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Classification of Heritage Residential Building Stock and Defining Sustainable Retrofitting Scenarios in Khedivial Cairo

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Abstract: This study aims to develop an integrated classification methodology for retrofitting that preserves both energy use and cultural value aspects in hot climates, especially, in North Africa, as a hot zone, which lacks retrofitting initiatives of built heritage. Despite the number of existing methods of classification for energy purposes, little attention has been paid to integrate the perceptions of cultural values in those methods. The proposed methodology classifies heritage building stocks based on building physical characteristics, as well as heritage significance levels, and then later integrates the outcomes into a matrix to propose sustainable retrofitting scenarios based on three dimensions, i.e., heritage value locations, types, and heritage significance level. For validation, the methodology was applied to the heritage residential building stock along with a microscale analysis on a building in Khedivial Cairo, Egypt. The findings include extracting twelve building classes, providing a reference building for each class, and a detailed catalogue of the extracted reference buildings that includes retrofitting scenarios for creating energy models. The originality of this work lies in integrating cultural values in a building classification methodology and providing a list of sustainable retrofitting scenarios for reference buildings. The findings contribute to fill the gap in existing building classifications, more specifically in hot climates.

Keywords: cultural values; built heritage; energy retrofitting; hot climates; downtown Cairo

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Citation: Ibrahim, H.S.; Khan, A.Z.; Attia, S.; Serag, Y. Classification of Heritage Residential Building Stock and Defining Sustainable Retrofitting Scenarios in Khedivial Cairo. *Sustainability* **2021**, *13*, 880. https://doi.org/10.3390/su13020880

Received: 30 December 2020
Accepted: 12 January 2021
Published: 17 January 2021

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1. Introduction

With respect to the international picture, the world has been increasingly, and alarmingly, dependent on energy, increasing by 92% from 1971 to 2014, according to the International Energy Agency (IEA) [1]. In addition, the predicted growth rate of energy consumption in built environments is 34% in the next 20 years, at an average rate of 1.5%. The contribution of the residential sector for energy use is predicted to be 67% in 2030, and near 33% for non-residential districts [2]. In addition, the building sector consumes 40% of the total energy usage and around one-third of the greenhouse gas emissions [3–5]. For that reason, the Paris Agreement posited the dire need for implementing retrofitting strategies for existing buildings by 2030 [6,7]. Retrofitting existing buildings has great potential for moving towards low carbon dioxide emissions (CO_2) [8,9]. However, heritage buildings constitute a large portion of the existing buildings in different countries [10]. For that reason, many studies have been working on reconciliation between conservation practice and energy retrofitting measures in built heritage [11]. Italy has the majority of those studies, while north Africa and the Middle East are a long way behind in this theme of research studies [12]. In addition, most of the case studies are carried out on individual buildings, while the least percentage of studies are on an urban scale such as neighborhoods and cities [12].

Regarding the local picture, in Egypt, as a hot climate, in 2019, the total sum of sold energy was 120,124,371 (GWh), with an average growth rate of 5.2% [13]. Additionally, in this context, the carbon dioxide emissions (CO_2) per capita was 2.5 (t), according to the latest data retrieved from the world bank for the year 2016 [14]. The residential buildings in Egypt consume about 42.3% of the total electricity consumption [13]. Albadry (2017) highlighted the fact that insulation levels in Egyptian residential buildings are low, which in turn increases energy consumption [15–17], and therefore the building sector is considered to be a promising area for reduction of energy demand and harmful emissions [3,16,18,19]. In Cairo, more specifically, 87% of the building stock (which consists of more than 688,000 buildings) belongs to residential buildings [20]. Moreover, Cairo has about 3300 heritage buildings and Khedivial Cairo has 650 listed heritage buildings [21], and more than 200 building are exposed to upgrading strategies, after moving most government buildings to the "New Administrative Capital" [22]. However, there have been very few attempts to integrate energy retrofitting measures, (with the exception of a hotel building called" La Viennoise", and it is cited in this article as an example) [23].

The international and local picture shows that there is a need to enhance energy performance and reduce CO_2 emissions in heritage residential buildings, more specifically in hot climates. Thus, in this article, we aim at developing an integrated classification methodology to analyze and improve energy performance of heritage buildings in historic districts in hot climates. Moreover, we also aim at setting sustainable retrofitting scenarios that balance between energy saving and conservation aspects in a list of buildings that will act as a representative sample of the larger number of heritage residential buildings in Khedivial Cairo. Accordingly, the following questions were asked: How can cultural values be integrated in building classification methods for energy purposes to propose suitable energy retrofitting scenarios in hot climates? and How can these values affect energy retrofitting choice? The research problems, objectives, and questions have been identified here in the introduction. In Section 2, we review previous studies. In Section 3, we explain the research methodology which is introduced in six subsections. In Section 4, we analyze the results. In Sections 5 and 6, we discuss the study results, implications, and limitations.

2. Literature Review

2.1. Building Typology and Classification

Several methods and tools have been presented to give an estimation of the effect of energy saving scenarios on energy performance of residential buildings [24]. The concepts of building typology and classification are tools of flexibility and strength that can be utilized to provide preliminary advice on energy performance and sustainable scenarios for retrofitting [25,26].

In 2011, Ballarini et al. provided different ways for choosing reference buildings, and highlighted the visible lack of standardized methods to carry out such a task. In order to set a building archetype that represents a wider building stock, in terms of climate and functionality, the data for choosing certain selected reference buildings can be divided into the following four groups: operation, system, envelope, and form. This method of data collection is also used in other studies on a national scale. The number of details in the gathered data depends on the size of the building stock and the study objectives [27].

In 2012, EU project TABULA developed an approach to categorize building typologies in twenty European countries. The criteria for building typology are based on climate zone, construction period (age), and building size (single family, multifamily). The criteria for selecting representative buildings are based on different parameters such as area, volume, number of floors, and connections between other buildings [4,28,29]. Moreover, there are three different approaches to select representative buildings: "real example building" (ReEx), "real average building" (ReAv), and "synthetical average building" (SyAv) [28]. The selection of each approach relies on the availability of data. Thus, the ReEx approach is used when there is no available statistical data. Accordingly, this approach relies on

experience and the data gathered by experts who select the most representative buildings in terms of building size and construction age in an actual climatic context [28]. The ReAv approach helps in identifying building types via statistical analysis of a considerably large sample of buildings. This analysis is carried out to find real buildings that show similar features of geometrical measurements and characteristics of construction to the statistical sample it previously analyzed. The SyAv approach aims to identify different building types and turns them into "archetypes". This is done also by statistical analysis of a large sample of buildings. An "archetype" is defined as "a statistical composite of the features found within a class of buildings in the stock" [30]. Therefore, it is not a real building, but rather a "virtual" one that has a statistically recognized set of characteristics in a certain building class. The same concept was referred to in other studies on similar topics [5,31,32].

In 2014, another study presented a method to evaluate energy saving scenarios and CO_2 reduction in building stocks. It is a bottom-up model called carbon and cost assessment for building stocks (ECCABS). This method was implemented first in Sweden, and then again implemented and verified in four different climate regions, i.e., the UK, Spain, Germany, and France [33,34]. The ECCABS model is built on the unilateral energy balance of a building that ultimately gives hourly heating energy demand using a description of archetype buildings as input to the said model. The results reveal that the description of the building stock which is provided via the archetype buildings presents a good estimation of thermal performance of such stocks.

In 2017, another building typology tool was developed by the Energy Efficiency for EU Historic Districts' Sustainability (EFFESUS), which is a research project that investigates energy efficiency of European historic urban districts [35]. This tool has been especially presented to determine energy saving in historic districts. The method is based on building inventory, classification, and selection of typical buildings. The classification depends on the number of floors, the number of adjoining walls, i.e., freestanding, one adjoining wall, two or more adjoining walls [35–37]. The selection of reference buildings is based on average size and volume. This method has been applied in Visby Sweden [38].

In 2018, the previous method was applied in Cairo by Raslan and others [39]. They categorized heritage building stock in two areas in Cairo (Al Darb Al-Ahmar and khedivial Cairo) into four and nine classes, respectively. The classification of Khedivial Cairo was done for a limited number of heritage residential buildings. Moreover, the classification excluded the construction type and materials, which have been considered to be crucial factors for energy analysis purposes. In addition, the study did not refer to the heritage protection restrictions in each representative building.

This previous review of studies shows there is a variety of methods for building typology and classification. Moreover, the criteria of selecting building typology and reference buildings mainly depend on data availability, quality, and the case study scale (national, neighborhoods or cities).

2.2. Heritage Value Types from a Retrofitting Perspective

The significance level attributed to values is always subject to conjecture because values are judged by community and cultural perspectives and are, therefore, inherently subjective [40,41]. U˘gural (2020) stressed that cultural values could very well predict attitudes and behaviors that are work related [42]. Drawing from the international conventions and national laws, heritage value is considered to be an identity of the heritage sites and buildings, and they use these values as indicators to reflect the importance of the heritage sites and buildings [43,44]. Consequently, heritage sites and buildings could be expressed by a rich combination of values. Overall, there are five main cultural values as follows: historical, symbolic, artistic value, urban and architectural, and social functional value [45–48]. Each heritage building is unique and has its own combination of values, which together show its heritage value significance [41]. However, certain indicators need to be determined to decide whether a building is worthy of listing. The assessment criteria are based on the nature of significance, the degree of significance, condition, integrity, and

authenticity. Significance of value for heritage buildings is assessed by considering various values, reflecting the uniqueness of each building.

