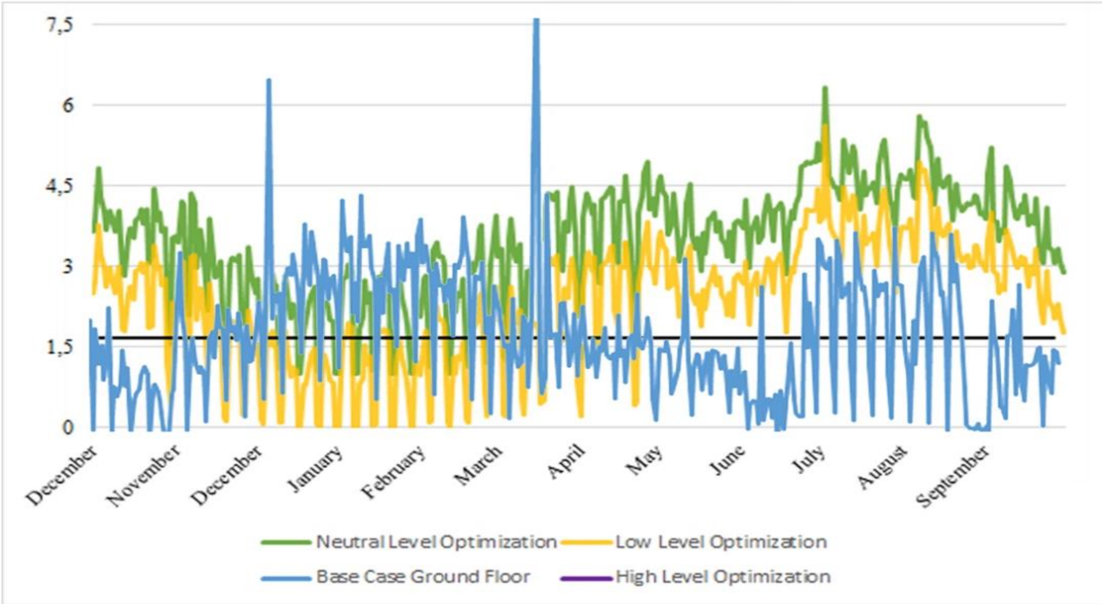


Figure 4. 37. Comparison of daily air temperature (Daily T) fluctuation in the ground floor between base case and scenarios

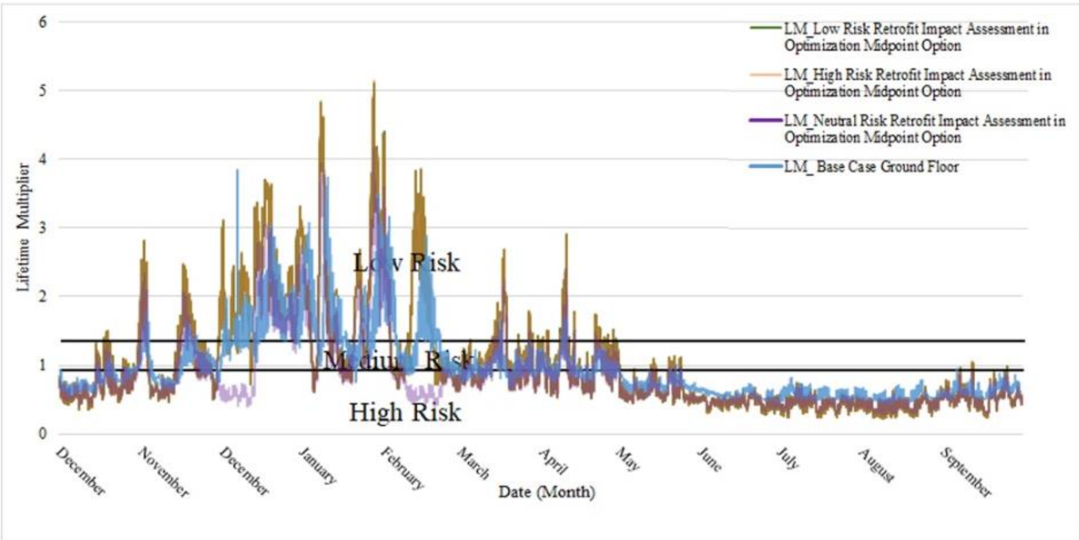


Figure 4. 38. LM value comparison between base case and all scenarios

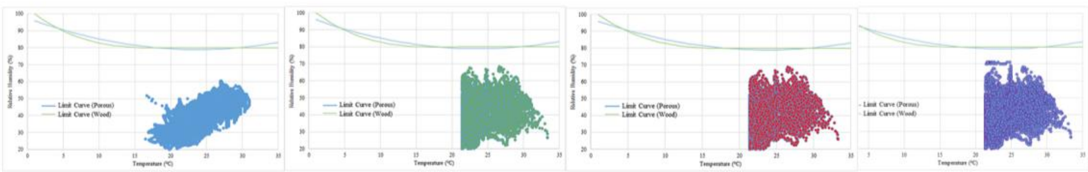


Figure 4. 39. Biological degradation comparison between base case, and all scenarios

