A DATABASE MODEL FOR CONTAINER USE IN PRODUCING SUSTAINABLE HOUSING: CONSENSUS

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ABSTRACT

There are numerous different techniques and implementation approaches including refunctioning, utilization of building elements appropriate for climate and topography, employment of sustainable materials as well as management of energy and water consumption in the field of sustainable housing production. It is not possible to assess all of these approaches by discussing them in a detailed way within a single scientific study and obtain meaningful results. To this end, a comprehensive literature search has been conducted through usage of The Dart Europe E-Theses portal, Turkish Higher Education Council Presidency Center and the ITU Electronic Database with an eye to limit the work and to determine the issue to be discussed. The data provided as a result of the cited researches have been systematically evaluated and the issue to be discussed has been determined as "description of a data base model that will assist the designer in utilization of containers in sustainable housing production". The design matrix and the classification system of this matrix which will constitute the main spine of the database model are constructed has been built at the first stage with a view to solve the cited issue. The criteria and codes representing household types, container types, combination alternatives of containers in architectural scale, and interior space alternatives suitable for these alternatives are included within this classification system. The conceptual model constituting the output of all the works so far is converted into a relational database model at an objective size by virtue of the Microsoft Access Relational Database Development Platform in the following phase. The benefits to be provided by the developed database model are discussed at the last stage.

Keywords: Database model, design of sustainable housing, re-functioning in the construction industry

INTRODUCTION

Humans have not aimed to dominate the natural environment until the mechanistic view which is accepted as an important break point in the field of ecology within the historical process (Bilgen, 2011). However, developments in industrialization, urbanization and technology have led to human beings' having the idea that humans can change nature as they wish and subsequently humans instead of living harmoniously with the nature, have become the only living creature trying to adapt the nature to itself. The cited understanding has caused unconscious consumption of natural resources thereby leading to the emergence of numerous global issues. The construction sector has an enormous share in this loss of ecology. The energy used in building production and the amount of carbon emitted are in substantial amounts. The construction industry is at the top of the graph according to the graph showing

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the distribution of emissions by sector in the article published by the American Institute of Architecture (AIA, 2016).

Destruction of ecology over time has made the emergence of new understandings and trends compulsory. The human beings have taken the first steps of today's environmentalist movement in the 1950s and 1960s by combining modern analysis techniques and technology. The idea of living with "nature" rather than "against nature" which has emerged during this period has revealed how wrong the path followed in most developed industries and countries of the world has been until then (Mirvis, 1994). The "sustainability" concept, which is one of the most frequently used concepts in our day, was discussed for the first time in the 1970s (Kamara et al., 2006). Sustainability, in general, is defined as the "ability to be permanent". Its meaning in the science of ecology is ensuring the continuity of the diversity and productivity of biological systems (Sustainability, 2016). In other words, sustainability is the ability to continuously process "without exhausting the basic resources of a society, an ecosystem or other similar interactive systems and without adversely affecting the environment" (Peterson and Dorsey, 2000).

Sustainable design, which is a sub-title of the sustainability concept, denotes strategic usage of design in order to meet current and future human requirements without damaging the environment. Sustainable design determines the relationship of products and time to environmental, economic and social systems that surround them and forms measurement systems with a view to prevent non-sustainable effects for the cited systems (Peterson and Dorsey, 2000). Sustainable design in the field of construction industry has gained momentum as from 2000s. Today, green buildings in developed and developing countries are rapidly increasing in the construction sector (Glavanich, 2008). Sustainable building production aims to build a system which furnishes equal and economic opportunities by ensuring that the natural environment and the structures constructed in this framework are in harmony. The cited insight expresses a holistic approach beginning from urban design scale to product design (Yorgancıoğlu, 2004).

It is observed that houses are in the first place in terms of production of building types in the construction sector, which has a big share as regards the damages given to ecology and annual energy consumption (TÜİK, 2010). In other words, construction of houses constitutes a significant part of the damage given to the nature by production of buildings.

Furthermore, inasmuch as the number of houses in the existing building stock is much higher compared to other building types the energy consumption for this type of buildings is much higher. Sure enough, when the data of Turkish Statistical Institute as to Distribution of Net Electricity Energy Consumption by Sectors is examined, it is observed that houses were responsible for 25% of total electricity consumption which was 156,894 GWh in 2009 (TÜİK, 2014). In this context, the subject of this scientific study was defined as "sustainable housing production" inasmuch as houses are both the most commonly produced types of buildings and the houses built cause many ecological problems.

When literature and application resources related in the field of sustainable housing production are explored, it is observed that there are numerous different techniques and implementation approaches including refunctioning, utilization of building elements appropriate for climate and topography, employment of sustainable materials as well as management of energy and water consumption. It is not possible to assess all of these approaches by discussing them in a detailed way within a single scientific study and obtain meaningful results. To this end, the scope of the study has been limited to “utilization of containers in sustainable housing production" which is a sub-title of the refunctioning approach. The reason for discussing this approach is that containers are produced at very high rates, most of them are replaced with new ones in an average of 7 years and in this case hundreds of containers that have not yet completed their usage lifetime are turned into waste (ISBU, 2010). Approximately 80% of the world transport is carried out by containers according to 2008 data (Ebeling, 2009). According to the date published by the World Bank, in 2010, a total of 542.2 million TEU (Twenty-foot Equivalent Unit) containers were transported in the world. In 2014, this figure has increased to 679.2 million TEU in the following years (World Bank, 2014). In in direct proportion to these increases in container production, 2.7% growth was observed in this market between 2011 and 2014. The projected increase between 2014 and 2017 is 5.3% (The Statistics Portal, 2016).