Thus, determining heritage values of heritage building is a challenge, especially when conducting energy retrofitting processes [10]. In addition, "there is no generally accepted standard detailing how heritage value should be evaluated, and procedures vary throughout Europe and across the world. The purpose of the heritage value evaluation is to establish the heritage significance of the subject buildings and district." [49]. Thus, heritage values should be more explicitly articulated and analyzed in qualitative and complementary quantitative approaches, in order to assess the impacts of retrofitting measures on these values [10,49,50]. Therefore, as mentioned previously, evaluating heritage values of a building is carried out before officially listing it as a heritage building. Moreover, heritage values are further qualified by assigning heritage grades, as explained previously. However, sometimes, heritage grades or classes are not detailed and generally do not specify different levels of importance for different parts of a building or a group of buildings. Therefore, a detailed evaluation of the effect of retrofitting processes must be done in order to decide the type and degree of changes to the building components.

EFFESUS is developing a flexible tool, the "heritage impact assessment" as a part of the EFFESUS project, to determine heritage values of individual parts of a district and its buildings, so that informed assessments can be made. The tool helps in assessing the balance of heritage significance levels, as opposed to already defined impact levels of retrofitting processes that are explained in the EFFESUS technical repositories. The system of assessment works by comparing two datasets, i.e., heritage significance evaluation and heritage impact levels, using a balancing technique. "The heritage impact assessment uses a structured approach with assessment locations (grouped into 'urban district', 'building exterior', and 'building interior') and three assessment types, i.e., visual, physical, and spatial." [36,50]. For better qualification of the level of heritage significance, EFFESUS proposes a five-step scale, which allows the "heritage significance levels (HSL) to be assigned from the range 0–4, with the higher the number, the higher the level of heritage significance. An HSL level of 4 identifies 'exceptionally outstanding significance', HSL 3 describes 'outstanding significance, HSL 2 refers to 'major significance', and HSL 1 indicates 'minor significance'. Level '0' is used for neutral or negative significance and also where an assessment is not applicable" [36,50]. This summary of previous studies helps in defining the" cultural value" of a heritage building and determines its type and importance, because the conservation practice and retrofitting decisions are mainly based on what heritage values are and how they should be conserved [9,51].

In summary, the above literature shows that there is a wide gap regarding integration of analysis of energy performance for a very large number of buildings in heritage districts, as well as in providing precise and clear data about their heritage values. Accordingly, it requires adding another classification method of heritage building stock based on different heritage protection levels. Therefore, the proposed methodology integrates different approaches to classify heritage building stocks in hot climates through five phases, as shown in Figure 1.



Figure 1. Proposed classification methodology for heritage building stock in hot climates, based on [36–38,50,52].

3. Materials and Methods

We summarized the research methodology of this work in a conceptual framework, as shown in Figure 2.

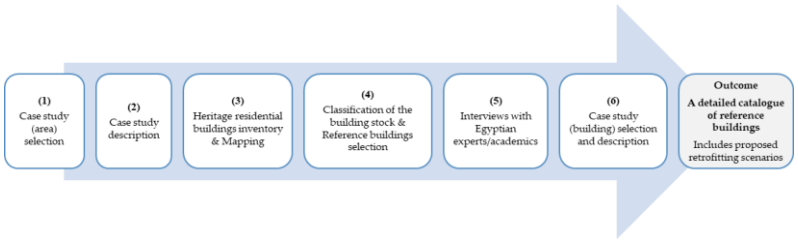


Figure 2. Conceptual framework of this study.

3.1. Case Study Selection

Khedivial Cairo was founded following a decision by the Khedive Ismail (1863 AD) [53,54]. The cultural importance of Khedivial Cairo lies in its labelling as a "buffer zone" for the Historic Cairo area by the UNESCO Heritage Sites [55]. Hence, it is considered a "Heritage precinct" [53,56,57]. The cultural value attributed to this area is explained in the following subsection, which conforms to all the heritage value criteria needed to ensure its success as a case study to validate the proposed classification methodology.

3.1.1. Historical Value

Khedivial Cairo has a rich historical value. One of the most important reasons of establishing the Khedivial Cairo area was the opening celebration of Suez Canal in 1869, which made Cairo an essential link in the international transportation network [54,58,59].

3.1.2. Symbolic Value

Khedivial Cairo has some places associated with characters or events that have had a significant impact on the march of society. "Abdeen" Square, for example, is linked to a memory related to the Urabi Revolution, and the national position of resisting the British occupation in Egypt from 1879 to 1882 A.D. [58,60]. In the modern era, "Tahrir" Square, or Liberation Square, is considered to be a symbol of the freedom and democracy [61].

3.1.3. Urban Value

The urban tissue of Khedivial Cairo was considered to be a turning point of urban design in Egypt in the nineteenth century. It was characterized by wide streets intersecting in the form of a network and penetrated by some of the main streets to meet in large squares, where statues of important Figures were placed [53,62].

3.1.4. Architectural Value

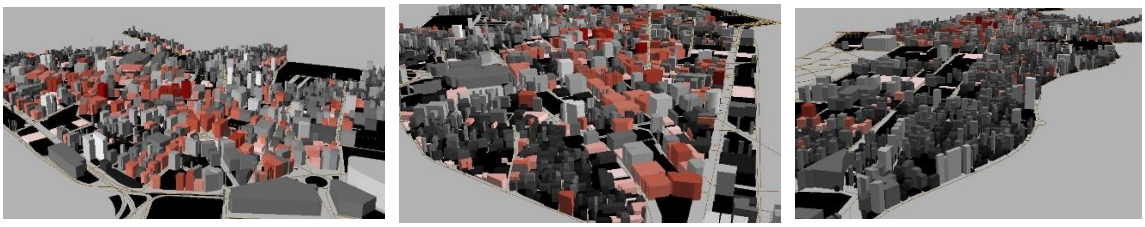
The architecture of Khedivial Cairo combines European styles with local influences and materials. These styles were characterized by new patterns derived from European origins (modern style of the Renaissance age, French, Italian, and English), and most of them were designed by famous national and international architects [63–65].

3.1.5. Functional Value

Khedivial Cairo had the most lucrative activities and areas of international activity, while secondary and more disturbing activities were directed towards the peripheries. The same was true for residential areas. The wealthy class occupied this area, while the communal, less privileged houses turned towards the out boundaries [62,63,66].

3.2. Case study Description

Khedivial Cairo covers about (6 km^2) on the eastern bank of the Nile, surrounded by contemporary neighborhoods of Greater Cairo from all directions [55]. Figure 3 shows different perspective shots of Khedivial Cairo. The area has (633) heritage buildings with distinctive values that have been listed by the National Organization of Urban Harmony (NOUH), according to law no 144/2006 [21]. Moreover, according to the World Heritage Site (UNESCO), Supreme Council of Antiquities (SCA), and National Organization for Urban Harmony (NOUH), Khedivial Cairo is comprised of five districts (El-Azbakeya, Abdin, Qasr el-Nil, El-Mosky, and Part of El_Sayda Zeineb) [55,56,67].



(**a**) (**b**) (**c**)

Figure 3. (**a**–**c**) Different perspective shots of Khedivial Cairo, Gray color and its gradation indicate non-heritage buildings (first author's Ph.D. research).

3.3. Heritage Residential Buildings Inventory and Mapping

Due to a lack of available data about the study area, the study relied on different sources to gather needed information. The methods of data collections were field surveys, interviews, the National Organization of Urban Harmony (NOUH), the Central Agency for Public Mobilization and Statistics (CAPMAS), and several documentation books such as "*Khedivian Cairo Book*" and "*Discovering Downtown Cairo*". The NOUH provides information about the listed heritage buildings on its official website. The data only includes building types, addresses, and owners. It should be noted that the data about heritage grades have not been available on its website or any sources yet, and therefore, for this present study, we conducted interviews with some Egyptian experts to complete all missing data about the heritage buildings in the study area, as shown in Section 3.4. By using Google Earth Pro, AutoCAD maps of Cairo by CAPMAS, and collected data of the blocks and buildings (e.g., buildings use, age, construction types, etc.), we were able to create a Geographic Information Systems (GIS) database for the study area. GIS tools were used to manage collected data about geometrics, energy parameters, and heritage values.

3.4. Classification of the Building Stock and Reference Buildings Selection

The heritage residential building stock in Khedivial Cairo, with a total number of 432 buildings, was categorized based on the collected data in a preliminary building inventory. This classification was carried out according to steps listed below that mainly relied on the physical characteristics of the buildings. This approach inspired the classification method used in the European project EFFESUS in Visby city and by [35,36,38,52,68,69]. The six steps are explained in detail as follows:

1. Number of floors

The first step of the classification clustered the total amount of buildings according to their number of floors. To simplify the number of classes in next steps, the building stock of 432 was divided into two groups, i.e., from one to five floor buildings and from six to fifteen floors. Figure 4 shows the relation between the number of residential buildings with the number of floors. Table 1 shows the first step in the classification division of building stock of 432 into two groups, from one to five floor buildings and from six to fifteen floor buildings.

2. Number of adjoining walls (boundaries)

The second step divided each abovementioned group of buildings into three subgroups according to their boundaries (connections with other buildings), freestanding, one adjoining wall, and two or more adjoining walls. Figure 5 shows the relation between the number of heritage residential buildings with the number of adjoining walls. Table 2 shows the second step in the classification that divided each group into three subgroups based on adjoining walls.

3. Building construction types

The third step divided each main class of buildings into two subgroups, according to their building construction system (types of concrete construction, load bearing burnt-brick walls, and limestone bricks). Figure 6 shows the relation between the number of heritage residential buildings with the building construction material types.

4. Floor area

The fourth step defined the floor area (m^2) of buildings based on their outer dimensions. This step was automatically provided in arc-GIS, taking into consideration the number of classes that were not affected by this step but were used to determine the buildings' physical features.