CHAPTER 5

CONCLUSION

5.1. Recommendations

Posterior recommendations can be made to reducing energy consumption and discomfort hours in İzmir National Library, and other similar libraries or archival buildings:

These days, the unique architecture of the historic building is not given much consideration during most retrofitting processes. In renovation work, changing of building materials are problem because constructors are not be careful of original architectural design. Hence, scenario 1 optimization aims to reduce energy consumption and discomfort hours only changing cooling and heating set points. This option is more economic and safer way to protect building. Although it cannot reduce energy consumption and discomfort hours as much as both optimization studies, it is a work to be done with at least zero damage to the building.

Energy consumption in historic buildings is often higher than in modern buildings, due to the fact that the buildings are built with old technology. In this case, it should not be ignored that the building is a historic building while certain moves are made to reduce energy consumption. Although fundamental changes cannot be made in historic buildings, some energy can be preserved with some design changes. In this thesis, as design changes, heating set point and cooling set point were glazing type, exterior door material, pitched roof floor construction, heating set point and cooling set point were set for optimization. This change, made without disturbing the unique architecture of the historic building, will be beneficial both financially and sustainably for many years. This type of retrofitting is called for low risk retrofit impact assessment (scenario 2).

In addition, a study can be conducted within the scope of scenario 3. In this case, a change in the exterior wall construction design was added to the low risk retrofit impact assessment procedure (scenario 2). The results showed that the right material choices made in the exterior wall construction reduced the amount of energy consumption considerably. An insulation work to be done while preserving the unique feature of the outer wall will greatly reduce the energy consumed by the historic building.

It is a complex and important situation to meet the comfort level of people in library buildings and the risks of degradation of manuscripts at the same time. The comfort of the people inside the building must be ensured, as the preserved manuscripts will eventually be read by a human. HVACs equipped with old technology found in historic buildings may also be causing this problem. But just like trying to reduce energy consumption, some interventions will help reduce discomfort hours. Optimization studies carried out in this thesis have shown that the design variables chosen to reduce energy consumption also increase comfortable hours. It has been observed that with the right materials selected in the design variables, discomfort hours can be reduced without changing the HVAC.

While working to reduce energy consumption and discomfort hours, the risks of mechanical, chemical and biological degradation of the historic building and the manuscripts inside the building should also be considered. These changes to be made should reduce the risks of degradation or at least keep them as they were. In this thesis, mechanical, chemical and biological degradation risk analyzes were made after the interventions. In line with the results obtained, the risk of mechanical degradation increased, the risk of chemical degradation decreased and did not show the risk of biological degradation.

Table 5. 1. Advantages and disadvantages of all scenarios (Red: High, Orange: Medium and Green: Low)

	Reduction Energy Consumption	Reduction Discomfort Hours	Changing Building Structure	Cost
Scenario 1				
Scenario 2				
Scenario 3				

In my point of view, scenario 2 is the most logical option to retrofitting historic İzmir National Library Building. As seen in Figure 5.1., scenario 2 was not the best but not the worst one in terms of energy consumption, discomfort hours, changing building structure and cost. In scenario 2, architecture of historic building was not change and construction cost was not more expensive than scenario 3. In my opinion, the scenario, which succeeds in reducing energy consumption and discomfort hours without changing the unique architecture of the building, is the most preferable one among the three scenarios.

5.2. Future Studies

In the light of the results obtained, the following studies will be carried out:

- Increasing the variety of interventions to reduce energy consumption will lead to more accurate and comprehensive results. HVAC change proposals will provide a different perspective to the studies to be carried out and it will be beneficial to observe the positive or negative effects.
- Sensivity analysis can be run in DesignBuilder Software. Sensitivity analysis shows how input parameter uncertainties impact significant building parameters, such as energy consumption, interior thermal comfort, or discomfort hours. To achieve most effective parameters, sensivity analysis should be use before optimization analysis.
- Future work should use new design variants and proposed new sustainable materials that will reduce energy consumption while also reducing discomfort hours. Reducing discomfort hours to almost zero while increasing energy conservation will make the historic building almost perfect for human use.
- In future studies, attention should be paid to reducing the risks of mechanical, chemical and biological degradation for historic buildings and manuscripts, while reducing discomfort hours and energy consumption. It should be aimed to bring the degradation risk factors to the most appropriate levels with the right design variables and sustainable suitable materials.
- Lighting systems used in buildings should be examined in order to reduce energy consumption, reduce discomfort hours and optimize the risks of degradation. Correct use of the lighting system will not only help conserve energy, but also increase comfortable hours.

