Applications and Economic Profiles of the Turnkey Contract Business Model

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Abstract. The real estate sector, particularly in Europe, plays a significant role in energy consumption, with older and post-World War II buildings contributing most to air emissions. To address this, the European Union has implemented directives since 2002, emphasizing energy efficiency in both existing and new buildings. In response, European countries' governments have introduced incentives to encourage efficiency in existing facilities and the construction of new, high-efficiency buildings. This has led to the development of innovative and sustainable business models, notably the Turnkey Contract model, originating from the United States and exclusively used for new constructions.

This article comprehensively analyses the Turnkey Contract business model, focusing on 11 European case studies from Belgium, Germany, the Netherlands, and Spain. The study employs Multiple Correspondence Analysis (MCA) and K-modes cluster analysis to identify economic profiles associated with this model. The results reveal two distinct clusters: one with private ownership, smaller-scale buildings for private use, and a construction company as the main contractor; the other with public ownership, larger-scale buildings for public use, and an architecture/engineering firm as the main contractor.

The analysis also highlights commonalities between the two clusters identified, such as a project duration of 1–3 years, energy class A properties, and subsidized interventions like insulation and renewable energy installations. The study provides insights into how ownership structure and intended use influence the variations in the Turnkey Contract business model, offering a foundational exploration for future research to consider economic, financial, and cultural specificities across European countries.

Keywords: economic profiles · Turnkey Contract · sustainable business model

1 Introduction

Since the 1990s, it has been recognized that the majority of greenhouse gas emissions are due to human activity, especially in the real estate sector. Research shows that old, inefficient buildings and properties constructed after the Second World War are responsible for the majority of these emissions [1, 2]. The European real estate sector reflects these characteristics perfectly. Not only is it inefficient and highly dependent on fossil

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O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14818, pp. 143–161, 2024.
https://doi.org/10.1007/978-3-031-65273-8_10

fuels for energy production, but it also accounts for around 38% of energy consumption in the EU. This result is due to the long-life cycle of existing properties, the construction of a limited number of new efficient buildings and an initial lack of 2 confidence in the increase in property value resulting from the efficiency measures promoted and the associated price premiums and cost premiums [3–6].

To overcome this problem, the European Union has promoted several directives since 2002 aimed at increasing the efficiency of existing installations or the construction of new buildings such as near-zero energy (NZeB) ones [7, 8]. Several amendments have been made to the two main directives (Directive 2002/91/EC and Directive 2010/31/EU) aimed at increasing the efficiency of existing buildings and the construction of new buildings with high energy efficiency. Those that focus mainly on the construction and efficiency of new buildings are Directive 2012/27/EU, Directive 2018/844 and the Energy Efficiency Directive (EU/2023/1791) [9–11], the latter, which is recently adopted, made the efficiency of buildings a fundamental principle of EU energy policy, giving it legal value for the first time [11].

In response to these directives, various European governments have issued several incentives over the years to promote the efficiency of existing facilities and the construction of new high-efficiency buildings [12]. This has also led to the development and simultaneous introduction of innovative and sustainable business models (SBMs) for the efficiency of existing facilities and the construction of new real estate assets [13–17].

In contrast to traditional ones, these SBMs aim to produce a service or a product that can be used by as many people as possible, rather than incentivizing the profit that results from its introduction. They are also characterized by the presence of numerous actors within the long production chain who share data and various information throughout the life of the project, which helps to reduce waste [15, 17–21]. Finally, unlike a traditional model, the revenue of a SBM must be calculated in the short and long term due to the extension of the production chain [15, 22–24].

This article represents an important contribution resulting from broader research dedicated to the analysis of different SBMs [25]. In this article, special emphasis is placed on examining and analyzing the SBM of the Turnkey Contract. This model, which originated in the United States, is used exclusively for the construction of new buildings and requires the presence of a main contractor who takes care of the design, construction and building of the real estate asset on behalf of the client. The article is organized as follows: Sect. 2 presents a literature review on the Turnkey Contract, describing its structure, its functioning and the different actors that interact and are involved within the model. Section 3 the method of analysis used, Sect. 4 presents the data analyzed, Sect. 5 the results and, finally, Sect. 6 the conclusions.

2 Literature Review

The Turnkey Contract business model originated in the United States within the construction and oil and gas industries before expanding to various sectors and other countries [26].

A first description of this model can be found in the works of Freeman [27]. He defines the Turnkey Contract as a contract whereby a single contractor secures and establishes

all premises, facilities, tools, materials, and operating people required to complete a project and make it operationally ready. The consumer only needs to turn the key to use the new facility fully and effectively, hence the name [28].

This business model envisages five different actors: the customer, the contractor (who is determined through a call for tenders), the project manager (who is appointed by the contractor), the project coordinator and the subcontractors (Fig. 1). Before the commencement of works, the contractor warrants that he has the necessary skills and organization to fulfil the client's needs and complete the works within the agreed deadlines [29]. When participating in the tender, the contractor must submit the project design. He must also submit a bid package in which he demonstrates his marketing, management, and coordination skills. Finally, he must submit a list of suppliers and subcontractors who can support him in fulfilling his contractual obligations.

Once awarded the contract, the contractor is under the obligation to appoint a project manager who will be responsible for the organization and the execution of the project. The project manager must have adequate managerial and technical training and be fully informed about the contractor's intervention methodology. Finally, he must be able to translate and interpret the client's requests and assign the most suitable staff depending on the phases of the project [26, 30–32].

Further to the above, the project manager is also obliged to duly inform the client on the state progress of the works and provide updates about the search and signing of contracts with subcontractors, should the contractor not be able to carry out some of the works under the main contract. Also, he must ensure that works are carried out pursuant to the deadlines agreed upon by the parties [26, 30–32].