5. Building volume

The fifth step calculated the volume (m^3) of buildings; generalized calculations were carried out relying on external dimensions floor area, the number of floors, and floor heights. After completing this step, the classes were defined and weighted. The mean volume of each class to the total volume of building stock was defined to provide a weighted share of stock (%) for each class. The weight of each class was defined because a certain class might have a few numbers of buildings, but with large volumes. Accordingly, this class may have more weight than one with many buildings and smaller volumes [35,36]. In some cases, a delimitation can be required to exclude atypical buildings in each class, with too small or too big volume, in each class but, in this present study, the delimitation was not carried out for reasons related to results as clarified in the results section.

6. Reference buildings

The final step of the classification was to represent each class by defining reference buildings. The "real average building" approach was applied, and the parameters used for selecting reference buildings were average values of floor area and building volume in each class.

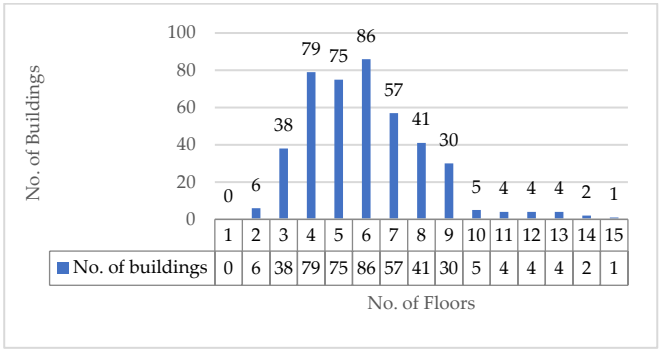


Figure 4. Relation between number of heritage residential buildings with the number of floors (first author's Ph.D. research), based on [70].

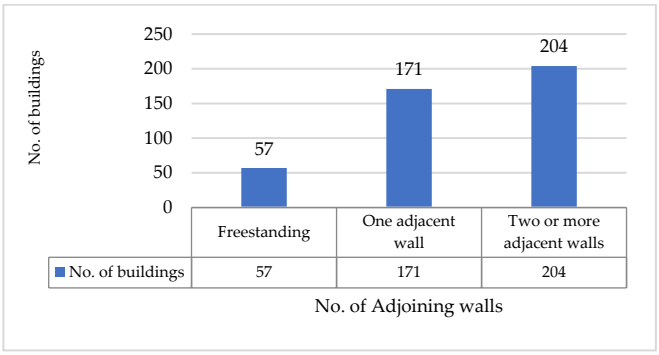


Figure 5. Relation between number of heritage residential buildings with the number of adjoining walls (first author's Ph.D. research), based on [70].

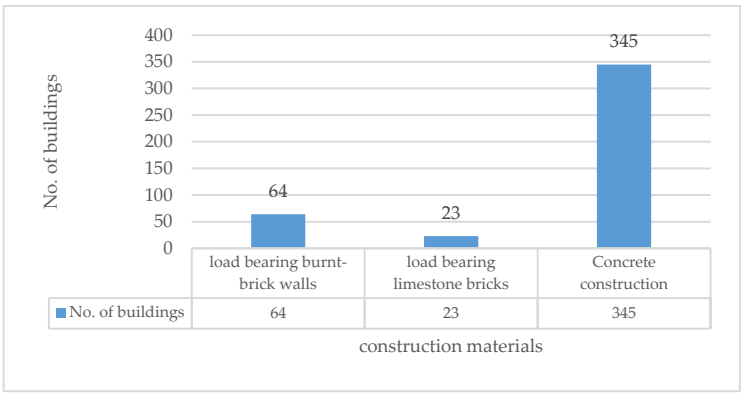


Figure 6. Relation between number of heritage residential buildings with the building construction material types (first author's Ph.D. research), based on [70].

Table 1. The classification divided building stock of 432 into two groups, from one to five floor buildings and from six to fifteen floor buildings.

Type	Group 1	Group 2
No. of floors	1–5	6–15
No. of buildings	198	234
Percentage (%)	45.8%	54.2%

Table 2. The second step in the classification divided each group into three subgroups based on adjoining walls (freestanding, one adjacent wall, and two or more adjacent walls).

Criteria	**Group 1 (1–5 Floors)**			**Group 2 (6–15 Floors)**		
Adjoining walls	Freestanding	One adjacent wall	Two or more adjacent walls	Freestanding	One adjacent wall	Two or more adjacent walls
No. of buildings	24	61	113	33	110	91
Percentage (%)	5.6%	14.1%	26.2%	7.6%	25.5%	21.1%

3.5. Interviews with Egyptian Experts/Academics

In the Egyptian context, heritage Grades (A), (B), or (C), do not provide criteria of classification that are clear enough. Even for the buildings that were already registered/listed into one of these classes, there was no mention of the reasons for including buildings into a particular class. Thus, it was essential to fill the gaps in this area. Thus, we conducted interviews with some of the Egyptian stakeholders such as experts and academics, to identify the criteria of the heritage classification. In addition, the interviews were conducted to precisely identify possible intervention actions for these heritage buildings. The feedback provided by the interviewees was based on the perceptions of heritage values and its types, which eventually must be preserved in retrofitting projects. Many of the base questions were asked to different interviewees to validate and obtain a more comprehensive perspective of the issue. Personal interviews were conducted with the local experts and academics. In order to guide the discussion to gain detailed insight and information about heritage values in the Egyptian context, we prepared interview questions based on specific points, inspired by the work of Marshall and Rossman (2011) [71]. To obtain more clarification on unclear points in the conservation law 144/2006, the interviews went through two axes. The first one is clarification of definitions of cultural value and heritage building classes in the Egyptian context. The second is clarification of possible retrofitting intervention scenarios in different heritage grades, in light of the conservation law 144/2006, inspired by the method (EFFESUS), which transforms heritage values into concrete elements to be applied to the buildings in order to bring out their distinctive characters. Through benefiting from the EFFESUS method, we can assume the effectiveness of substitution of heritage significance levels by the three heritage Grades (A, B, and C) as they are defined in the Egyptian system, as well as the substitution of heritage impact with the type of possible retrofitting scenarios.

Twelve semi-structured interviews were conducted with Egyptian experts, academics, and some officials during the summer of 2019. In addition, most of the interviews were audio recorded to ensure all the information shared was kept, noting that some of the interviewees did not agree to be recorded. Afterwards, we analyzed the main outcome of the interviews and incorporated it with the results section. This approach was inspired by the work of [72,73].

3.6. Case Study (Building) Selection and Description

According to the abovementioned interviews, we selected a case study to investigate the possible retrofitting scenarios in a real retrofitted heritage building. The criteria for selection of the case study included the following: a building already retrofitted, the scenarios met the heritage value requirements, and finally, a significant energy saving was achieved [74].

On the basis of the said criteria, the selected building was identified as a freestanding, three-story building with a load bearing wall structure. Figure 7 shows the following: (a) the main façade before retrofitting scenarios, (b) the main façade after retrofitting scenarios, and (c) another façade after retrofitting scenarios. The selected building is a hotel building called" La Viennoise", located on Champollion Street, downtown Cairo, built in 1890s with the Italian-Renaissance style [23]. It had recently been retrofitted and reopened in 2018. It

was originally built as an apartment building, and after the retrofitting process it was being re-used as an administrative building. The "La Viennoise" is considered to be a landmark building in Khedivial Cairo. It is listed by the NOUH as a heritage building class "B".



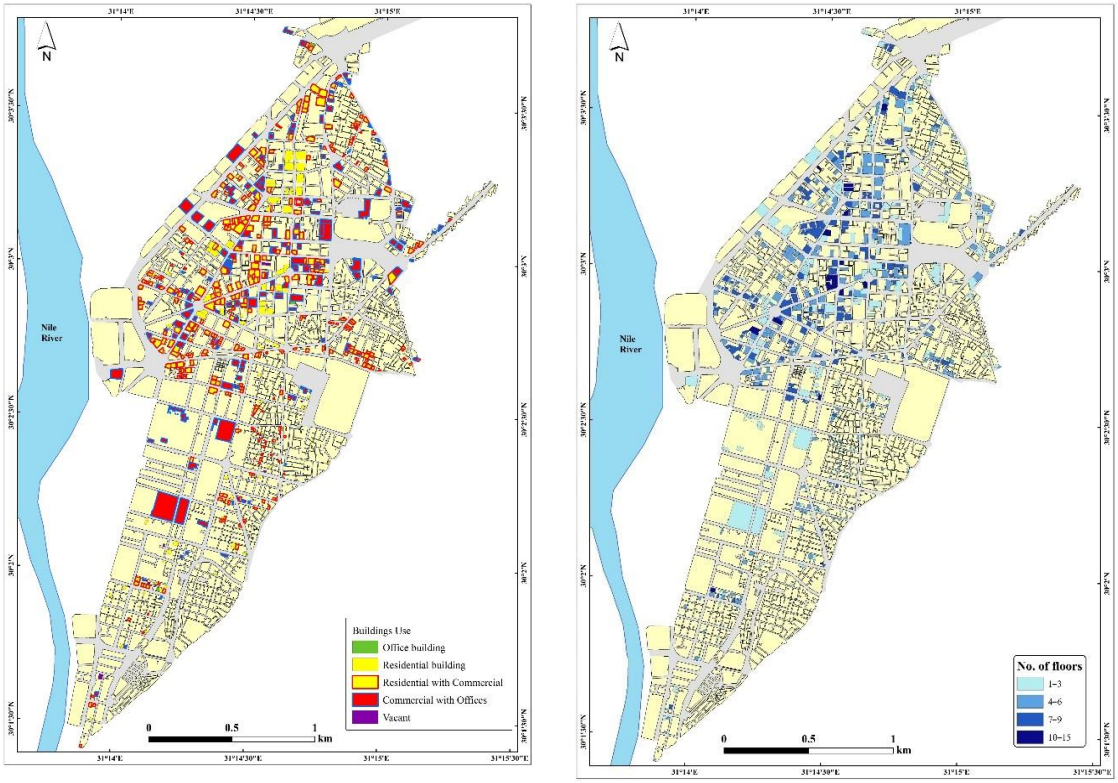
(**a**) (**b**) (**c**)

Figure 7. (**a**) Main façade before retrofitting scenarios (**b**) Main façade after retrofitting scenarios (first author's Ph.D. research); (**c**) Another façade after retrofitting scenarios (first author's Ph.D. research).