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APPENDICES

APPENDIX A

T. C.
KÜLTÜR BAKANLIĞI
GAYRİMENKUL ESKİ ESERLER ve ANITLAR
YÜKSEK KURULU BAŞKANLIĞI

KARAR

Toplantı No. ve Tarihi: 327, 19.6.1981 — Toplantı yeri: İSTANBUL
Karar No. ve Tarihi: A-2954, 20.6.1981

Sı.No:	Adı		Adresi (Bulmalık):
376-	Konut	-	İzmir İl Merkezi,Kemeraltı,848 sok.No:21,24-o-III paf. 178 ada,69 parsel.
377-?	"	-	İzmir İl Merkezi,Kemeraltı,846 sok.No:51,24-o-III paf. 178 ada, 78 parsel.
378-	"	-	İzmir İl Merkezi,Kemeraltı,848 sok.No:15,24-o-III paf, 178 ada,10 parsel.
379-	"	-	İzmir İl Merkezi,Kemeraltı,848 sok.No:13,24-o-III paf. 178 ada,70 parsel.
380-	Akşam Ticaret Lisesi		İzmir İl Merkezi,Kemeraltı,848 sok.No:5,24-o-III paf. 178 ada,15-75 parsel.
381-	Türkiye Muharip Gaziler Derneği		İzmir İl Merkezi,Kemeraltı,848 sok.No:7,24-o-III paf. 178 ada,74 parsel.
382-	Milli Kütüphane		İzmir İl Merkezi,Kemeraltı,Rifatpaşa cad.24-o-III paf. 179 ada,1 parsel.
383-	Elhamra Sineması		İzmir İl Merkezi,Kemeraltı,Rifatpaşa cad.24-o-III paf. 179 ada, 2 parsel.
384-	Özel İzmir İşhanı		İzmir İl Merkezi,Rifatpaşa cad.No:11,24-o-3 paf. 179 ada, 10 parsel.
385-	Konut		İzmir İl Merkezi,Kemeraltı,848 sok.45,24-o-3 paf. 180 ada, 69 parsel.
386-	"	-	İzmir İl Merkezi,Kemeraltı,848 sok.No:43,24-o-III paf. 183 ada,63 parsel.
387-	"	-	İzmir İl Merkezi,Kemeraltı,848 sok.41/41A/41B,/41C, 24-o-III paf.180 ada, 50 parsel.
388-	"	-	İzmir İl Merkezi,Kemeraltı,848 sok.24-o-III paf. 180 ada, 58 parsel.
389-	"	-	İzmir İl Merkezi,Kemeraltı,848 sok.No:49, 24-o-3 paf. 180 ada, 64 parsel.

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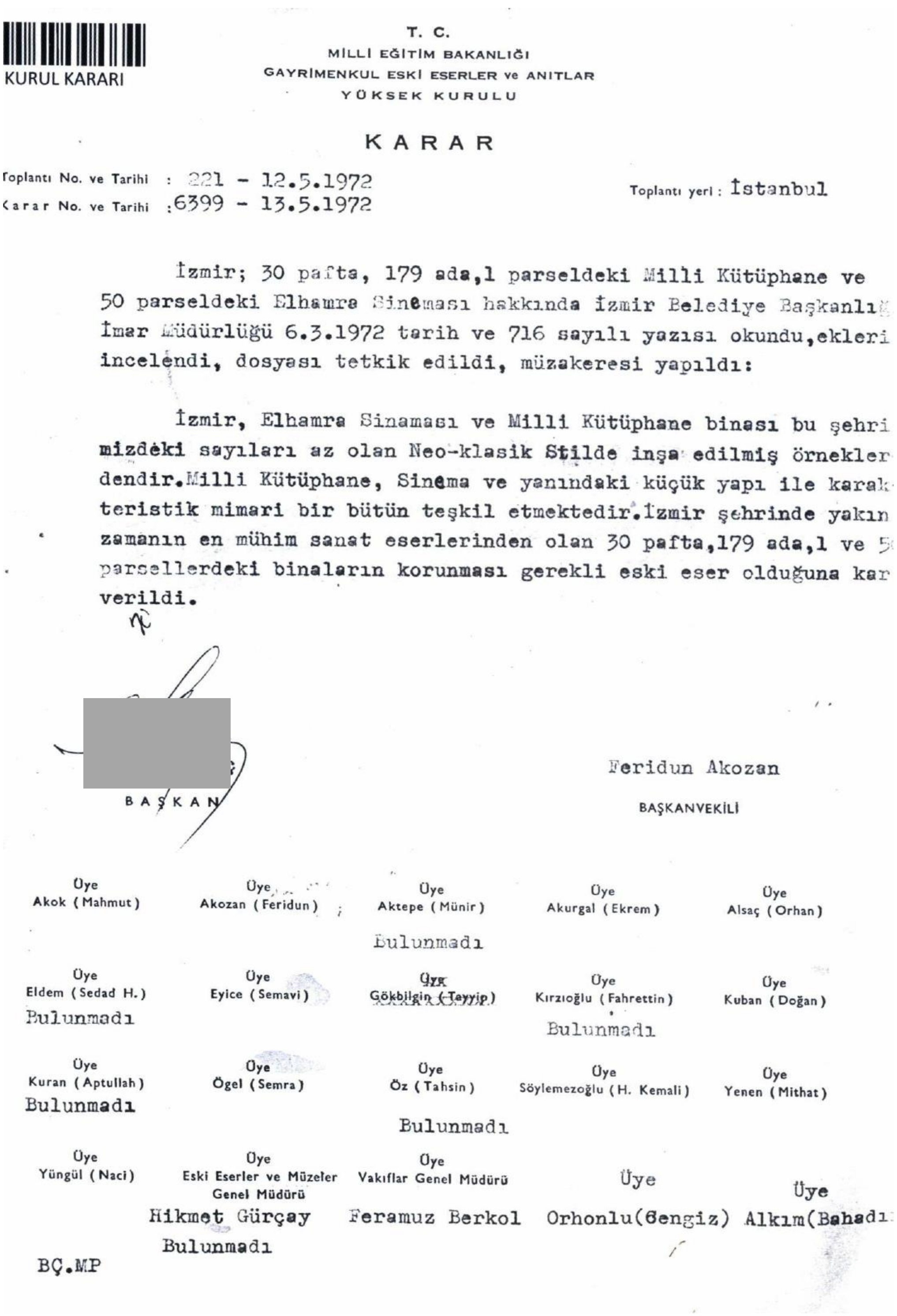
Figure A. 1. Official registiration document of İzmir National Library Building (Decision Number: 2954-382, Date: 20.06.1981) by The Republic of Türkiye, Ministry of Culture and Tourism, İzmir Regional Board of Protection of Cultural Heritage No. I