For his part, the project manager may require that a project coordinator is appointed in order to attend to the definition of the different design phases and the setting of the budget, as well as to provide quality control, production and timely delivery of the project [29, 32–34].

The execution of works may however run into some setbacks, should the customer request any variation, or the delivery of the works be non-timely [28, 29, 35, 36].

As for the first case, usually, the contract entitles the customer to demand that variations be made when the project was not fully defined at the beginning. As a result, the construction company is under the obligation to perform the requested additional works, provided the additional price is paid by the customer. As far as the non-timely delivery is concerned, failure to execute the works under the agreed deadlines may be due to impediments which are related to both the customer and the contractor. Such situations are often expressly addressed by the parties in the contract, which may or may not allow for a time extension should execution by the contracting company be non-timely [26, 33–36].

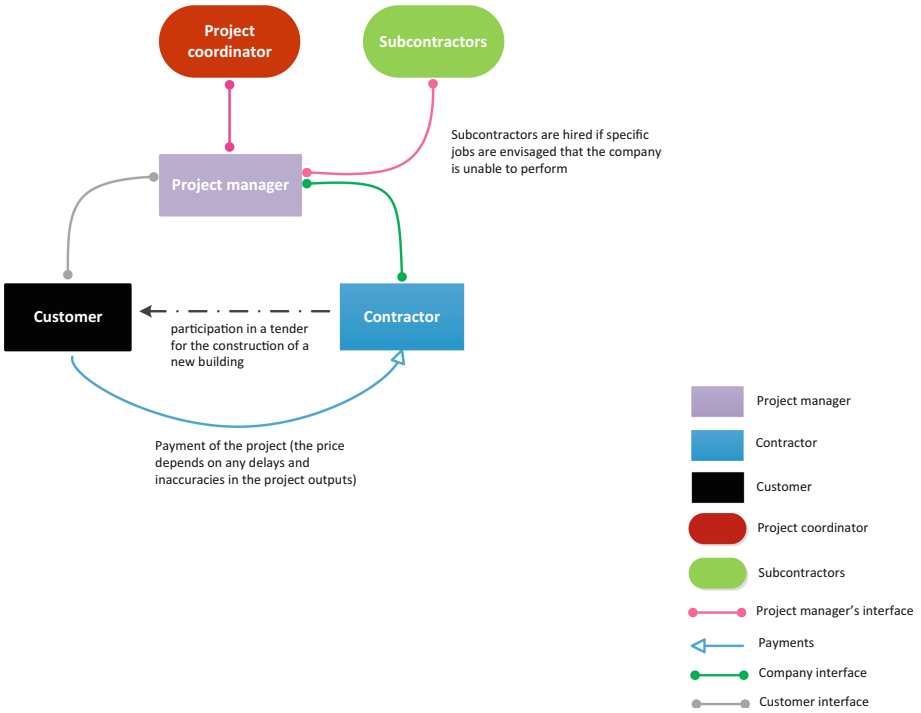

Fig. 1. Scheme of the Turnkey Contract business model

3 Method

3.1 Multiple Correspondence Analysis (MCA)

Multiple Correspondence Analysis (MCA) was chosen to analyze the relationship between two or more categorical variables in a multidimensional table.

This approach is an extension of Correspondence Analysis (CA), a statistical method for examining and visualizing relationships between the rows and columns of a contingency table using a map. In the data set, each point is placed in a multidimensional space and has a specific weight and the chi-square distance between the points can be calculated. The latter is an important tool for evaluating and visually representing relationships between categories of categorical variables, allowing patterns, associations and structures to be recognized in contingency data. The chi-square distance is calculated based on the chi-square statistic, which measures the discrepancy between the observed frequencies and the expected frequencies in the contingency table and reflects how much the observed frequencies differ from those that would be expected if the two variables were independent [37–39].

The graphical representation and analysis of the correlations and distances between the different categories of the considered variables form the basis for interpreting the results (e.g. the variable categories that are close to each other in two-dimensional space are more strongly associated, while those that are far away are less correlated) [37].

The qualitative characteristics of each point determine its position within the diagram, and the chi-square distance measures the distance between them. Let us define:

- $x_i = [x_1, x_2 \ldots x_n]$ a vector representing one set of coordinates or characteristics for a data point in a multidimensional space. Each element $(x_1, x_2 \ldots x_n)$ corresponds to a specific feature or dimension;
- $y_i = [y_1, y_2 \ldots y_n]$ a vector representing a second set of coordinates or characteristics for another data point in the same multidimensional space. Similar to x_i, , each element $(y_1, y_2 \ldots y_n)$ corresponds to a feature or dimension.
- $c_i = [c_1, c_2 \ldots c_n]$ a vector of ratios, where c_i is the ratio of the total frequencies in the columns of a contingency table to the overall sum of frequencies in the table. These ratios are associated with each dimension or feature in the vectors x and y.

The equation for determining the Chi-square distance for the vectors x_i and y_i given their vector of ratios c_i is as follows:

$$\text{Chi} - \text{square distance} = \sqrt{\frac{(x_1 - y_1)^2}{c_1} + \frac{(x_2 - y_2)^2}{c_2} + \ldots + \frac{(x_n - y_n)^2}{c_n}} \quad (1)$$

To reflect the difference between the groups under consideration, the Pearson chi-square statistic is calculated in the table and the result is divided by the sample size n. This value, often referred to as inertia, represents the total variance in CA and MCA. A higher inertia indicates that the observed data points are more dispersed or varied in the multidimensional space, suggesting a richer structure or more pronounced relationships between categories [37–39].