4. Results

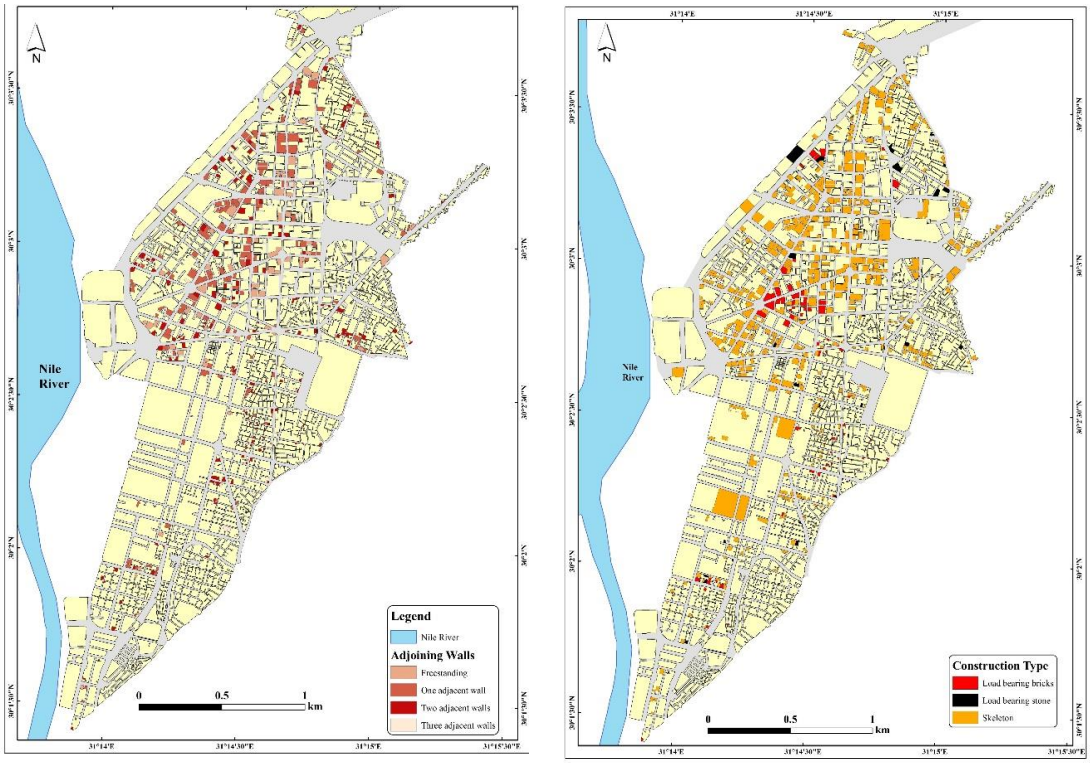
4.1. Database and Documentation

The results of collecting and processing data on the study area can be found in Figures 8 and 9. Figure 8 shows maps of the building data in terms of building use, number of floors, adjoining walls, and construction material types. Figure 9 shows maps of the building data in terms of the following heritage data: (a) the boundaries of Khedivial Cairo as stated by the Urban Regeneration project for Historic Cairo (URHC) in 2012 [75], (b) all listed buildings as heritage properties in Khedivial Cairo, (c) building size, and (d) buildings evolution between the 19th and 20th centuries.



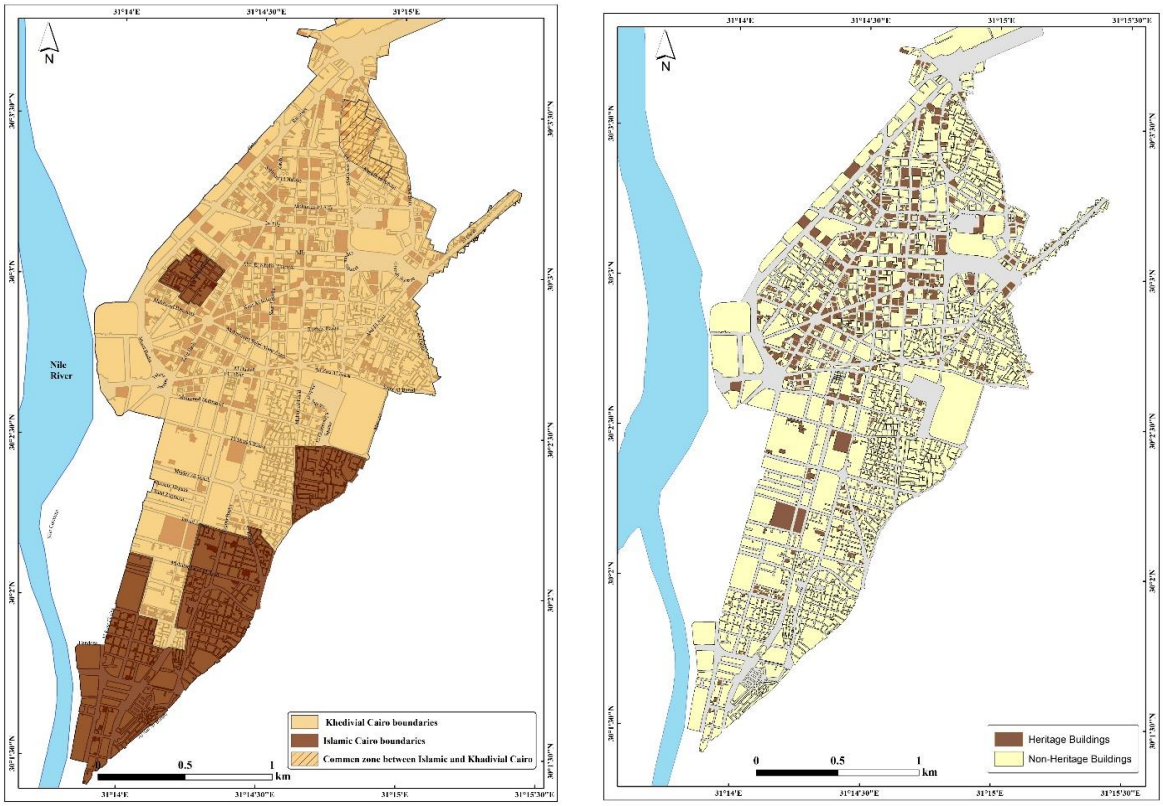
(**a**) (**b**)

Figure 8. *Cont.*



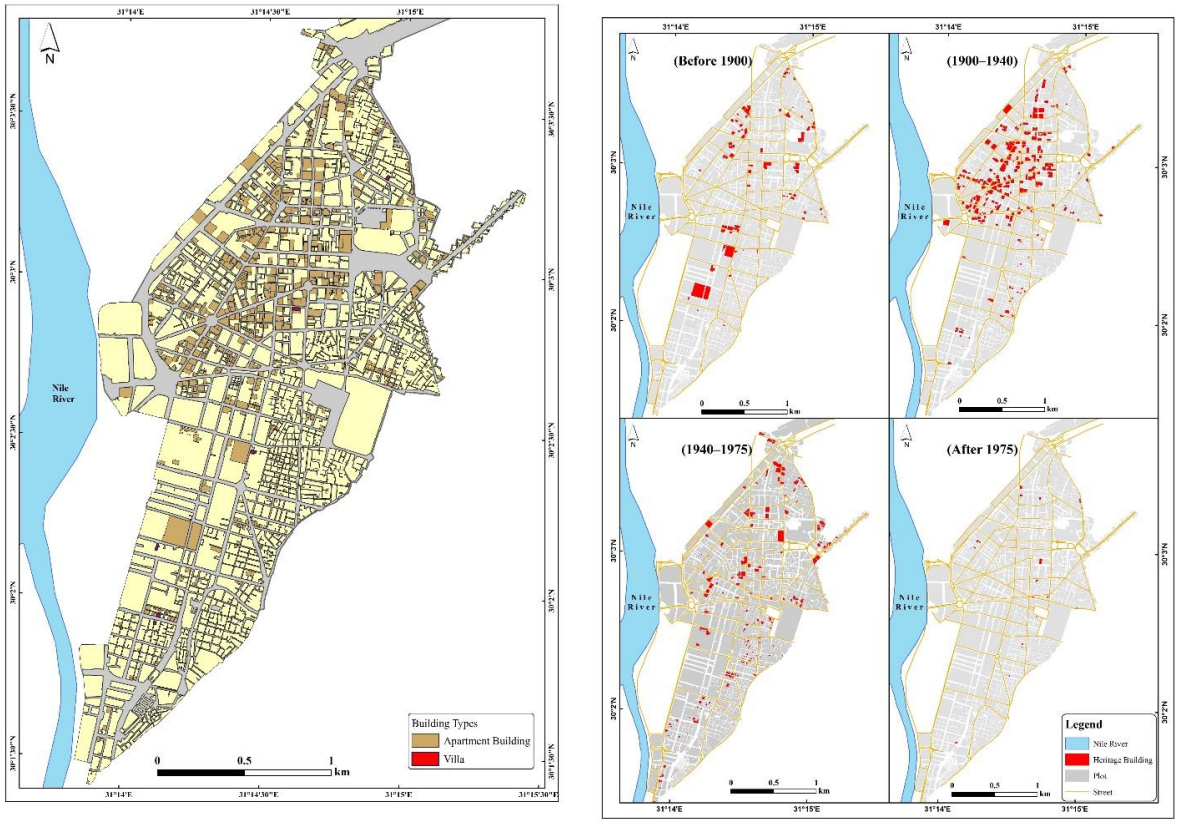
(**c**) (**d**)

Figure 8. Building data 1. (**a**) Building use; (**b**) Number of floors; (**c**) Adjoining walls; (**d**) Construction material types (first author's Ph.D. research).