Furthermore, 9 different sustainability criteria have been defined basing on 38 different sources and it has been proved that containers have all of these criteria in the study carried out by Akar et al. (2017), with respect to the advantages of containers in terms of sustainability of their use in housing production. Containers' allowing housing production at very low cost is the most emphasized feature thereof in terms of sustainability in this study. This feature has a special significance for the construction sector in which production costs are very high. Furthermore, it was concluded within the scope of the same study that the containers have substantial additional features in terms of sustainability inasmuch as they are resistant to difficult climate conditions, have longevity, are not easily damaged while being transported from one place to another, are prefabricated and modular and their construction process takes short time and is easy (Akar et al., 2017; Belhaouari and Peschanski, 2008; CIMC Building Systems, 2016; Eko Yapı Dergisi, 2014; Forrest, 2015; Garcia, 2014; Garrido, 2015; Kalkin, 2004; Olivares, 2010; Radwan, 2015; Reynolds and Sural, 2016; Robinson and Swindells, 2012; Taşçı, 2016; Santa Cruz Architect, 2016; Marine in Sight, 2016; Investopedia, 2016; Icontainers, 2016).

PURPOSE AND METHODOLOGY

The results obtained through examination of previously conducted theses and articles on the use of containers in sustainable housing production have been evaluated at the first stage in a systematic way as methodology in line with the subject and scope of the study, which is defined as "the use of containers in sustainable housing production". The Dart Europe E-Theses portal (Dart-Europe, 2017), in which a total of 723,933 theses of 605 universities from 28 European countries are published; T.R. Board of Higher Education Thesis Center (Council of Higher Education, 2017) and Istanbul Technical University's Electronics Database (ITU Electronic Database, 2017) were utilized while the cited literature survey was conducted. The data obtained as a result of this literature survey conducted were evaluated in a systematic manner and the problem to be addressed under study was described as "description of a database model that can help designers in use of containers in sustainable housing production".

The design matrix and the classification system of this matrix which will constitute the main spine of the database model are constructed has been built at the first stage with a view to solve the cited issue. The criteria and codes representing household types, container types, combination alternatives of containers in architectural scale, and interior space alternatives suitable for these alternatives are included within this classification system. The conceptual model constituting the output of all the works so far is converted into a relational database model at an objective size by virtue of the Microsoft Access Relational Database Development Platform in the following phase.

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DESIGN MATRIX AND CREATION OF CLASSIFICATION SYSTEMATIC OF THIS MATRIX

The following steps will be realized primarily with a view to determine by which systematic the design matrix will be structured:

i. Creation of classification systematic of the container types.
ii. Creation of classification systematic of the household types.
iii. Creation of classification systematic of the architectural and interior design alternatives.

Creation of classification systematic of the container types

Containers are waterproof, economical and safe products designed to store products and transport same too far distances (Garrido, 2015). On the other hand container transport is a term used for transportation by means of various container types. Container transport, current examples of which began to be observed since the 1960s, has become the main transport method in the world following the global economic integration (Zhao et al., 2016).

The first successful container was produced and its patent was received by a U.S.A. national named Malcolm McLean in 1956. In 1956, McLean purchased a company named Pan Atlantic Tanker Company and repaired and reorganized the tankers to fit the new container transport concept. McLean made experiences as to methods of loading and unloading vessels and trucks more rapidly and effectively in this company. Designed ISO Containers (ISBU Association, 2017), in the light of experience.

Container production is performed according to standard measurements in our day. The most commonly used container standards are the ones specified by ISO (International Standard Organization). Numerous container producers produce their products according to ISO 6346-coded standards, including container dimensions and building elements. The most commonly utilized container types in line with these standards are as in Table 1.

Table 1. Standard container measurements (Freight Traders, 2016)

	20 ft Container		**40 ft Container**		**40 ft High-Cube Container**		**45 ft High-Cube Container**	
	English	Metric	English	Metric	English	Metric	English	Metric
Length	20’ 0’’	6.096 m	40’ 0’’	12.192 m	40’ 0’’	12.190 m	45’ 0’’	13.716 m
Width	8’ 0’’	2.438 m	8’ 0’’	2.438 m	8’ 0’’	2.438 m	8’ 0’’	2.438 m
Height	8’ 6’’	2.591 m	8’ 6’’	2.591 m	9’ 6’’	2.896 m	9’ 6’’	2.896 m

The container types in Table 1, which are the most commonly used were taken as basis in creation of the classification system for the container types in the design matrix. Accordingly, container type code system is defined as in Table 2.

Table 2. Container Type code system of

Container Types According to Measurements	**Container Type Code No**
20 ft Container	K1
40 ft Container	K2
40 ft High-Cube Container	K3
45 ft High-Cube Container	K4

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Creation of classification systematic of the household types

It was decided to consider the proportional distribution of the number of persons living in a house and the household types that are predominantly encountered when the system of classification of the household types were created. To this end, Family with Statistics 2015 (İstatistiklerle Aile 2015), Number and Rate of Households according to Household types published by the Turkish Statistical Institute were examined. The code system of the household type in line with the obtained data is described as specified in Table 3 (TÜİK, 2015).