After collecting the data through interviews, questionnaires or other survey methods that reflect the characteristics or preferences in the different categories of interest, these are represented in the vectors x_i and y_i. These vectors are then used to create a map that clearly highlights the appropriate scale for the categories and the differences between each group. The results can be represented by a symmetrical or asymmetrical map. In a symmetrical map, the positions of points/categories on the map reflect the overall structure of relationships in the data without emphasizing specific variables. It provides a global view of the associations between categories, irrespective of the variable they belong to. An asymmetrical map emphasizes the relationships between categories within specific variables. It allows for a more detailed exploration of the associations within each variable individually, revealing how categories within one variable relate to each other [37, 39].

3.2 Cluster Analysis: K-modes Algorithm

Once the initial exploratory phase of data analysis is complete, cluster analysis is proceeded with to determine the results. Clustering analysis processes the data by generating associations between data points based on the characteristics. Each cluster is determined by a center called the centroid (a point in the feature space that mediates the distances between all the data belonging to the cluster) and by a distance (generally, Euclidean distance is used for clustering). Data belonging to the same region (and therefore close

to the centroid of the cluster) can be defined as similar, while data belonging to different regions (with large distances compared to the analyzed centroid) can be defined as dissimilar. The calculation of the centroid of a cluster in the k-means analysis is given by the squared Euclidean distance between two objects X and Y in a two-dimensional space:

$$d(X, Y) = \sum_{i=1}^{n} (x_i - y_i)^2 \tag{2}$$

where

- n is the number of attributes (features) in each object X and Y;
- x_i and y_i are the values of the i-th attribute in objects X and Y, respectively;
- $(x_i - y_i)^2$ calculates the squared difference between the i-th features of X and Y;
- denotes the summation over all dimensions, adding up the squared differences for each dimension.

The algorithm aims to minimize the sum of these squared distances within clusters, leading to well-defined cluster centroids and compact clusters.

In this article, it is decided to use the k-modes algorithm, an extension of the k-means algorithm, for the data analysis (for a detailed analysis of cluster analysis with the k-means algorithm, please refer to the following literature [40–45]). It is decided to use this algorithm because the dataset consists only of categorical data for which there is no a priori definable sorting criterion and which have no geometric properties [46, 47]. To calculate the distance (d_1) in the k-modes cluster analysis, it is determined by the number of deviations between the attributes of two objects X and Y and results from the following formula:

$$d_1(X, Y) = \sum_{\mathrm{i}=1}^{n} \delta(x_i, y_i) \tag{3}$$

where

- n, x_i and y_i have the same meanings in the formula (2);
- $\delta(x_i, y_i)$ is a function that equals 0 if $x_i = y_i$ (attributes are equal) and 1 if $x_i \neq y_i$ (attributes are different).

So, $d_1(X, Y)$ is calculated by summing up the values of $\delta(x_i, y_i)$ for each attribute. The function δ essentially counts the number of attributes that differ between X and Y.

The model, defined as the maximum relative frequency for each attribute, acts as a representative vector of a group of objects (Q_l) in the k-modes analysis and minimizes the sum of the distances of all objects in a cluster $d\left(X_{l,i}, Q_l\right)$ from the mode itself [46, 48, 49]. The distance calculation with the k-modes algorithm results from the following minimization formula:

$$D(X_l Q_l) = \sum_{i=1}^{n_l} d\left(X_{l,i}, Q_l\right) \tag{4}$$

where

- $X_l = \left\{X_{l,1}, \ldots, X_{l,n}\right\}$ corresponds to the set of objects in cluster l;
- Q_l represents the mode (representative vector) for cluster l;

- $d\left(X_{l,i}, Q_l\right)$ is the distance between is the distance between the object X_l and the mode Q_l;
- n_l is the number of objects in the cluster l.

The MCA is performed using the statistical software Stata, while the cluster analysis with the k-modes algorithm is performed using the programming language Python, as Stata only displayed the cluster analysis using the k-means algorithm and the k-median.

4 Data

The data analysis includes 11 European case studies of buildings built from scratch using the Turnkey Contract business model in specific countries. The properties are located respectively in Belgium (CSEU01), Germany (CSEU02, CSEU03, CSEU04 and CSEU05), the Netherlands (CSEU06 and CSEU07) and Spain (CSEU07, CSEU08, CSEU09, CSEU10 and CSEU11). They were built between 2015 and 2020 and are both publicly and privately owned (Table 1 and Fig. 2).

Table 1. List and description of the 11 case studies

Code	Case study	Country	Ownership	Construction year
CSEU01	Center Perex, Namur	Belgium	Public	2017
CSEU02	Passivhaus Parklogen München-Schwabing, Munich	Germany	Private	2017
CSEU03	Project NEWTON house 1, Berlin Adlershof	Germany	Private	2018
CSEU04	Wood hybrid construction: 132 new residential units in passive house standard, Wuppertal	Germany	Public	2020
CSEU05	Wood hybrid construction: 258 new living spaces in passive house standard, Bochum	Germany	Public	2020
CSEU06	City Hall, Venlo	Netherlands	Public	2016
CSEU07	City Hall, Almelo	Netherlands	Public	2015
CSEU08	Entrepatios Las Carolinas: ecological cohousing, Madrid	Spain	Private	2020
CSEU09	Villa Eulietta, Donostia-San Sebastian	Spain	Private	2017
CSEU10	Cooperative of 74 dwellings in the Park of the Offices, La Coruña	Spain	Private	2017
CSEU11	29Soto, Pamplona	Spain	Private	2017

Once the case studies had been localized, the process of defining the basic variables for the subsequent analyses began. The variables considered cover several aspects, including the actors involved in the Turnkey Contract model, their roles, the investment provided and the physical characteristics of the building being constructed, as well as the works carried out as part of the project (Table 2 and Table 3).