(**a**) (**b**)

Figure 9. *Cont*.



(**c**) (**d**)

Figure 9. Heritage data. (**a**) The boundaries of Khedivial Cairo as stated by the Urban Regeneration project for Historic Cairo (URHC) in 2012; (**b**) All listed buildings as heritage properties in Khedivial Cairo; (**c**) Building size; (**d**) Buildings evolution between the 19th and 20th centuries (first author's Ph.D. research).

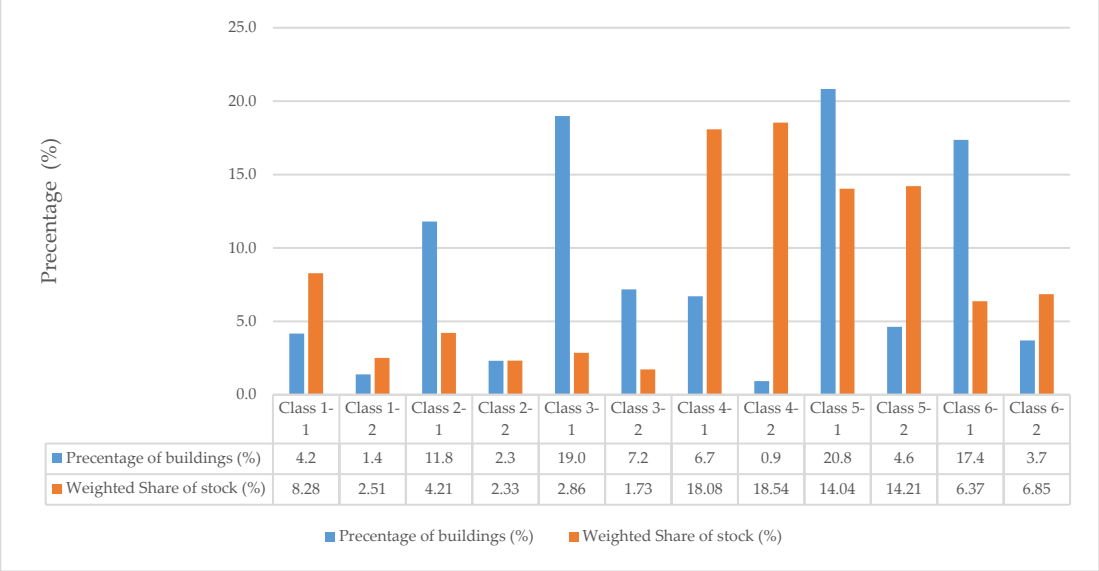
4.2. Classification of the Building Stock and Reference Buildings

The results of classification were to extract twelve classes (see Table 3). The number of buildings and percentages in each class were calculated. In addition, more clarification of building use was defined in each class. Seventy-five percent of the total buildings was residential with other uses, especially in the first two floors. More specifically, in some buildings, the ground floors were used as commercial shops and, in some others, the first floors were used as offices. Moreover, in each class, the mean area and building volume were calculated to define the weighted share of stock. Figure 10 shows the relation between the percentage of buildings and their weighted share of stock in each class. Accordingly, the largest classes in terms of building percentages were (5.1), (3.1), and (6.1), representing 20.8%, 19%, and 17.4% respectively, while the least classes were (4.2), (1.2), and (2.2), representing 0.9%, 1.4%, and 2.3% respectively. The largest classes in terms of weighted share of stock were (4.2), (4.1), (5.2), and (5.1), representing 18.54%, 18.08%, 14.21%, and 14.04% respectively, while the least classes were (3.2), (2.2), and (1.2), representing 1.73%, 2.33%, and 2.51% respectively. Moreover, the classification was done without delimitation because of the limited number of buildings in the classes, such as class (1.2), (2.2), and (4.2) with six, ten, and four buildings, respectively. Furthermore, most of the buildings were apartment buildings with more than two floors (see Figure 4); accordingly, their volumes had significant impact on the energy use. Twelve reference buildings were extracted, and the location and geometry of each building was provided. Figure 11 shows the classification and the reference buildings map.

Table 3. The classification of the heritage residential building stock in Khedivial Cairo.

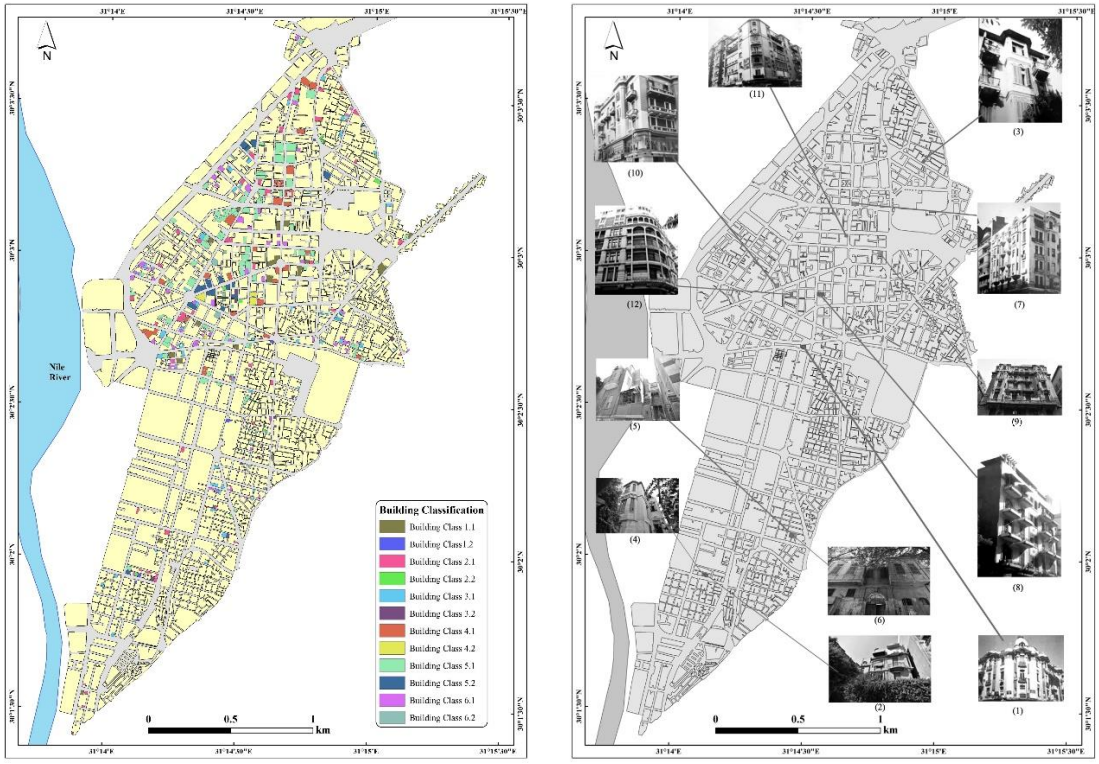
Classification without Delimitation of the Total Buildings 432													
Criteria	**Class 1**		**Class 2**		**Class 3**		**Class 4**		**Class 5**		**Class 6**		**Total**
No. of floors	From 1 to 5		From 1 to 5		From 1 to 5		From 6 to 15		From 6 to 15		From 6 to 15		
Adjoining walls	Freestanding		One adjacent wall		Two or 3 adjacent walls		Freestanding		One adjacent wall		Two or 3 adjacent walls		
No. of buildings	24		61		113		33		110		91		
Percentage (%)	5.6		14.1		26.2		7.6		25.5		21.1		
Mean area (m^2)	802.20		450.17		278.59		1117.38		841.12		383.88		
Mean volume (m^3)	12,024.2		7443.2		4563.0		33,829.3		25,492.2		11,695.5		
Weighted Share of stock (%)	13		8		5		36		27		12		
	Cl. 1-1	**Cl. 1-2**	**Cl. 2-1**	**Cl. 2-2**	**Cl. 3-1**	**Cl. 3-2**	**Cl. 4-1**	**Cl. 4-2**	**Cl. 5-1**	**Cl. 5-2**	**Cl. 6-1**	**Cl. 6-2**	
Construction material types	T1	T2 or 3	T1	T2 or 3	T1	T2 or 3	T1	T2 or 3	T1	T2 or 3	T1	T2 or 3	
No. of buildings	18	6	51	10	82	31	29	4	90	20	75	16	432
Percentage (%)	4.2	1.4	11.8	2.3	19.0	7.2	6.7	0.9	20.8	4.6	17.4	3.7	100%
Weighted share of stock (%)	8.28	2.51	4.21	2.33	2.86	1.73	18.08	18.54	14.04	14.21	6.37	6.85	
Residential	5	3	14	0	29	16	8	2	15	3	6	3	104
Residential + others	13	3	37	10	53	15	21	2	75	17	69	13	328
Mean area (m^2)	963.52	318.21	466.10	368.88	307.94	200.94	1092.62	1296.79	838.98	850.72	376.20	419.87	
Mean volume (m^3)	14,999.12	4554.97	7624.1	4213.0	5174.1	3130.33	32,749.74	33,589.38	25,434.3	25,752.7	11,545.0	12,401.0	

Note: T1, concrete construction system; T2, load bearing wall construction system (burnt-brick walls); T3, load bearing wall construction system (limestone bricks).