Table 3. Code system of the household type

Main Group	Subgroup	Number of Children aged between 0-17	Household Type Code No
One person Household			HHT1
Household composed of nuclear family	Nuclear family composed of only spouses		HHT21
	Nuclear family composed of spouses and children	1	HHT22-1
		2	HHT22-2
		3	HHT22-3
		4	HHT22-4
		5	HHT22-5
		...	...
	Nuclear family composed of parents and children	1	HHT23-1
		2	HHT23-2
		...	...
	Nuclear family composed of father and children	1	HHT24-1
		2	HHT24-2
		...	...
	Nuclear family composed of mother and children	1	HHT25-1
		2	HHT25-2
		...	...
Household composed of extended family	...	...	HHT3
Household without nuclear family	...	...	HHT4

Creation of classification systematic of architectural and interior design alternatives of the containers

It is necessary first and foremost to determine what the minimum indoor requirements are for the household types in Table 3 with an eye to establish the classification system of the architectural and interior design alternatives of the containers. To this end, the Planned Type Zoning Regulation issued by the Ministry of Environment and Urban Planning has been taken into consideration. According to Article 38 of this regulation, which was updated on September 8, 2013, minimum number of rooms and corridors in houses have been determined as follows; 1 living room, 1 bedroom or niche, 1 kitchen or cooking space, 1 bathroom or washing space and 1 toilet. Moreover, according to the same article; in houses with 3 or less than 3 rooms, the toilet and the washing place can be arranged in the same place. There are also some limitations brought for the minimum narrow edges and spaces of these functions. These limitations are as indicated in Table 4 (Ministry of Environment and Urban Planning, 2011).

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Table 4. Minimum room sizes in houses

(Ministry of Environment and Urbanism, 2011)

Space	Narrow edge (m)	Area (m^2)
Living Room	3.00	12.00
Bedroom or Niche	2.40	8.00
kitchen or cooking space	1:50	3.30
Bathroom or washing space	1.20	3.00
Toilet	1.00	1.20
Hall and Corridors	1.10	

The spatial requirements and minimum lengths stated in Table 4 for architectural and interior architectural arrangements have been considered in the database model and the design matrix which constitutes the theoretical part of this model. In this context, the code system of architectural and interior design alternatives which meet the minimum spatial requirements according to the type of households is formed as in Table 5.

Table 5. Design matrix architecture and interior design project alternatives systematic code

Household Type Code No	Container Type Code No According to Capacity	Number of Containers To Be Used	Container Connection Type Code No in Architectural Scale	Interior Design Project Alternative Code No
HHT1	K 1	1	HHT1/K1-1-M1	HHT1/K1-1-M1-ICM 1 HHT1/K1-1-M1-ICM 2 ...
		2	HHT1/K1-2-M1	HHT1/K1-2-M1-ICM 1 HHT1/K1-2-M1-ICM 2 ...
			HHT1/K1-2-M2	HHT1/K1-2-M2-ICM 1 HHT1/K1-2-M2-ICM 2 ...
			HHT1/K1-2-M3	HHT1/K1-2-M3-ICM 1 HHT1/K1-2-M3-ICM 2 ...
			HHT1/K1-2-M4	HHT1/K1-2-M4-ICM 1
...	...	...	...	...

BUILDING OF DATABASE MODEL FOR USE OF CONTAINERS IN SUSTAINABLE HOUSING PRODUCTION

The conceptual model was transformed into a relational database model at an objective size basing on the output of the studies mentioned hereinabove made at conceptual dimension by

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using the Microsoft Access Relational Database Development Platform. The database architecture that includes the tables and the relationships between the information organized in the model in conceptual dimension is seen in the "Relationships" interface in Figure 1.

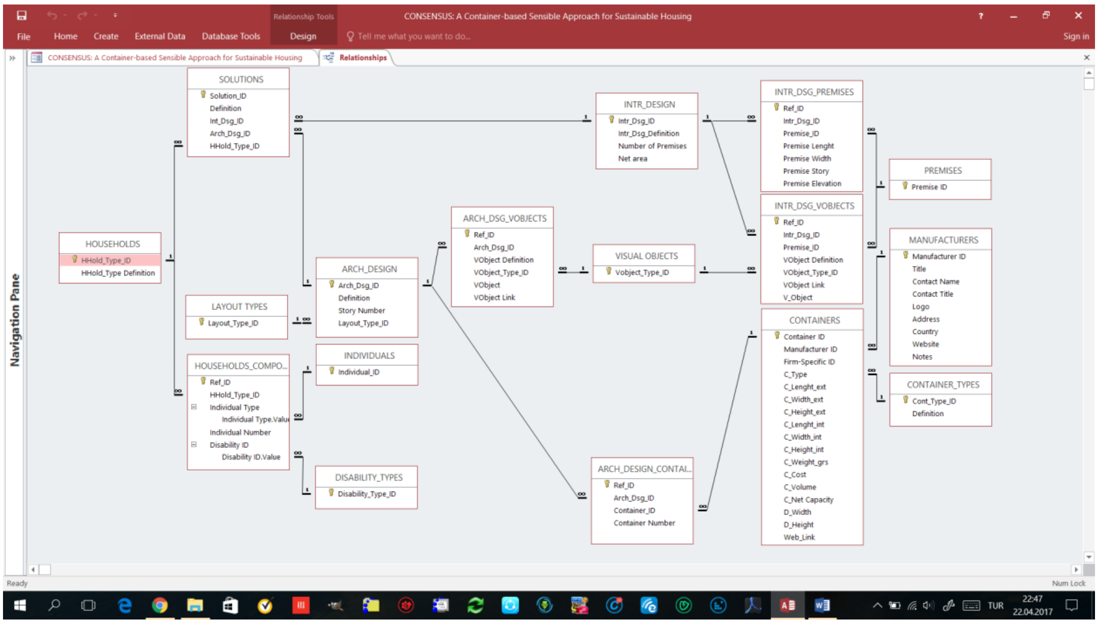

Figure 1. The relationships screen expressing the conceptual structure of the Model: Relation between tables and relational database architecture

In the model of the objective dimension, many objects that make up the model are under the headings which are on the left side of this screen. These objects constitute the scope of the model as Tables, Query Objects (Queries), User Interfaces (Forms) and Command Objects (Macros) (Figure 2).