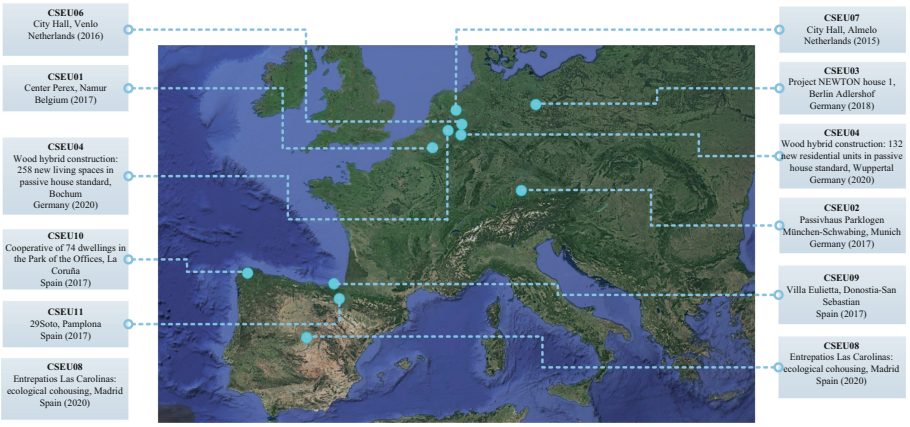

Fig. 2. Geolocalization of the 11 case studies

Table 2. Variables description

Code	Variable	Description
OW	Ownership	The ownership of the property to be built
CST	Customer	Subject to whom the construction of the property is directed. He can provide initial results for the realization of the project, but the design and execution phase is the exclusive task of the contractor with whom the contract has been concluded
C	Contractor	The main contractor is responsible for the design, construction and inspection of the property. He may also use subcontractors to carry out certain work that he cannot do himself
SubC	Subcontractor	Existence or non-existence of subcontractors within the business model who were responsible for carrying out certain work that the main contractor could not carry out itself

(*continued*)

Table 2. (*continued*)

Code	Variable	Description
IC	Investment cost (€)	Total cost of constructing the property
PP	Project period	Time spent on the construction of the property (excluding the planning phase)
NFA	Net floor area (m^2)	Net floor area of the built property
Use	Intended use	Intended use of the built property. It can be intended for private purposes (apartment or office) or for public purposes (office)
EC	Energy class	The energy class achieved after the construction of the property
EPI	Energy performance index after the efficiency measures (kWh/m^2 year)	The energy performance index obtained after the construction of the property
Insul	Insulation	Promotion of works carried out as part of the project that have favored the insulation of the building envelope or even the installation of highly energy-efficient devices
Syst	Systems	Support for works carried out as part of the project that have improved the building's heating, cooling and ventilation system
Renew	Renewable energy	Promotion of works within the project that favor the installation of renewable energy systems: photovoltaic and solar thermal panels

Table 3. List of variables and their values

Code	Variables	Values
Ow	Ownership	1:Private; 2:Public
CST	Customer	1:Natural person; 2:Real estate company; 3:Capital company; 4:Construction company; 5:Public financial institution
C	Contractor	1:Architecture/engineering studio; 2:Construction Company
SubC	Subcontractor	1:Only 1 subcontractor; 2:Between 2 and 3 subcontractors; 3:More than 3 subcontractors; 4:No subcontractors
IC	Investment cost (€)	0: N/A; 1: €509.000 – €3.000.000; 2: €3.071.611 – €9.509.725; 3: €16.000.000 – €19.130.000; 4: €35.316.112 – €58.765.578

(*continued*)

Table 3. (*continued*)

Code	Variables	Values
PP	Project period	0: N/A; 1: Between 1 and 3 years; 2: Between 4 and 10 years
NFA	Net floor area (m^2)	1: 162 m^2–1.732 m^2; 2: 2.012 m^2– 7.884 m^2; 3: 8.400 m^2– 9.681 m^2; 4: More than 10.000 m^2
Use	Intended use	1: Private homes and offices; 2: Public offices
EC	Energy class certificate	1: A; 2: B; 3: D
EPI	Energy performance index after the efficiency measures (kWh/m^2 year)	
	A	1: 1,00–17,00 kWh/m^2 year; 2: 22,00–33,30 kWh/m^2 year; 3: 39,00–50,00 kWh/m^2 year
	B	4: 80,00–90,00 kWh/m^2 year
	D	5: 155,00–158,33 kWh/m^2 year
Insul	Insulation	1: Walls; 2: Walls and windows
Syst	Systems	1:Heating system, cooling system and ventilation system; 2:Heating system and ventilation system; 3:Heating system and cooling system
Renew	Renewable energy	1: Installation of photovoltaic and solar thermal panels; 2:Installation of photovoltaic panels; 3:Installation of solar thermal panels; 4:Anything

5 Results and Discussion

5.1 Multiple Correspondence Analysis (MCA)

Due to the large number of variables, it has been decided to perform an initial MCA analysis by first considering all the variables related to the business model of the Turnkey Contract and then the variables related to the energy aspects of the buildings.

The variables of the business model concern the ownership of the property to be built (OW), the client (CST), the main contractor (C), the existence of subcontractors (SubC), the investment costs (IC), the construction period (PP), the intended use and the net floor area (Use, NFA). Variables related to the energy aspect of the building include the energy class (EC), the energy performance index (EPI) and the work on the envelopes, systems and renewable energy sources (Insul, Syst, Renew).

Figure 3 shows the MCA analysis for the variables representing the characteristics of the Turnkey Contract business model. The first aspect that can be seen from the graph is how the y-axis contributes to the formation of 2 clusters within the dataset: one on the right and one on the left.