	Class 1-1	Class 1-2	Class 2-1	Class 2-2	Class 3-1	Class 3-2	Class 4-1	Class 4-2	Class 5-1	Class 5-2	Class 6-1	Class 6-2
Precentage of buildings (%)	4.2	1.4	11.8	2.3	19.0	7.2	6.7	0.9	20.8	4.6	17.4	3.7
Weighted Share of stock (%)	8.28	2.51	4.21	2.33	2.86	1.73	18.08	18.54	14.04	14.21	6.37	6.85

Figure 10. Relation between the percentage of buildings and their weighted share of stock in each class.



(**a**) (**b**)

Figure 11. (**a**) Map of the building classes; (**b**) Map of the reference buildings and their geometries (first author's Ph.D. research).

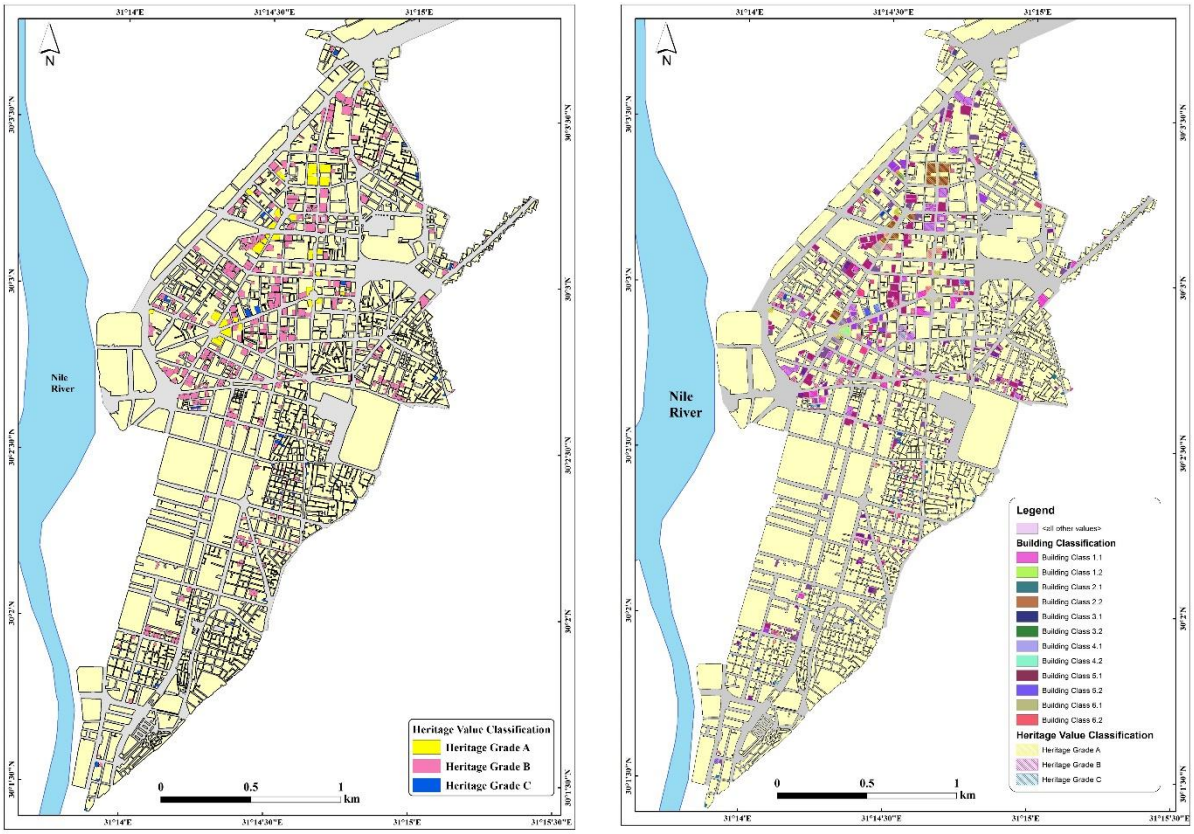
4.3. Classification of the Heritage Grades

Egyptian experts define "eritage" as all that was before our time, has value in a society, and is characterized by resilience, continuity, and community acceptance, whether it is artefacts, knowledge, traditions, holdings, monuments, buildings, etc. Heritage values are defined by Egyptian experts as dynamic perceptions or explicit concepts that characterize an individual or group and define what is desirable socially and culturally. Moreover, the NOUH clarifies that a building of heritage value has an architectural or urban value and

dates back to the nineteenth or early twentieth centuries, along with other historic buildings that were not registered as monuments and meets one or more of the following criteria: (1) corresponding to the country's national history, (2) an outstanding architectural value, (3) a historic figure, (4) represents a historical epoch, (5) a building of architectural/urban importance, (6) considered to be a tourist sight. Therefore, these buildings are not subject to Law 117 of 1983 on the protection of antiquities, but these buildings are subject to both Law 144 of 2006 on "regulating the demolition of non-dilapidated buildings and establishments, and the preservation of architectural heritage" [45,55,56]. The experts clarified the definition of different heritage grades. Accordingly, they defined "heritage building Grade A" as one that has an outstanding architectural value and expresses a distinct design style and unique artistic creativity. It is created according to the philosophy, concepts, and architectural standards or architectural school, reflects the features of a specific historical era, or is characterized by scarcity and exclusivity, including the architectural details and decorations, and which its retrofitting would contribute to the public interest. While they defined "heritage building Grade B" of special heritage importance for the city, as they include examples containing certain elements worthy of inclusion. It is specifically determined for external characteristics that contribute to the value of the city or the group within it. Modifications of this type of building contribute to the private interest. This grade includes buildings that have a special architectural or historical value. The buildings categorized under this grade form the image and identity of the city. Finally, "heritage building Grade C" acquires importance from its presence in a heritage area of a special nature, which forms the memory of the city. The building cannot be separated from its urban surroundings. The building itself is not necessarily unique, but its importance is due to considerations of its integrated relationship with the surrounding buildings and its urban location. Buildings under this grade have a functional value that distinguishes architectural work and can be measured by the importance of the job that the building performs for society, and this value is less in unused buildings. This grade includes buildings that are not usually eligible for permanent retention, but nevertheless have some historical or architectural significance and contribute to determining the character of the area. Accordingly, the abovementioned clarification of the heritage grades helped us to complete maps of different heritage grades of the buildings as a second classification of the building stock, as shown in Figure 12a. A map was also made of the number of the three heritage grades defined in the extracted building classes, shown in Figure 12b. Furthermore, Figure 13 shows the relation between the number of the three heritage grades with the extracted building classes.

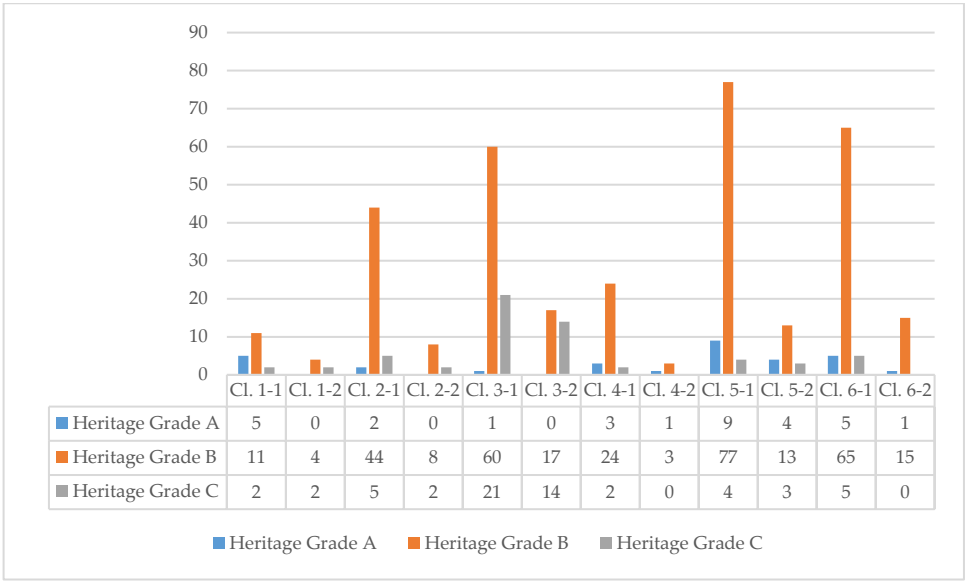
4.4. Retrofitting Scenarios Based on Cultural Values

Inspired by the work of the European project EFFESUS, we proposed a matrix of possible retrofitting scenarios. This matrix consists of the following three main axes: heritage value locations (urban district, building exterior, and interior), heritage value types (visual, physical, and spatial), and (heritage significance level), or in other words, as used in this research, the limits of the interventions allowed for each heritage grade, see Table 4. The results of interviews reveal that the three heritage Grades "A", "B" and "C" are committed to preserving heritage values on an urban district level such as streetscape underground, vistas, etc. The heritage values on urban districts should not be affected by retrofitting scenarios, in terms of visual appearance or aesthetic proportions, used materials, and layout. In the section that follows we discuss the limiting interventions for each heritage grade.



(**a**) (**b**)

Figure 12. (**a**) Map of different heritage grades of the heritage buildings; (**b**) Map of the number of the three heritage grades in the extracted building classes (first author's Ph.D. research).