KURUL KARARI

T. C.
MİLLİ EĞİTİM BAKANLIĞI
GAYRİMENKUL ESKİ ESERLER ve ANITLAR
YÜKSEK KURULU

KARAR

Toplantı No. ve Tarihi : 221 - 12.5.1972
Karar No. ve Tarihi : 6399 - 13.5.1972

Toplantı yeri : İstanbul

İzmir; 30 pafta, 179 ada,1 parseldeki Milli Kütüphane ve 50 parseldeki Elhamra Sineması hakkında İzmir Belediye Başkanlı İmar Müdürlüğü 6.3.1972 tarih ve 716 sayılı yazısı okundu,ekleri incelendi, dosyası tetkik edildi, müzakeresi yapıldı:

İzmir, Elhamra Sinaması ve Milli Kütüphane binası bu şehrimizdeki sayıları az olan Neo-klasik Stilde inşa edilmiş örneklerdendir.Milli Kütüphane, Sinema ve yanındaki küçük yapı ile karakteristik mimari bir bütün teşkil etmektedir.İzmir şehrinde yakın zamanın en mühim sanat eserlerinden olan 30 pafta,179 ada,1 ve 5 parsellerdeki binaların korunması gerekli eski eser olduğuna kar verildi.

BAŞKAN

Feridun Akozan
BAŞKANVEKİLİ

Üye Akok (Mahmut)	Üye Akozan (Feridun)	Üye Aktepe (Münir) Bulunmadı	Üye Akurgal (Ekrem)	Üye Alsaç (Orhan)
Üye Eldem (Sedad H.) Bulunmadı	Üye Eyice (Semavi)	Üye Gökbilgin (Tayyip)	Üye Kırzıoğlu (Fahrettin) Bulunmadı	Üye Kuban (Doğan)
Üye Kuran (Aptullah) Bulunmadı	Üye Ögel (Semra)	Üye Öz (Tahsin) Bulunmadı	Üye Söylemezoğlu (H. Kemali)	Üye Yenen (Mithat)
Üye Yüngül (Naci)	Üye Eski Eserler ve Müzeler Genel Müdürü Hikmet Gürçay Bulunmadı	Üye Vakıflar Genel Müdürü Feramuz Berkol	Üye Orhonlu(Cengiz)	Üye Alkım(Bahadı