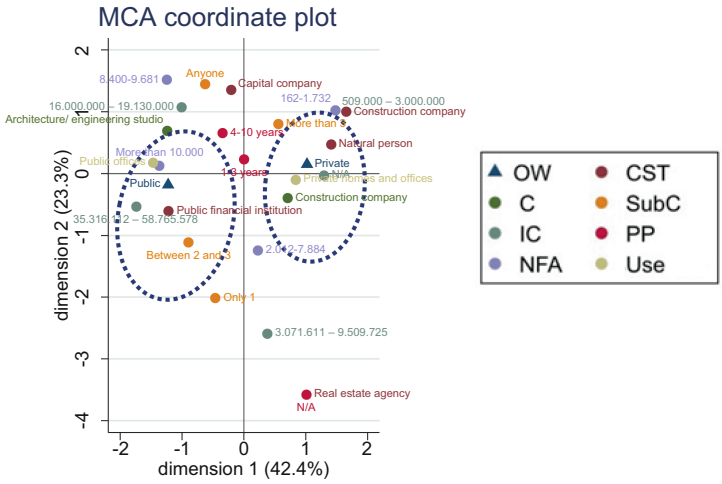

Fig. 3. MCA among the variables: Nature of customer (NCST), Customer (CST), Contractor (C), Subcontractor (SubC), Intervention cost (IC), Project period (PP), Net floor area (NFA) and Intended use (Use). The percentages given as Dimension 1 (42.4%) and Dimension 2 (23.3%) refer to the proportion of variation explained by the two main dimensions of the map. These percentages indicate how effective the main dimensions of the map are in capturing the variation in the original data (higher percentages may explain a greater proportion of the variation in the data).

The cluster on the right side of the y-axis is characterized by private ownership and a construction company as the main contractor within the business model, as well as an intended use associated with private homes and offices. Furthermore, these elements seem to be closely related to having a natural person as a client and having more than 3 subcontractors within the project. Finally, although to a lesser extent, these variables are associated with a net built-up area of between 162 and 1.732 m^2 and an investment cost of between €509,000 and €3,000,000.

The cluster to the left of the y-axis is characterized by public ownership, the identification of a public institution as the main client and an architecture/engineering studio as the main contractor. Other characteristic elements in this cluster are the presence of 2 or 3 subcontractors within the model. Other variables related to those previously described are an investment cost between €16,000,000 and €19,300,000, a project duration between 4 and 10 years and the construction of real estate for public and institutional purposes with a net floor area between 35.316 and 58.765 m^2.

Figure 4 shows the MCA analysis for the variables associated with the physical and energy characteristics of the finished property. It can be seen from the graph that energy class A is the most strongly associated compared to the other two classes present in the dataset (B and D). Indeed, an energy performance index (EPI) between 1.00 and 17.00 kWh/m^2 year and between 22,00 e 33,30 kWh/m^2 year are closely associated with this energy class.

When exploring the other considered variables, those most related to class A concern the insulation of the walls, all the building systems (heating, cooling and ventilation)

and the one-off installation of photovoltaic and solar thermal panels. Also significant, although to a lesser extent than those previously described, are the project works that only involve the building's heating and ventilation system, as well as the simultaneous installation of photovoltaic and solar thermal panels and, finally, an index of energy performance (EPI) between 39.00 and 50.00 kWh/m^2 year.

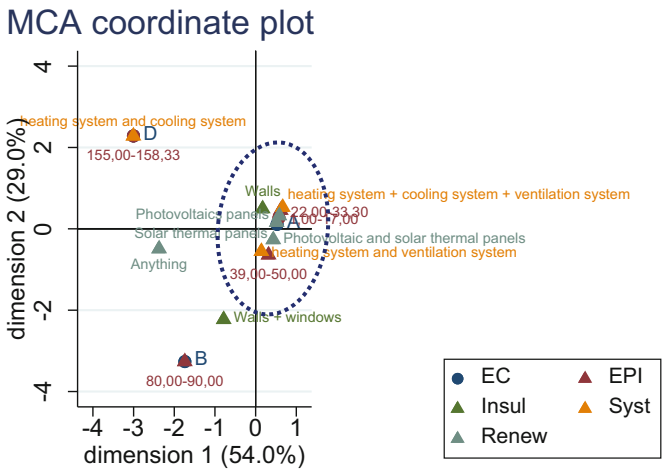

Fig. 4. MCA among the variables: Energy Class (EC), Energy performance index (EPI), Insulation (Insul), Systems (Syst) e Renewable energy (Renew). The percentages given as 'Dimension 1 (54.0%) and Dimension 2 (29.0%)' refer to the proportion of variation explained by the two main dimensions of the map. These percentages indicate how effective the main dimensions of the map are in capturing the variation in the original data.

5.2 Cluster Analysis: K-modes Algorithm

The cluster analysis with the k-modes algorithm begins with an implementation of the "elbow method" to determine the optimal number of clusters (k) for the analyzed data set. In this method, the clustering algorithm is run for a set of cluster values and the explained variation is plotted as a function of the number of clusters. The "elbow" in the graph represents the point at which adding additional clusters does not significantly improve the explained variation. Therefore $k = 2$ turns out to be the optimal number of clusters to analyze the dataset, since upon reaching $k = 3$ numerous similarities emerge between 2 out of 3 clusters (Fig. 5).

After establishing $k = 2$, the identification and subdivision of the different case studies based on their characteristics are conducted, with each case study belonging to a cluster being assigned a value of 1 (Table 4 and Fig. 6).

Upon completion of this process, the definition of the characteristics of each cluster and, consequently, each economic profile starts (see Table 5). The k-modes analysis performed on the dataset shows that the two identified clusters (economic profiles) differ from each other in almost all variables, with the exception of the energy class of

the built property (EC), its energy performance index (EPI), the project duration (PP) and, finally, the project works carried out (Insul, Syst and Renew) (Table 4). The two clusters therefore have similar economic profiles in terms of the project work carried out, but differ completely in the structure of the business model.

Although both apply the Turnkey Contract business model for the construction of the property, the first profile (cluster = 0) is characterized by private ownership, a natural person as the customer and a construction company as contractor, as well as the presence of more than 3 subcontractors. Other characteristic and exclusive elements of this profile are the investment costs between €509,000 - €3,000,000, a constructed property with a net floor area between 162–1.732 m^2 and finally the private use of the property which can be traced back to private homes and offices.