	Cl. 1-1	Cl. 1-2	Cl. 2-1	Cl. 2-2	Cl. 3-1	Cl. 3-2	Cl. 4-1	Cl. 4-2	Cl. 5-1	Cl. 5-2	Cl. 6-1	Cl. 6-2
Heritage Grade A	5	0	2	0	1	0	3	1	9	4	5	1
Heritage Grade B	11	4	44	8	60	17	24	3	77	13	65	15
Heritage Grade C	2	2	5	2	21	14	2	0	4	3	5	0

Figure 13. Relation between the number of the three heritage grades with the extracted building classes.

Table 4. Proposal checklist of sustainable retrofitting scenarios for each heritage grade in Egyptian context, based on the Energy Efficiency for EU Historic Districts' Sustainability (EFFESUS) method.

Heritage Value Locations	Elements	The Limits of the Interventions Allowed in Each Heritage Grade								
		Grade A			Grade B			Grade C		
		Visual	Physical	Spatial	Visual	Physical	Spatial	Visual	Physical	Spatial
Urban district	Streetscape	P	P	P	P	P	P	P	P	P
	Roofscape	P	P	P	P	P	P	P	P	P
Building exterior	Finishes	P	P	P	P	R or C	P	R or C	C	R or C
External walls	Insulation	NA	NA	NA	A *	A *	A *	A	A	A
	Decoration	P	P	P	P	R	P	P	R or C	P
Roof	Finishes	R	R	R	R	R or C	R	R or C	C	R or C
	Insulation	A **	A **	A **	A	A	A	A	A	A
	Decoration	P	P	P	P	R	P	P	R or C	P
	Parapet	P	P	P	R	R or C	R	R or C	C	R or C
Windows	Glazing	P	R	P	R	R or C	R	R or C	C	R or C
	Frame	P	R	P	R	R or C	R	R or C	C	R or C
	Joints	P	R	P	R	R or C	R	R or C	C	R or C
	Shading	P	R	P	R	R or C	R	R or C	C	R or C
Doors	Frame	P	R	P	R	R or C	R	R or C	C	R or C
	Finishes	P	R	P	R	R or C	R	R or C	C	R or C
	Glazing/Wooden	P	R	P	R	R or C	R	R or C	C	R or C
Balconies	Finishes	P	R	P	R	R or C	R	R or C	C	R or C
	Decoration	P	P	P	P	R	P	P	R or C	P
	Handrail	P	P	P	R	R or C	R	R or C	C	R or C
Shops	Glazing	P	R	P	R	R or C	R	R or C	C	R or C
	Frame	P	R	P	R	R or C	R	R or C	C	R or C
	Signs	P	R	P	R	R or C	R	R or C	C	R or C
Building interior	Finishes	P	R	P	R	R or C	R	R or C	C	R or C
Internal walls	Decoration	P	P	P	P	R	P	P	R or C	P
	Finishes	P	R	P	R	R or C	R	R or C	C	R or C
Ceiling	Finishes	P	R	P	R	R or C	R	R or C	C	R or C
	Decoration	P	P	P	P	R	P	P	R or C	P
	Glazing	P	R	P	R	R or C	R	R or C	C	R or C
Windows	Frame	P	R	P	R	R or C	R	R or C	C	R or C
	Joints	P	R	P	R	R or C	R	R or C	C	R or C
	Frame	P	R	P	R	R or C	R	R or C	C	R or C
Doors	Finishes	P	R	P	R	R or C	R	R or C	C	R or C
	Glazing/Wooden	P	R	P	R	R or C	R	R or C	C	R or C

Note: P, elements must be preserved; R, elements can be retrofitted; C, elements can be changed. R or C elements can be retrofitted or changed. NA, not allowed to add; A, allowed to add. * transparent materials, and ** elements are invisible.

4.4.1. Heritage Grade A

Heritage buildings Grade "A" must be kept under permanent preservation with limited external and internal adjustments, as follows: The building exterior must be preserved without fundamental changes, except in the strictest limits. So, there is no

permission to change any external component of the building, whether visually, in terms of material or spatially. For example, balconies, porches, shopfronts, walls external wall finishes, and parapets are included in this setup. However, external doors and windows are excepted, as their materials can be retrofitted without change to their appearance and dimensions. Moreover, roofs and roof finishes are excluded, as they can be retrofitted without change to their appearance if they are visible. While in the building interior, it is not allowed to add or remove any structural elements, except in case of construction safety (if required). However, some flexibility is allowed to change ceiling finishes, doors, floor finishes, internal window features, and internal wall finishes. These interventions should not change the original appearance and layout of the previous elements.

4.4.2. Heritage Grade B

Heritage buildings Grade "B" can be retrofitted with some flexibility of external and internal adjustments, as follows: It is possible to retrofit the building exterior, or change parts of its external component or elements, bearing in mind that any decorative elements must be kept in order to preserve visual value and layout. External component or elements include balconies, doors, porches, shopfronts, walls external wall finishes, external windows, window features, and parapets. But roofs and roof finishes are excluded, as they can be retrofitted with unlimited interventions without changing their appearance if they are visible, for example, solar panels and roof plants are allowed. It is not permitted to add or remove any structural elements in the building interior, except in the case of construction safety if it is required. More flexibility is allowed, however, to retrofit ceiling and its finishes, doors, floor and its finishes, internal window features, wall, and its finishes.

4.4.3. Heritage Grade C

Heritage buildings Grade "C" can be retrofitted with maximum flexibility of external and internal adjustments, as follows: It is possible to change parts of the building exterior's external component or elements, bearing in mind that any decorative elements must be kept in order to preserve visual value and layout. Any used materials and its dimensions can be changed according to conditions as mentioned by the municipality, in terms of allowed colors, etc. In addition, roofs and roof finishes can be totally changed, allowing adding extra elements such as solar panels or roof plants, but adding extra floor is prevented. In building interior, it is allowed to add or remove any structural elements. With maximum flexibility to modify or change any internal components and elements, if it improves the performance.

4.4.4. Analysis of the Case Study (Building)

The retrofitting measures regarding elements and materials used were analyzed in terms of heritage value, to verify the proposed checklist of possible retrofitting scenarios for each heritage grade in the Egyptian context [74]. Table 5 shows the possible retrofitting scenarios that have been already implemented in the selected case study.

Table 5. Summary of sustainable retrofitting scenarios applied in the selected case study heritage Grade B.

Heritage Value Locations	Elements	Heritage Value Types		
		Visual	**Physical**	**Spatial (Layout)**
Urban district	Streetscape	Preserved	Preserved	Preserved
	Roofscape	Preserved	Preserved	Preserved
Building exterior	Finishes	Retrofitted	Retrofitted	Retrofitted
External walls	Insulation		Not Added	
	Decoration	Preserved	Retrofitted	Preserved

Table 5. *Cont.*

Heritage Value Locations	Elements	Heritage Value Types		
		Visual	**Physical**	**Spatial (Layout)**
Roof	Finishes	Retrofitted	Changed	Retrofitted
	Insulation		Added	
	Decoration	Preserved	Retrofitted	Preserved
	Parapet	Retrofitted	Retrofitted	Retrofitted
Windows	Glazing	Retrofitted	Changed	Retrofitted
	Frame	Retrofitted	Changed	Retrofitted
	Joints	Retrofitted	Changed	Retrofitted
	Shading	Retrofitted	Changed	Retrofitted
Doors	Frame	Retrofitted	Changed	Retrofitted
	Finishes	Retrofitted	Changed	Retrofitted
	Glazing/wooden	Retrofitted	Changed	Retrofitted
Balconies	Finishes	Retrofitted	Retrofitted	Retrofitted
	Decoration	Preserved	Retrofitted	Preserved
	Handrail	Retrofitted	Retrofitted	Retrofitted
Shops	Glazing	Retrofitted	Changed	Retrofitted
	Frame	Retrofitted	Changed	Retrofitted
	Signs	Retrofitted	Changed	Retrofitted
Building interior	Finishes	Retrofitted	Changed	Retrofitted
Internal walls	Decoration	Preserved	Retrofitted	Preserved
	Finishes	Retrofitted	Changed	Retrofitted
Ceiling	Insulation		Added	
	Finishes	Retrofitted	Changed	Retrofitted
	Decoration	Preserved	Retrofitted	Preserved
Windows	Glazing	Retrofitted	Changed	Retrofitted
	Frame	Retrofitted	Changed	Retrofitted
	Joints	Retrofitted	Changed	Retrofitted
Doors	Frame	Retrofitted	Changed	Retrofitted
	Finishes	Retrofitted	Changed	Retrofitted
	Glazing/wooden	Retrofitted	Changed	Retrofitted

4.5. A Detailed Catalogue of the Reference Buildings

Table 6 shows a catalogue of the reference buildings. The provided information includes building addresses, age, construction materials, number of apartments and floors, heritage grade, building type, and some energy parameters (length, area, volume, and surface to volume ratio). Moreover, a list of proposed retrofitting scenarios was defined for each reference building.

Table 6. A detailed catalogue of the reference buildings of the heritage residential building stock in Khedivial Cairo.