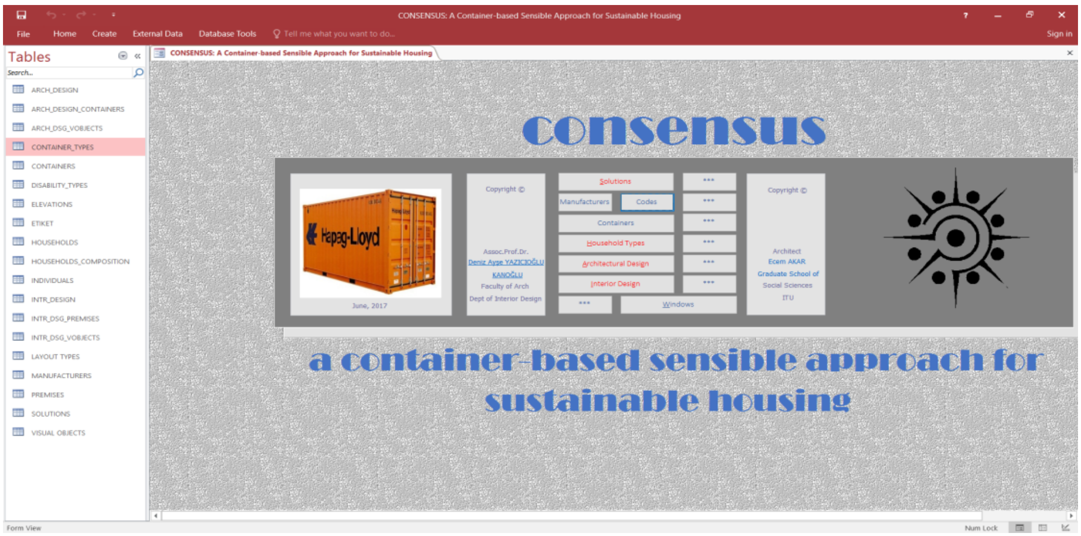

Figure 2. Opening interface of the model in objective size

The model provides accesses to numerous interfaces which are modularized with the initial opening interface. These modules are as follows:

a. Total Design Solutions Module
b. Household Definition Module
c. Architectural Designs Module

d. Interior Designs Module
e. Containers Definition Module
f. Manufacturers Definition Module
g. Codes Definition Module

Total Design Solutions Module

Compositions related to Total Solution Sets which are created by selections made from modules including architectural design and interior architectural design solutions and the sets defined in Households module are defined in this module.

Different filters can be made by defining the desired criteria (household type, architectural solution set, internal architecture solution set) to the boxes opened in the "Total design solution sets" which can be accessed from the opening interface and the results of these filters can be reported (Figure 3).

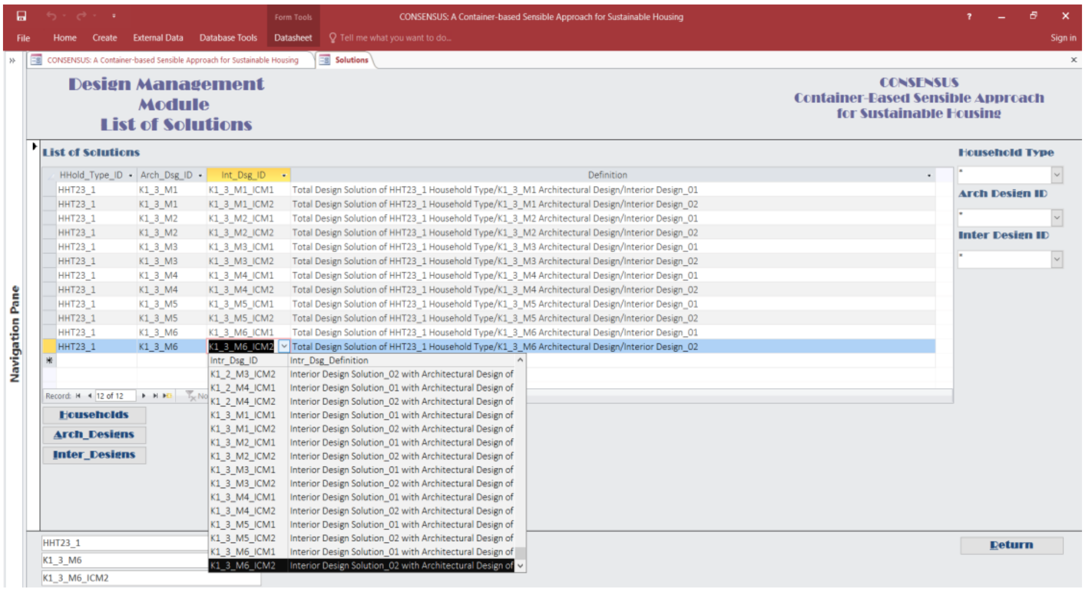

Figure 3. Imaging and filtering interface for solutions sets related to design

The household information of the selected design solution set can be displayed with details in the next interface reached by the Household button (Figure 4). And in the interface accessed by the household composition button in this interface, the total number of individuals as well as the types of individuals can be displayed in the selected household type (Figure 5).