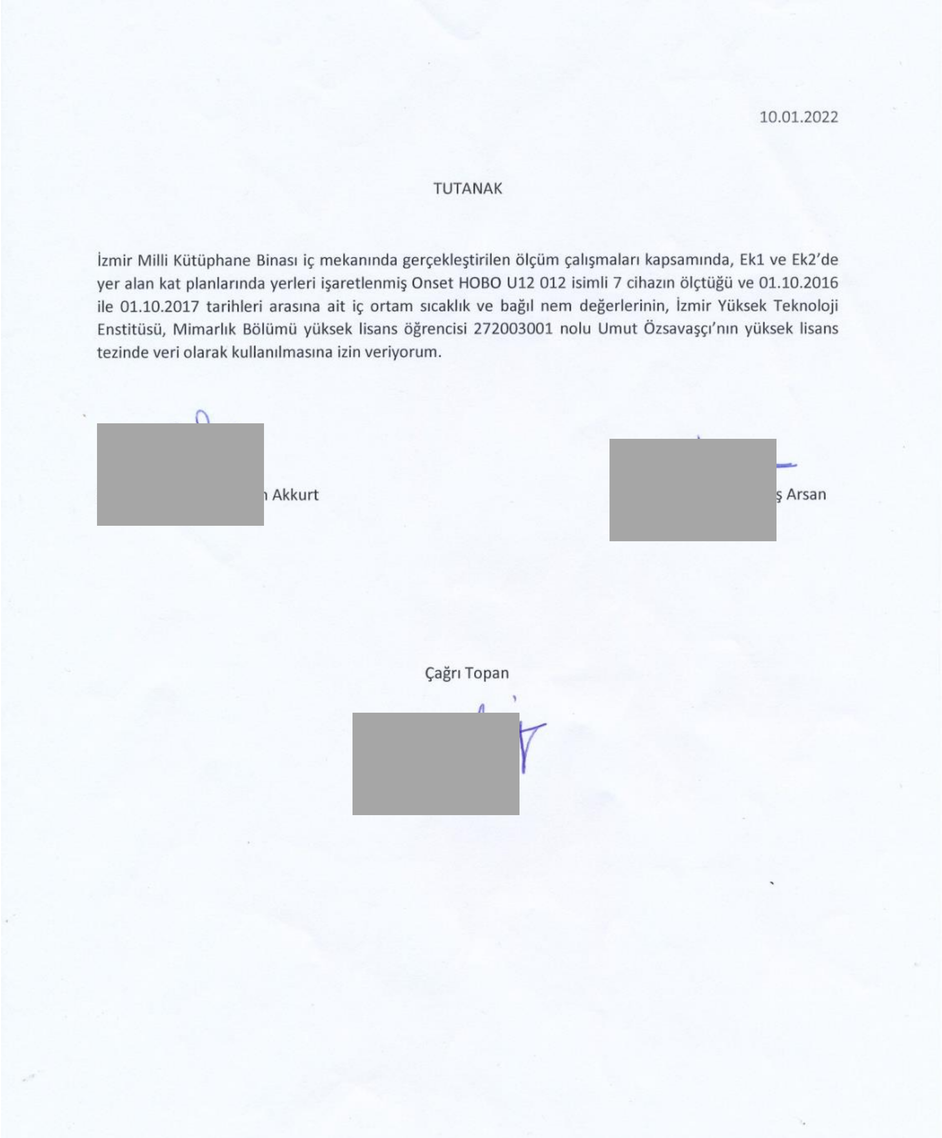
BÇ.MP

Figure A. 2. Official document by The Republic of Türkiye, Ministry of National Education, İzmir Regional Board of Protection of Cultural Heritage No. I stating that İzmir National Library Building as the historic buildingmust preserved (Decsison Number: 6399, Date: 13.05.1972)

APPENDIX B

The Turkish translation of official approval document (Appendix B.1) and its supplementary documents (Appendix B.2 andB.3) signed by Çağrı Topan, Zeynep Durmuş Arsan and Gülden Gökçen Akkurt is given as follows:

Within the scope of the measurement studies carried out in the interior of the İzmir National Library Building, the indoor temperature and relative humidity values between 01.10.2016 and 01.10.2017, measured by 7 devices named Onset HOBO U12 O12, whose locations are marked on the floor plans in Annex 1 and Annex 2. I hereby give permission as Umut Özsavaşçı, graduate student of the Institute of Technology, Department of Architecture, number 272003001, to be used as data in his master's thesis.



10.01.2022

TUTANAK

İzmir Milli Kütüphane Binası iç mekanında gerçekleştirilen ölçüm çalışmaları kapsamında, Ek1 ve Ek2'de yer alan kat planlarında yerleri işaretlenmiş Onset HOBO U12 012 isimli 7 cihazın ölçtüğü ve 01.10.2016 ile 01.10.2017 tarihleri arasına ait iç ortam sıcaklık ve bağıl nem değerlerinin, İzmir Yüksek Teknoloji Enstitüsü, Mimarlık Bölümü yüksek lisans öğrencisi 272003001 nolu Umut Özsavaşçı'nın yüksek lisans tezinde veri olarak kullanılmasına izin veriyorum.