The second profile (cluster = 1) has, as part of its Turnkey Contract business model, a public property, a client associated with a public financial institution, a main contractor associated with an architecture/engineering firm and the presence of 2 or 3 subcontractors working with the main contractor in the construction of the property. Other exclusive elements of this profile are investment costs between €16,000,000 and €19,130,000, a net floor area of the built property of more than 10.000 m^2 and finally, the intended public use of the property which can be traced back to public offices or institutions.

The common characteristics of both economic profiles instead concern the duration of the project implementation, the energy characteristics of the property and the interventions promoted. The properties of both economic profiles have a project period between 1 and 3 years, a final energy class of the property of A and an energy performance index between 1,00–17,00 kWh/m^2 year. Finally, in both clusters (economic profiles), the insulation of the envelope, the installation of a heating and ventilation system and photovoltaic systems are subsidized as part of the new construction project (Fig. 6).

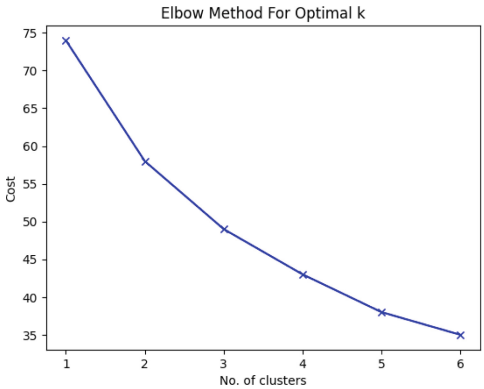

Fig. 5. "elbow method" graphic



Fig. 6. Histogram k-modes analysis

Table 4. Cluster assignment for each case study

Code	Cluster 0	Cluster 1
CSEU01	0	1
CSEU02	1	0
CSEU03	1	0
CSEU04	0	1
CSEU05	0	1
CSEU06	0	1
CSEU07	0	1
CSEU08	1	0
CSEU09	1	0
CSEU10	0	1
CSEU11	1	0

5.3 Discussion

The analysis carried out using Multiple Correspondence Analysis (MCA) and the K-modes algorithm provides a detailed overview of the characteristics of the Turnkey Contract business model and the energy aspects of the buildings.

Cluster 0 is characterized by private properties, with an individual customer and a construction company as the main contractor, as well as the presence of more than 3 subcontractors. This profile is associated with lower investment costs and smaller properties that are mainly used as private residences or offices.

Cluster 1, on the other hand, shows a tendency towards public properties, with public institutions as customers and architecture/engineering firms as main contractors, together with 2 or 3 subcontractors. This profile is associated with significantly higher investment costs and larger properties intended for public use, such as government offices or institutions.

These differences have a significant impact on both the real estate market and urban planning. It may be more favorable for private investors to focus on smaller projects suitable for private residential or commercial use, while the public sector is more likely to invest in larger projects for public services or infrastructure.

Table 5. Cluster properties description

Variables	Cluster 0	Cluster 1
Ownership (OW)	1	2
Customer (CST)	1	5
Contractor (C)	2	1
Subcontractor (SubC)	3	2
Investment cost (IC)	1	3
Project Period (PP)	1	1
Net floor area (NFA)	1	4
Intended use (Use)	1	2
Energy certification (EC)	1	1
Energy performance index (EPI)	1	1
Insulation (Insul)	1	1
System (Syst)	2	2
Renewable sources (Renew)	2	2

The similarities between the two profiles, such as the energy class A, the energy performance index, and the specifications of the subsidized buildings, indicate that energy efficiency and sustainable technologies are priority aspects for both sectors. This suggests a general trend towards more sustainable and environmentally friendly building practices, regardless of differences in the business model or end use of the properties.

6 Conclusions

The research aims to deepen the knowledge of the sustainable Turnkey Contract business model by analyzing a dataset of 11 case studies. The aim is to identify the economic profiles associated with this model. After defining the variables, the MCA highlights two different groups in relation to the business model, one with private ownership and one with public ownership, and instead a single group for the variables associated with the energy characteristics of the property. This shows that energy class A is the most significant within the dataset and that the latter is closely correlated with an EPI between 1.00 and 17.00 kWh/m^2 year and between 22.00 and 33.30 kWh/m^2 year. Among the variables representing the work carried out as part of the project, those most strongly associated with class A concern the insulation of the walls and all the building's systems (heating, cooling and ventilation).

The case studies are then divided into clusters using the k-modes analysis. The number of clusters is determined using the "elbow method", which suggests an optimal number of clusters of 2. Both clusters are given energy class A properties with similar characteristics from an energy point of view (EPI between 1.00 and 17.00 kWh/m^2 year), the project works carried out and the project period (between 1 and 3 years) but they

are distinguished by their intended use: private homes and offices in cluster 0 and public offices in cluster 1.

The variables that differentiated the two economic profiles are mainly related to the structure of the Turnkey Contract business model. Cluster 0 is associated with a private owner, a natural person as the customer, a construction company as the contractor, the presence of more than 3 subcontractors within the business model and the construction of a property for private use, while Cluster 1 is associated with a public owner, a public financial institution as the client, an architecture/engineering firm as the contractor, the presence of 2 or 3 subcontractors within the business model and the construction of a building for public use.

The results of the study are of great importance for various areas such as real estate, urban planning, sustainability, and finance. Examining the different economic profiles associated with Turnkey Contract projects sheds light on market demand and urban redevelopment. In addition, the increasing focus on energy efficiency reflects a growing commitment to sustainable approaches. Furthermore, the distinction between private and public ownership provides valuable insights for refining financing and investment strategies aligned with risk and return considerations. Further exploration of factors such as cultural influences and regional differences could provide deeper insights into the adoption of Turnkey Contract models.