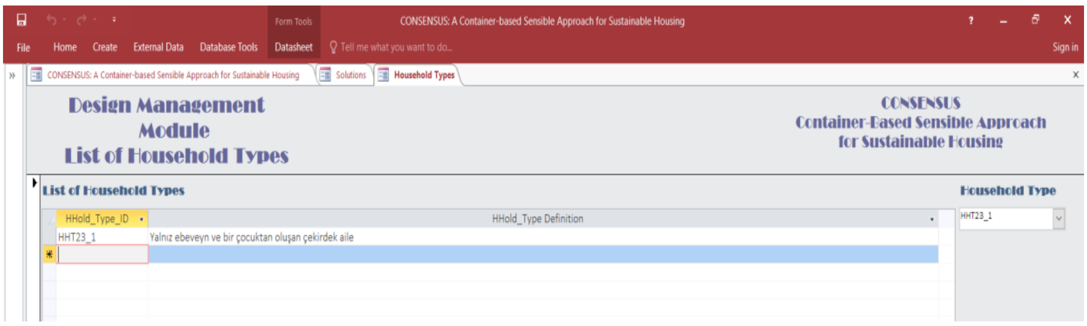

Figure 4. Identification and display interface for types of households in the selected solution related to design

Filtering can be made through the parameters opened in the right-hand drop-down boxes seen in the interface in Figure 5. From this interface, the individual types in the coding module and lists of the obstacle types that the individuals have can be accessed while their interfaces can be given in the coding module.

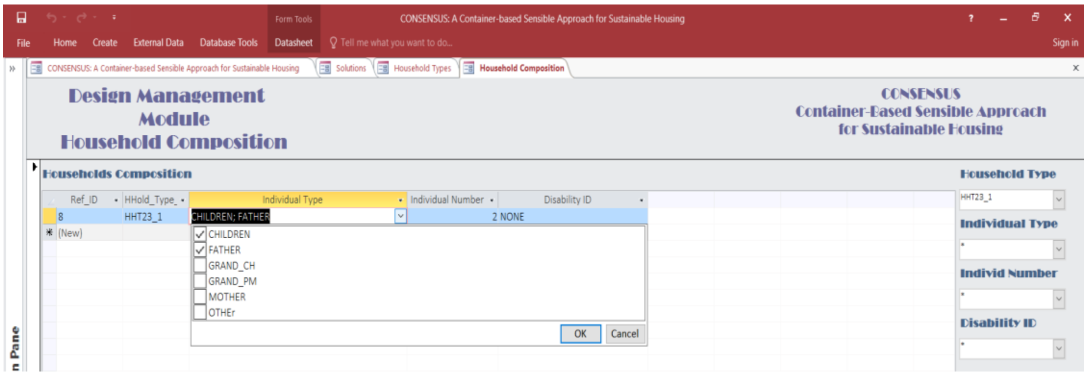

Figure 5. Display interface for type of household individuals within the selected design solution set and composition in the context of individual disability

It is possible to access to the container layout compositions in the architectural design included in the selected design solution also through the interface of design solutions; layout type can be filtered depending on the number of floors parameters in this interface. Additionally from this interface, it is also possible to access visual objects related to container types and architectural design alternatives in the architectural solution by virtue of the buttons on the left (Figure 6-Figure 8).

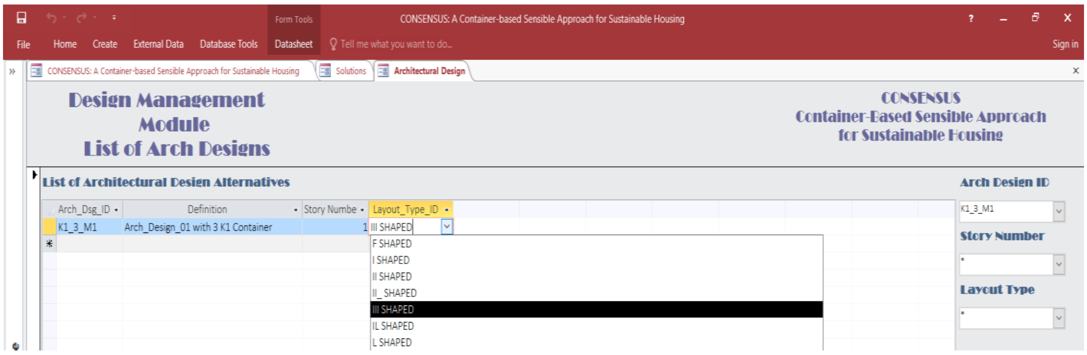

Figure 6. Identification and display interface for architectural design solutions in the selected solution set related to design

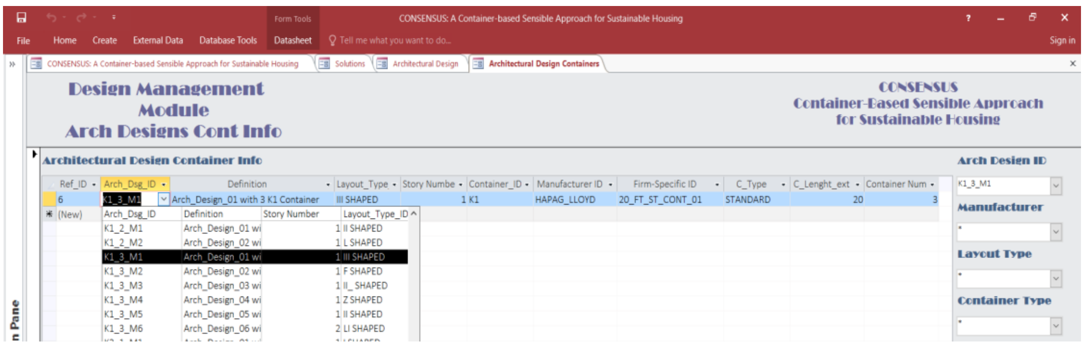

Figure 7. Display interface for container information for architectural design solutions in the selected solution set related to design