[redacted] Akkurt

[redacted] Arsan

Çağrı Topan

[redacted]

Figure B. 1 Official approval document

Ek 1: Cihazların yerini gösterir giriş kat planı

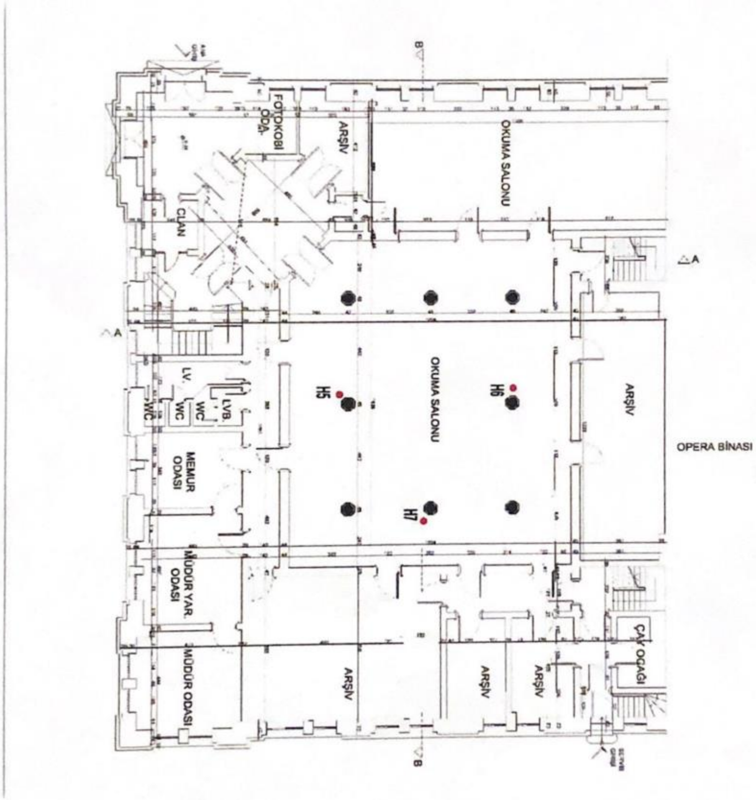


Figure B. 2 Suplementary document 1 (Ek 1) indicating the location of Onset Hobo devices in the ground floor of İzmir National Library Building

Ek 2: Cihazların yerini gösterir birinci kat planı

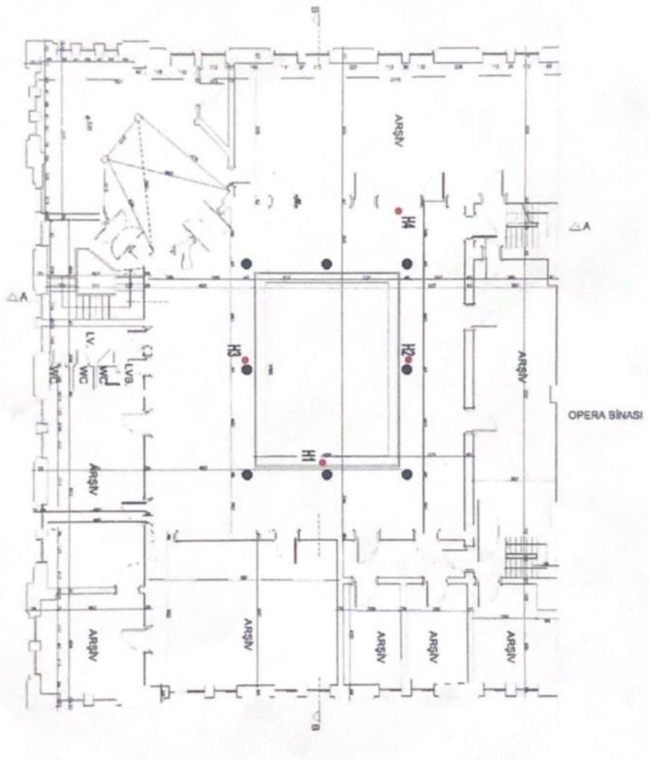


Figure B. 3 Suplementary document 2 (Ek 2) indicating the location of Onset Hobo devices in the first floor of İzmir National Library Building