Continued research in this area promises to enrich the relevance and timeliness of the topic and promote a more holistic understanding of sustainable urban redevelopment practices.

References

1. Mironiuc, M., Ionașcu, E., Huian, M.C., Țaran, A.: Reflecting the sustainability dimensions on the residential real estate prices. Sustainability **13**(5) (2021). https://doi.org/10.3390/su13052963
2. Vanags, J., Butane, I.: Major aspects of development of sustainable investment environment in real estate industry. Procedia Eng. **57**, 1223–1229 (2013). https://doi.org/10.1016/J.PROENG.2013.04.154
3. Hirsch, J., Spanner, M., Bienert, S.: The carbon risk real estate monitor - developing a framework for science-based decarbonizing and reducing stranding risks within the commercial real estate sector. J. Sustain. Real Estate **11**(1), 174–190 (2019). https://doi.org/10.22300/1949-8276.11.1.174
4. Tan, Y., Liu, G., Zhang, Y., Shuai, C., Shen, G.Q.: Green retrofit of aged residential buildings in Hong Kong: a preliminary study. Build. Environ. **143**, 89–98 (2018). https://doi.org/10.1016/J.BUILDENV.2018.06.058
5. Copiello, S., et al.: Building industry and energy efficiency: a review of three major issues at stake. In: Gervasi, O., Murgante, B., Misra, S., Garau, C., Blečić, I., Taniar, D., Apduhan, B.O., Rocha, A.M.A.C., Tarantino, E., Torre, C.M. (eds.) ICCSA 2021. LNCS, vol. 12954, pp. 226–240. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-86979-3_17
6. Copiello, S., Donati, E.: Is investing in energy efficiency worth it? evidence for substantial price premiums but limited profitability in the housing sector. Energy Build **251**, 111371 (2021). https://doi.org/10.1016/j.enbuild.2021.111371
7. DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002 on the energy performance of buildings

8. DIRECTIVE 2010/91/EU of 10 December 2010 amending Council Directive 91/414/EEC to include as active substance and amending Decision 2008/934/EC, EFSA Journal, vol. 8, no. 5. Wiley-Blackwell Publishing Ltd, May 01 (2010). https://doi.org/10.2903/j.efsa.2010.1592
9. DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (2012)
10. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance)
11. I (Legislative acts) DIRECTIVES DIRECTIVE (EU) 2023/1791 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast) (Text with EEA relevance)
12. Kuzemko, C.: Re-scaling IPE: local government, sustainable energy and change. Rev. Int. Polit. Econ. **26**(1), 80–103 (2019). https://doi.org/10.1080/09692290.2018.1527239
13. Bocken, N., Short, S., Rana, P., Evans, S.: A value mapping tool for sustainable business modelling. Corp. Gov. Int. J. Bus. Soc. **13**(5), 482–497 (2013). https://doi.org/10.1108/CG-06-2013-0078
14. Munaro, M.R., do C. D. Freitas, M., Tavares, S.F., Bragança, L.: Circular business models: current state and framework to achieve sustainable buildings. J. Constr Eng. Manag. **147**(12), 04021164 (2021). https://doi.org/10.1061/(ASCE)CO.1943-7862.0002184
15. Morioka, S.N., Evans, S., de Carvalho, M.M.: Sustainable business model innovation: exploring evidences in sustainability reporting. Procedia CIRP **40**, 659–667 (2016). https://doi.org/10.1016/j.procir.2016.01.151
16. Boons, F., Lüdeke-Freund, F.: Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. J. Clean. Prod. **45**, 9–19 (2013). https://doi.org/10.1016/j.jclepro.2012.07.007
17. Zhao, X., Pan, W., Lu, W.: Business model innovation for delivering zero carbon buildings. Sustain. Cities Soc. **27**, 253–262 (2016). https://doi.org/10.1016/j.scs.2016.03.013
18. Stubbs, W., Cocklin, C.: Conceptualizing a 'sustainability business model.' Organ. Environ. **21**(2), 103–127 (2008). https://doi.org/10.1177/1086026608318042
19. Xu, A.: Turunen, Mäntymäki, and Heikkilä, platform-based business models: insights from an emerging Ai-enabled smart building ecosystem. Electronics (Basel) **8**(10), 1150 (2019). https://doi.org/10.3390/electronics8101150
20. Ensign, P., Roy, S., Brzustowski, T.: Decisions by key office building stakeholders to build or retrofit green in toronto's urban core. Sustainability **13**(12), 6969 (2021). https://doi.org/10.3390/su13126969
21. Leising, E., Quist, J., Bocken, N.: Circular economy in the building sector: three cases and a collaboration tool. J. Clean. Prod. **176**, 976–989 (2018). https://doi.org/10.1016/j.jclepro.2017.12.010
22. Antonini, E., Longo, D., Gianfrate, V., Copiello, S.: Challenges for public-private partnerships in improving energy efficiency of building sector. Int. J. Housing Sci. Appl. **40** (2016)
23. Sovacool, B.K., Turnheim, B., Martiskainen, M., Brown, D., Kivimaa, P.: Guides or gatekeepers? incumbent-oriented transition intermediaries in a low-carbon era. Energy Res. Soc. Sci. **66**, 101490 (2020). https://doi.org/10.1016/j.erss.2020.101490
24. Tronchin, L., Manfren, M., Nastasi, B.: Energy efficiency, demand side management and energy storage technologies – a critical analysis of possible paths of integration in the built environment. Renew. Sustain. Energy Rev. **95**, 341–353 (2018). https://doi.org/10.1016/j.rser.2018.06.060