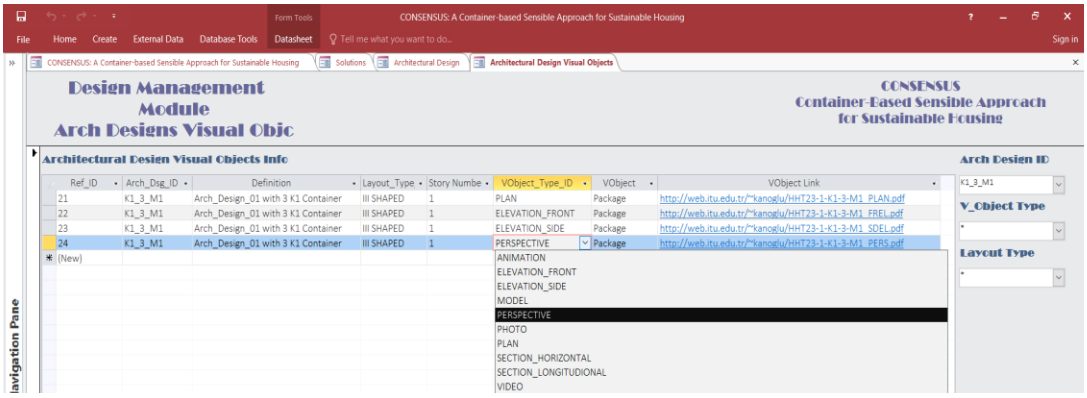

Figure 8. Display interface for visual objects including architectural design schemes for architectural design solutions in the selected solution set related to design

Access to the composition of interior space created for the selected architectural design alternative is also possible through the interface of design solutions; the list can be filtered based on the net area and number of space parameters in this interface; access to visual objects related to interior information and interior design solutions in each interior architecture solution can be provided by the buttons on the left (Figure 9-Figure 11).

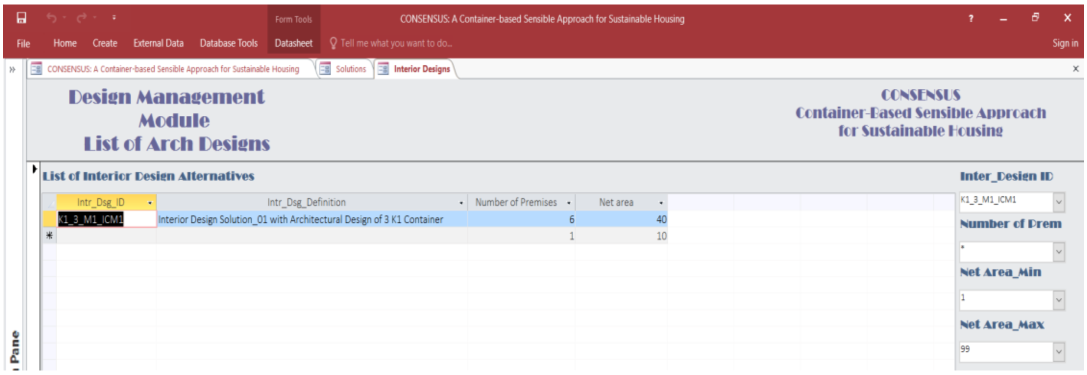

Figure 9. Display interface for interior design alternative for architectural design solutions in the selected solution set related to design

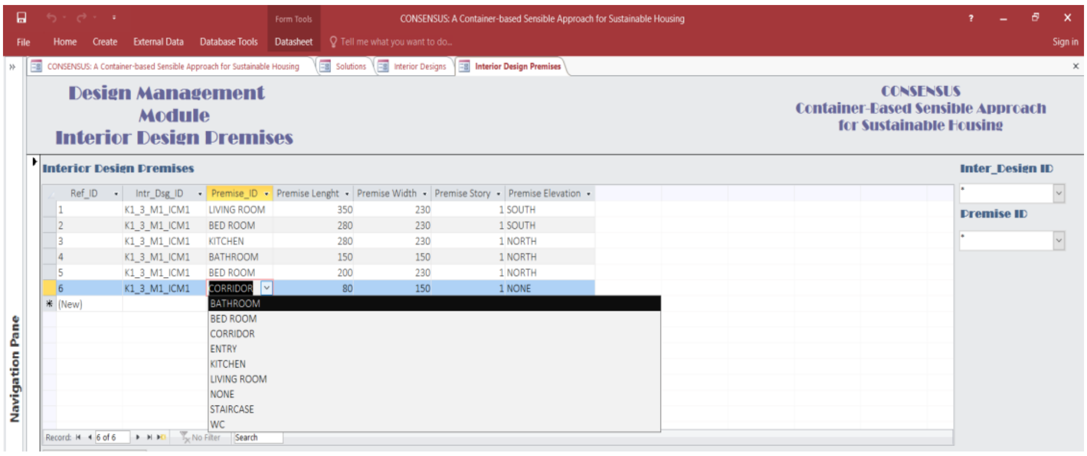

Figure 10. Display interface for space information of interior design alternative for architectural design solutions in the selected solution set related to design