APPENDIX C

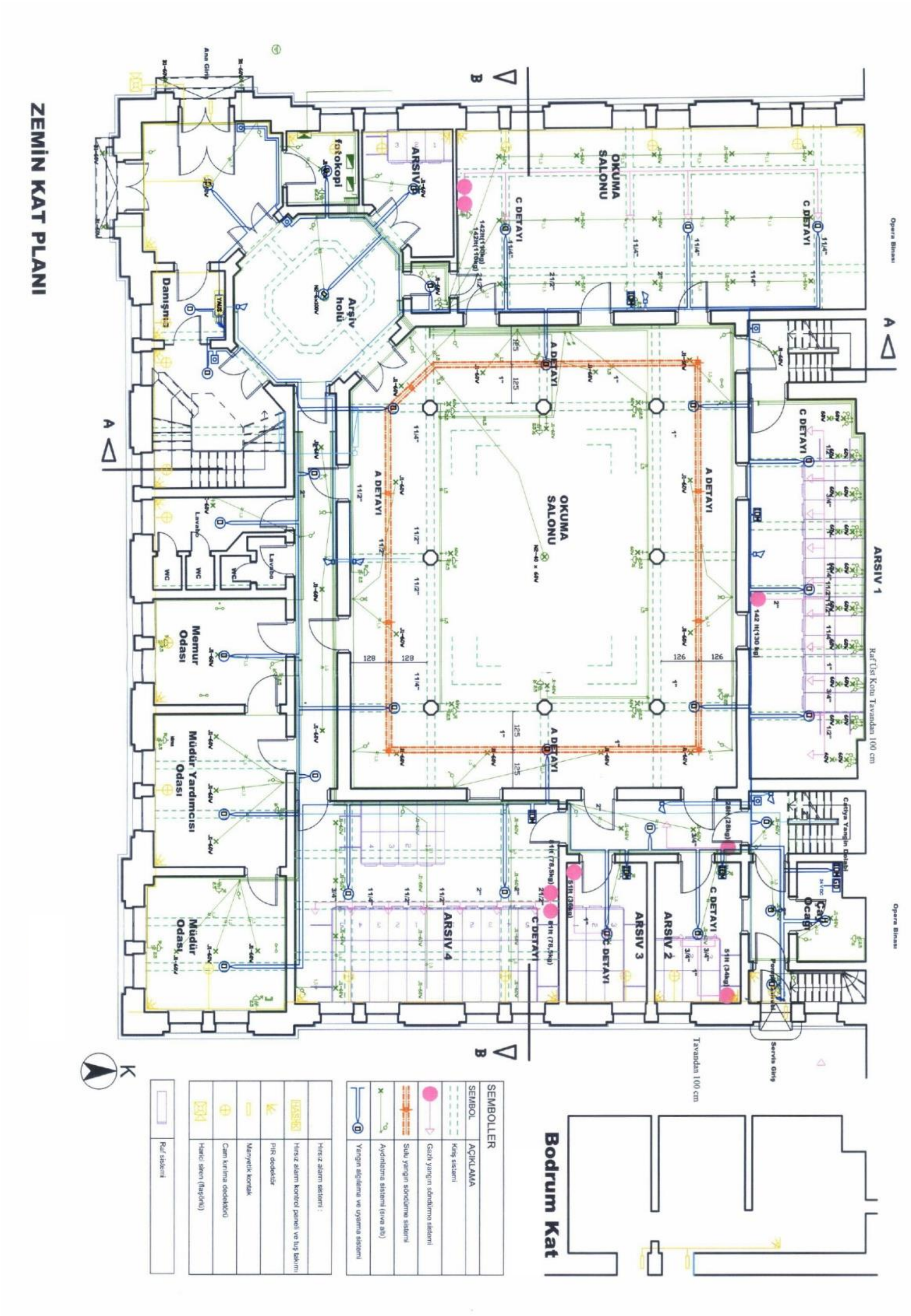


Figure C. 1.Ground Floor Plan of İzmir National Library Building (Source: The Republic of Türkiye, Ministry of Culture and Tourism, No. 1 Regional Board of Conservation of Cultural Heritage)