25. Donati, E., Copiello, S.: The one-stop shop business model for improving building energy efficiency: analysis and applications. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), Springer Science and Business Media Deutschland GmbH, pp. 422–439 (2023). https://doi.org/10.1007/978-3-031-37111-0_30
26. Schneider, M.E.: Turnkey Contracts - Concepts, liabilities, claims. In: The international Construction law Review, in 4, vol. 3. LLYOD'S OF LONDON PRESS LTD (1986). https://www.lalive.law/wp-content/uploads/2019/10/mes_turnkey_contracts.pdf
27. Ralston, A., Reilly, E.D.: Encyclopedia of Computer Science and Engineering, 2nd edn. Van Nostrand Reinhold Co, New York (1983)
28. Merna, A., Smith, N.: Project managers and the use of Turnkey contracts. Int. J. Project Manage. **8**(3), 183–189 (1990). https://doi.org/10.1016/0263-7863(90)90021-3
29. Doe, J., Nitek, D., Minamikata, N., Smith Freehills, H.: Construction Arbitration and Turnkey Projects, Construction Arbitration and Turnkey Projects (2021). https://globalarbitrationreview.com/guide/the-guide-construction-arbitration/fourth-edition/article/construction-arbitration-and-turnkey-projects
30. Encinas, F., Marmolejo-Duarte, C., Sánchez de la Flor, F., Aguirre, C.: Does energy efficiency matter to real estate-consumers? survey evidence on willingness to pay from a cost-optimal analysis in the context of a developing country. Energy Sustain. Dev. **45**, 110–123 (2018). https://doi.org/10.1016/J.ESD.2018.05.008
31. Christopher Gordon, B.M.: Choosing Appropriate Construction Contracting Method
32. Kumar Guha, S.: Turnkey Construction Contracts in Construction and Infrastructure Projects: An Introductory Overview **11**(2) (2020). http://financial-dictionary.thefreedictionary.com/Turnkey+Construction+Contract
33. Olsson, S., Malmqvist, T., Glaumann, M.: Managing sustainability aspects in renovation processes: Interview study and outline of a process model. Sustainability (Switzerland) **7**(6), 6336–6352 (2015). https://doi.org/10.3390/su7066336
34. Rodney, M., Mshali, M., Aldridge, M.D.: Public Infrastructure Financing Using EPC (Engineer-Procure-Construct)/Turnkey Contracts
35. Solimene, F.: Use of FIDIC forms in the oil and gas construction sector and possible amendments to the yellow and silver books. J. World Energy Law Bus. **7**(6), 558–571 (2014). https://doi.org/10.1093/jwelb/jwu035
36. Guha, S.K.: Turnkey construction contracts in construction and infrastructure projects: an introductory overview. Indian J. Law Justice **11**(2), 211–224 (2020). https://www.scopus.com/inward/record.uri?eid=2-s2.0-85169149600&partnerID=40&md5=22e282abd7f9e3386e7b88d449053cf8
37. Greenacre, M.J.: Correspondence analysis. Wiley Interdiscip. Rev. Comput. Stat. **2**(5), 613–619 (2010). https://doi.org/10.1002/wics.114
38. Moschidis, O.E.: A different approach to multiple correspondence analysis (MCA) than that of specific MCA. Mathématiques et Sci. Humaines **186**, 77–88 (2009). https://doi.org/10.4000/msh.11091
39. Abdi, H., Valentin, D.: Multiple Correspondence Analysis. http://www.utd.edu/
40. Ahmed, M., Seraj, R., Islam, S.M.S.: The k-means algorithm: a comprehensive survey and performance evaluation. Electronics (Basel) **9**(8) (2020). https://doi.org/10.3390/electronics9081295
41. Ding, C., He, X.: K-means clustering via principal component analysis. In: Proceedings of the Twenty-First International Conference on Machine Learning, in ICML 2004. New York, NY, USA: Association for Computing Machinery, p. 29 (2004). https://doi.org/10.1145/1015330.1015408

42. Na, S., Xumin, L., Yong, G.: Research on k-means clustering algorithm: an improved k-means clustering algorithm. In: 2010 Third International Symposium on Intelligent Information Technology and Security Informatics, pp. 63–67 (2010).https://doi.org/10.1109/IITSI.2010.74
43. Kanungo, T., Mount, D.M., Netanyahu, N.S., Piatko, C.D., Silverman, R., Wu, A.Y.: An efficient k-means clustering algorithm: analysis and implementation. IEEE Trans. Pattern Anal. Mach. Intell. **24**(7), 881–892 (2002). https://doi.org/10.1109/TPAMI.2002.1017616
44. Wu, J., Xiong, H., Chen, J.: Adapting the right measures for K-Means Clustering. In: Proceedings of the 15th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, in KDD 2009. New York, NY, USA: Association for Computing Machinery, pp. 877–886 (2009). https://doi.org/10.1145/1557019.1557115
45. Morissette, L., Chartier, S.: The k-means clustering technique: General considerations and implementation in Mathematica. Tutor Quant Methods Psychol. **9**(1), 15–24 (2013). https://doi.org/10.20982/tqmp.09.1.p015
46. Chaturvedi, A., Green, P.E., Caroll, J.D.: K-modes Clustering. J. Classif. **18**(1), 35–55 (2001). https://doi.org/10.1007/s00357-001-0004-3
47. Dorman, K.S., Maitra, R.: An efficient k-modes algorithm for clustering categorical datasets. Stat. Anal. Data Min. **15**(1), 83–97 (2022). https://doi.org/10.1002/sam.11546
48. Carreira-Perpiñán, M.A., Wang, W.: The K-modes algorithm for clustering (2013). http://arxiv.org/abs/1304.6478
49. Goyal, M., Aggarwal, S.: A review on K-Mode clustering algorithm. Int. J. Adv. Res. Comput. Sci. **8**(7). https://doi.org/10.26483/ijarcs.v8i7.4301