Reference	Cl.	Address	Age	Construction	No. of Apartments	Heritage	Type	No. of Floors	Length (m)	Area (m^2)	Volume (m^3)	S/V (%)	Retrofitting Scenarios
1	1.1	25 Al Bustan St.	1921–1930	Concrete construction system	15	B	Apartment building	4	112.82	773.21	14,227.1	0.00793	See Table 4
2	1.2	13 Ismail Pasha Serry St.	1900–1910	Burnt-brick walls	5	B	Single family (villa)	4	81.78	419.21	6707.43	0.012193	See Table 4
3	2.1	42 Naguib El Rihani St.	Before 1900	Concrete construction system	22	B	Single family (villa)	5	79.54	367.45	7349.126	0.010824	See Table 4
4	2.2	15 Ismail Pasha Serry St.	1900–1910	Limestone brick walls	3	B	Apartment building	3	75.41	315.42	3785.10	0.019924	See Table 4
5	3.1	10 Wahbi St.	1900–1910	Concrete construction system	18	B	Apartment building	4	115.40	374.18	5238.61	0.02203	See Table 4
6	3.2	8 Wahbi St.	1900–1910	Limestone Bricks	9	B	Apartment building	3	97.36	339.23	3053.10	0.031889	See Table 4
7	4.1	13July 26 st	1900–1940	Concrete construction system	53	B	Apartment building	9	127.77	1031.85	32,610.34	0.003918	See Table 4
8	4.2	15 Sherif Pasha St.	Before 1900	Burnt-brick walls	22	B	Apartment building	7	135.04	380.77	31,058.67	0.004348	See Table 4
9	5.1	45 Abdel Khalek Sarwat St.	1900–1940	Concrete construction system	12	B	Apartment building	7	119.51	800.5	22,393.75	0.005337	See Table 4
10	5.2	1 Bahler Pass-Shaldjian St.	1900–1940	Burnt-brick walls	36	A	Apartment building	9	107.28	697.74	25,118.85	0.004271	See Table 4
11	6.1	18 Adly St.	1900–1940	Concrete construction system	14	B	Apartment building	8	76.39	364.67	11,669.68	0.006547	See Table 4
12	6.2	3 Bin Taalab St.	1928	Burnt-brick walls	26	B	Apartment building	7	91.40	497.68	13,935.04	0.006559	See Table 4

5. Discussion

In the discussion section, we address the results of the study and include the following three subsections: main findings and recommendations, strengths and limitations of the study, and study implications and future research.

5.1. Main Findings and Recommendations

The main findings of this study show application of the five phases of the proposed methodology in Khedivial Cairo and the outcome from the methodology application.

1. Phase one provides a database of the case study area, Khedivial Cairo, and includes geometric, construction, building age and heritage data, etc. The database was created based on data by CAPMAS in 2017 and recently created GIS maps by the authors, keeping in mind that there is no map available at this moment for these heritage buildings.
2. Phase two classifies the heritage building stock in Khedivial Cairo based on the following steps: number of floors, number of adjoining walls, building construction type and materials, floor area building volume, and reference buildings. All the buildings are located in hot dry climate, and most of these buildings were built in the nineteenth century, see Figure 9d, and are apartment buildings, see Figure 9c, accordingly, climate zone, construction age, and building size were excluded from the proposed methodology. The outcome of this classification were twelve subclasses, and accordingly twelve reference buildings were extracted. Additionally, determining the building volume for each building class and highlighting the largest building classes in terms of weighted share of stock that significantly impact energy demand. It is noted that it is not necessary for a building class that has a large number of buildings to have the same percentage of weight/volume. In this study, the Class 4.2 is the least one in terms of percentage of buildings, as it has only four buildings, but it is the largest class in terms of weighted share of stock. While Class 5.1 has the largest class in terms of percentage of buildings, but it comes in fourth order in terms of largest weighted share of stock.
3. Phase three clarifies obscure interpretations of the local conservation law through interviews with the relevant experts. Accordingly, the heritage building stock was classified once again based on heritage Grades (A, B, and C), and the actual numbers of these heritage grades were defined in each extracted building class.
4. Phase four classifies the heritage Grades (A, B, and C) in terms of heritage value locations (urban district, building exterior, and interior) and types (visual, physical, and spatial). Accordingly, a checklist of the retrofitting scenarios allowed in each heritage grade was proposed. The proposed checklist is a matrix based on the following three dimensions: heritage value locations, types, and heritage building grades. This checklist was proposed based on the EFFESUS methodology, taking into consideration the local context of the study area. For its validation, a real retrofitted heritage building was analyzed by comparing a list of retrofitting scenarios, and it was implemented in this case study with the proposed checklist.
5. Phase five provides a catalogue of reference buildings represented in twelve buildings, the parameters for creating energy models of the selected buildings, and a list of sustainable retrofitting scenarios were defined.

Finally, this study recommends that the reference buildings can be used for building simulation and modelling to allow more accurate performance analysis (building envelope, energy use, and embodied energy) at a building level, in order to explore energy performance and reduce CO_2 emissions of the largest sectoral contribution in Cairo. Accordingly, another classification for energy consumption based on simulation results could be added to determine buildings that are the most energy consuming buildings, in order to channel funding to the most vulnerable and most historically important buildings.

5.2. Strengths and Limitations of the Study

The strengths of this study lie in the combination of the data, i.e., site observations with an advanced tool of creating maps, compiling, and managing geographic information in a database. It used high-quality obtained data gathered through documentations, observations, field surveys, and semi-structured interviews with local experts. Moreover, to the best of our knowledge, this is the first study that integrates heritage significance/protection levels in building classification methods, see Figures 12b and 13. Additionally, translating a conservation law to specific points to propose sustainable retrofitting scenarios, integrating experts' feedback, and benefiting from a real example as crucial factors to propose these scenarios. On the one hand, it is distinct from previous work that did not include construction types and materials such as [39], and the work of [35–37] did not refer to sustainable retrofitting scenarios suitable for heritage protection levels in reference buildings. On the other hand, from a heritage point of view, this work is distinct from previous work of [36–38,50] that assess the impact or risk levels of proposed retrofitting scenarios on the heritage significance. On the contrary, this present work determines firstly possible interventions in each heritage significance grade to ensure preserving cultural values. However, the study is limited by focusing on developing an integrated classification method within the cultural heritage field and defining sustainable retrofitting scenarios in hot climates to provide reference buildings for further energy investigations. More importantly, this study does not address analysis of building envelope, energy use, or embodied energy for these buildings.

5.3. Study Implications and Future Research

This study addresses developing a classification methodology of heritage building stocks as an essential step towards setting a guideline for energy efficient retrofitting of built heritage in hot dry climates. The proposed methodology helps to explore the energy performance and reduction of CO_2 emissions for a very large number of buildings and provides sustainable retrofitting scenarios that balance between conservation measures and energy saving. Accordingly, this would help policy makers to make decisions to retrofit heritage building stocks. Heritage residential building stock in Khedivial Cairo acts as a case study for expanding this concept to other heritage residential buildings in North Africa and the Middle East. On the one hand, this work is trying to fill the gap in existing schemes for classifying heritage buildings by integrating a heritage perceptions aspect. This work is part of an ongoing wider-scale research project that will continue to develop a detailed framework to define specific materials and their dimensions suitable for each type of heritage grade. Therefore, the next part of the research will suggest adding another dimension to the proposed matrix, which would be the energy efficiency of the selected materials. In addition, it would add the economic dimension as well, in order to obtain various options of materials in real practice. On the other hand, the paper is trying to fill the gap between the mentioned actions in the 144/2006 Egyptian law. Therefore, the next step will be in-depth analysis of the building performance of the reference buildings and proposing retrofitting solutions based on the extracted catalogue in the already ongoing research project. Accordingly, another classification-based energy performance of the heritage building stock would be added.

6. Conclusions

This study aims at developing an integrated classification methodology to analyze and improve the energy performance of heritage buildings in historic districts in hot climates, which have few studies dealing with such a topic. The central questions this study revolve around include how cultural values can be integrated in building classification methods for energy purposes to propose suitable energy retrofitting scenarios in hot climates, and how these values can affect energy retrofitting choice. To find answers, an integrated classification methodology was proposed, and for its validation, it was applied in a case study area with a microscale analysis on a building. Khedivial Cairo was selected as

the case study to expand this concept in other building stock with similar conditions. This area was chosen due to its significant cultural values. The proposed methodology includes the following five-phase process: (1) creating a database based on Geographic Information Systems (GIS) tools; (2) classifying heritage building stock (based on building physical characteristics) into representative building types to provide reference buildings; (3) classifying them once again based on their different heritage significant/protection levels; (4) classifying heritage values in each significant/protection level based on and value locations (urban district, building exterior, and interior), and value types (visual, physical, and spatial); and (5) integrating the results in a final matrix that allows to propose retrofitting scenarios based on last classification, to apply them in the extracted reference buildings in phase one. The main findings of this study revealed that the proposed classification methodology is a useful tool, as shown in the results of its application in Khedivial Cairo. The outcome of this application is a representative list of reference buildings with proposed retrofitting interventions. The study is limited by focusing on developing an integrated classification method in hot climates and it does not address building energy performance analysis. This study expects to fill the gap in the existing building classification methodologies of heritage building stocks in hot climates. On a local scale, this work tries to fill the gap between the conservation laws and the actual retrofitting actions needed. Therefore, the next part of the research project that this paper was derived from will suggest adding another dimension to the proposed matrix, which is the energy efficiency of the selected materials, carrying out building simulation and modelling for the reference buildings for further energy analysis, and evaluating the potential of using new technologies.

Author Contributions: Conceptualization, H.S.I., A.Z.K., S.A., and Y.S.; methodology, H.S.I., A.Z.K. and S.A.; software, H.S.I. and Y.S.; field surveys, H.S.I., resources, H.S.I., A.Z.K., and Y.S.; data curation, H.S.I.; writing—original draft preparation, H.S.I.; writing—review and editing, H.S.I.; A.Z.K.; S.A., and Y.S.; visualization, H.S.I.; supervision, A.Z.K., S.A. and Y.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The institutional review board of FUE, Egypt, and ULB, Belgium, provided consent for this research and had no objections.

Informed Consent Statement: The residents of the buildings were informed regarding the research, survey, and data collection. The experts also consented to the interview. The authors can provide the essential data upon request, considering privacy and data protection.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors acknowledge the Future University in Egypt (FUE) for providing necessary funds and resources for the completion of the PhD. degree of the first author.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of the data; in the writing of the manuscript, or in the decision to publish the results.

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