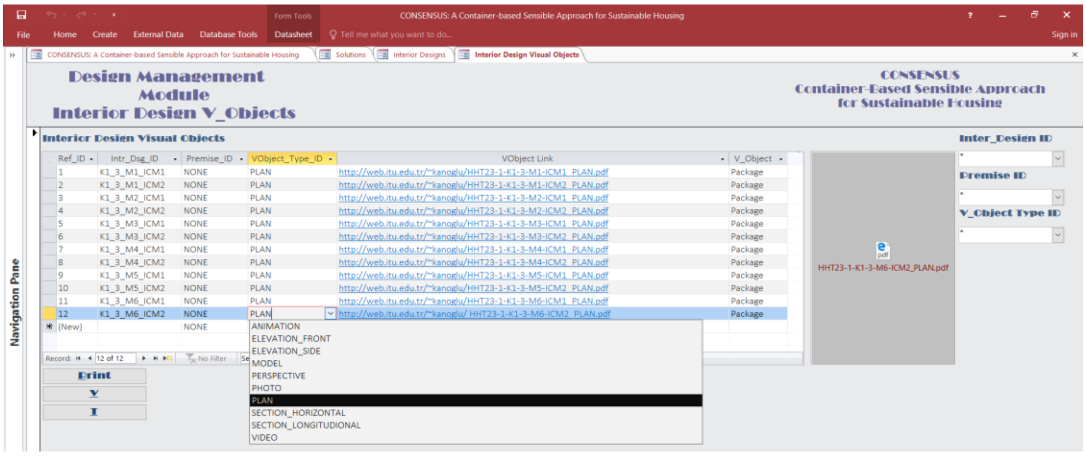

Figure 11. Display interface for visual objects for architectural design solutions in the selected solution set related to design.

Household Definition Module

This module includes the interfaces for defining the types and sizes of families that design solution models will address. First, the types of households are formed in the relevant interface to include codes and household definitions (Figure 12).

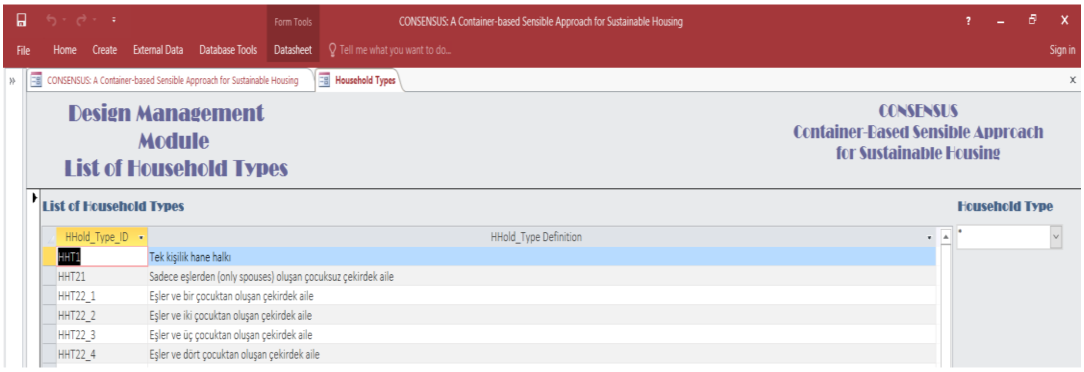

Figure 12. Interface for display and identification of household types

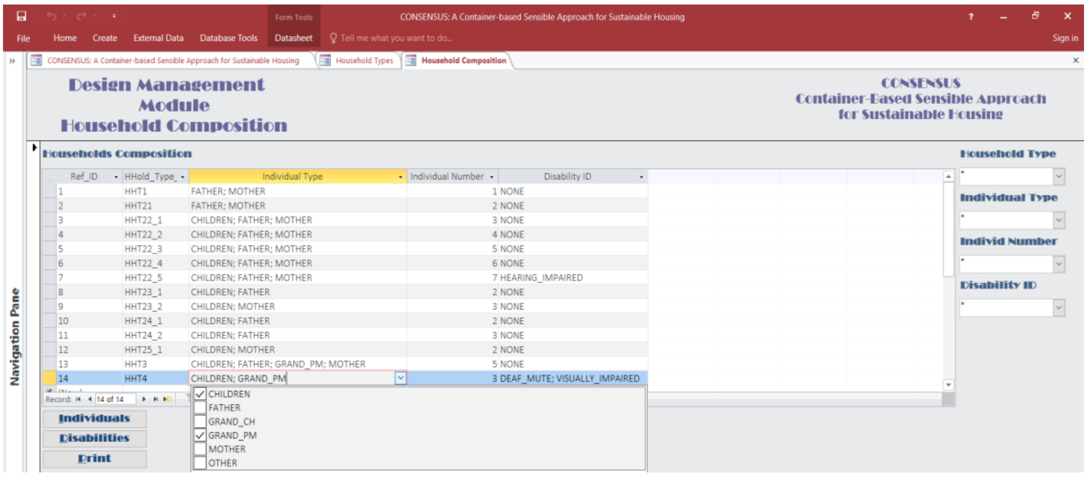

Figure 13. Interface for display and identification of composition consisting of types number, and disability status of household individuals

In the interface in Figure 13, it is possible to define each selected household type within the context of individuals and disabilities these individuals may have.

Architectural Designs Module

In this module, container layout schemes and the floor number are defined in addition to the design codes and definitions of architectural solution sets containing the container layout schemes created through the selected container types (Figure 14).