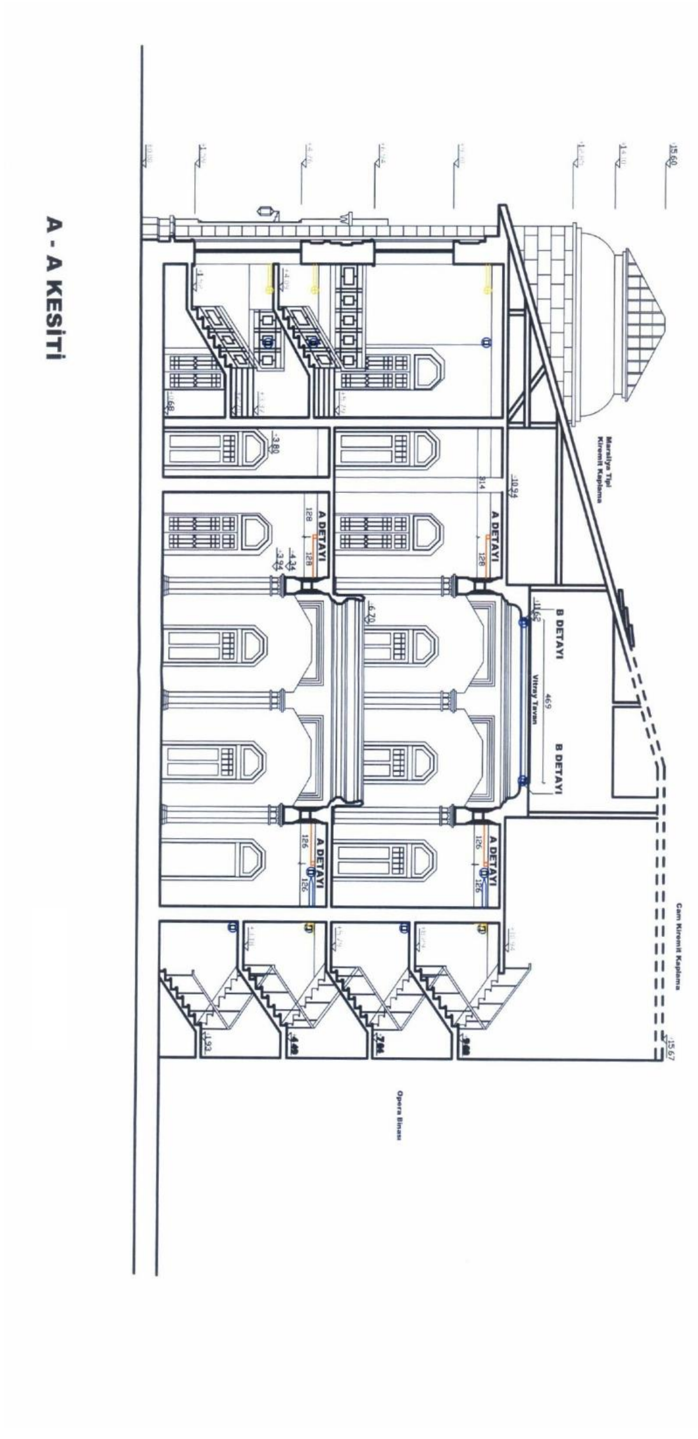


Figure C. 2 Section A-A of İzmir Nation Library Building (Source: The Republic of Türkiye, Ministry of Culture and Tourism, No. 1 Regional Board of Conservation of Cultural Heritage)

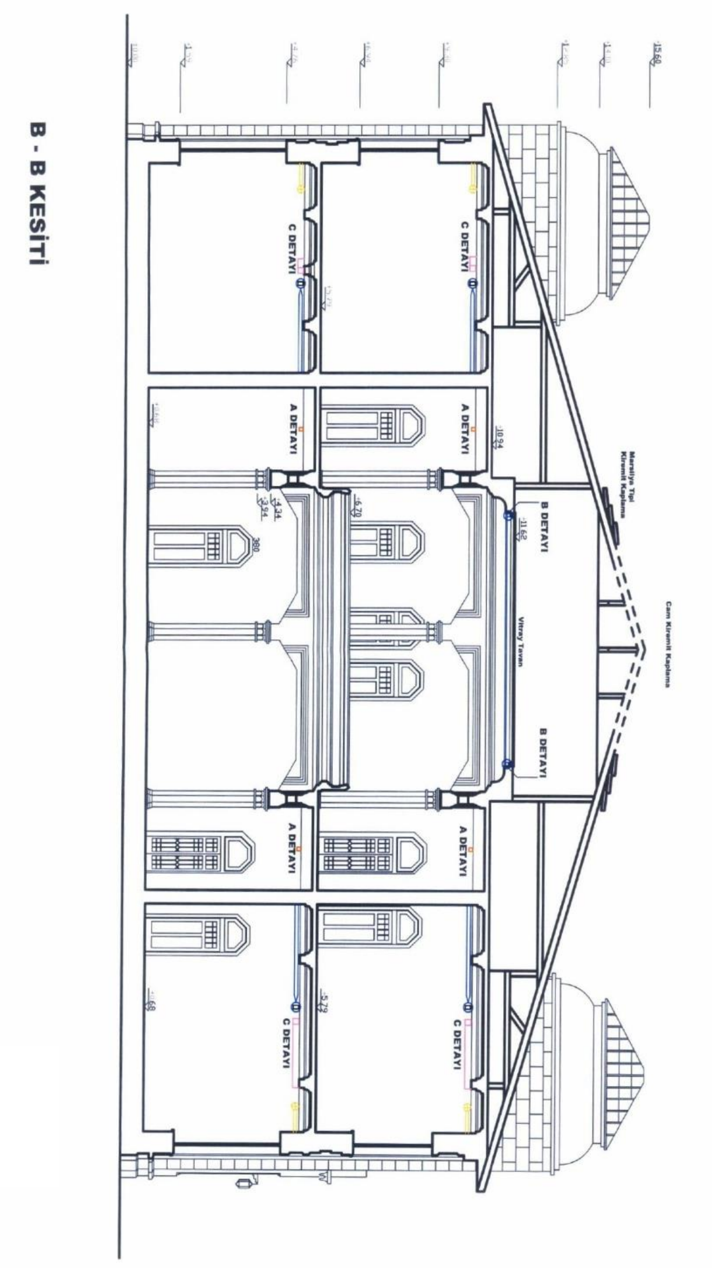


Figure C. 3 Section B-B of İzmir Nation Library Building Section A-A of İzmir Nation Library Building (Source: The Republic of Türkiye, Ministry of Culture and Tourism, No. 1 Regional Board of Conservation of Cultural Heritage)