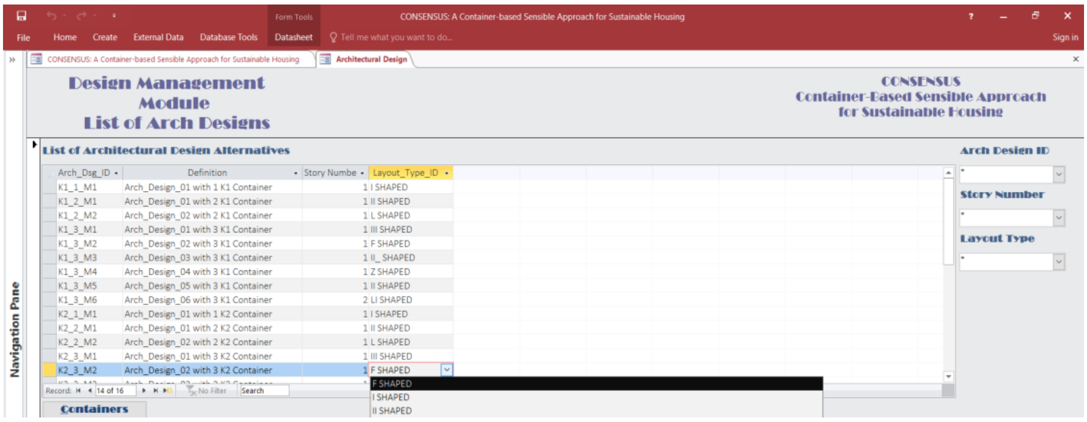

Figure 14. Interface for display and identification of container compositions related to architectural solution types

It is possible to access to the container interface enable access which contains information about container types in the selected architectural solution scheme as well as the interface of the visual objects that include the architectural resolution schemes from this interface by virtue of the buttons on the left (Figure 15-Figure 16).

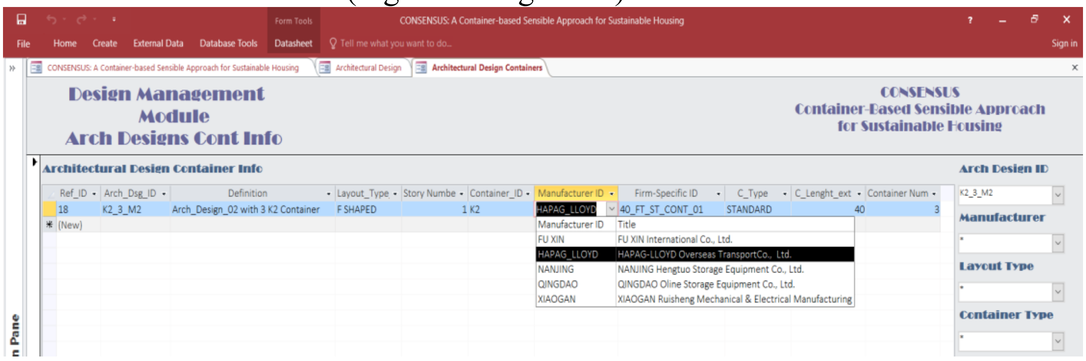

Figure 15. Identification and display interface for detailed information of container regarding the selected architectural solution type (container type, container manufacturer, number of containers used in this type of architectural solution)

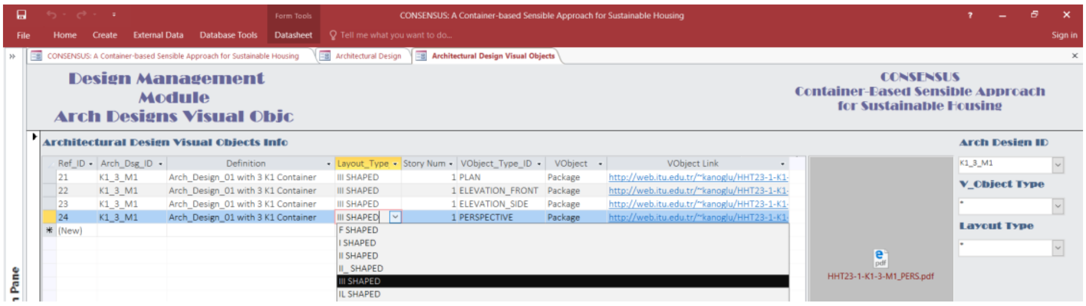

Figure 16. Identification and display interface for visual object information of container regarding the selected architectural solution type

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Interior Architecture Designs Module

In this module, interior architectural solution sets, including space organizations and interior furnishings created from selected container types, are defined in addition to the design codes and definitions, as well as the number of rooms and net space data (Figure 17).

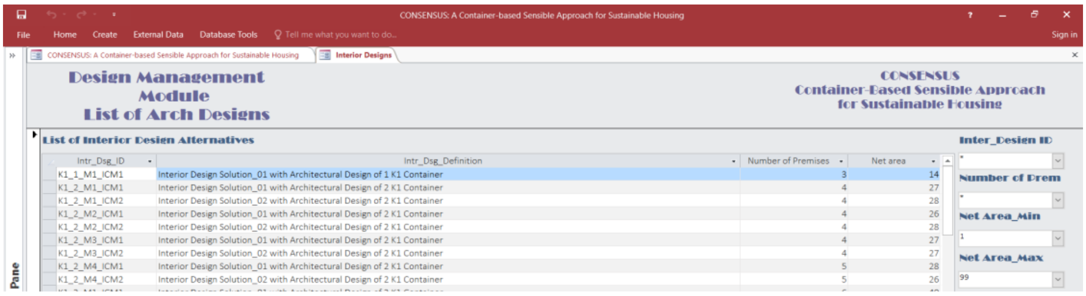

Figure 17. Identification and display interface for alternative space organization and regarding internal architecture solutions types

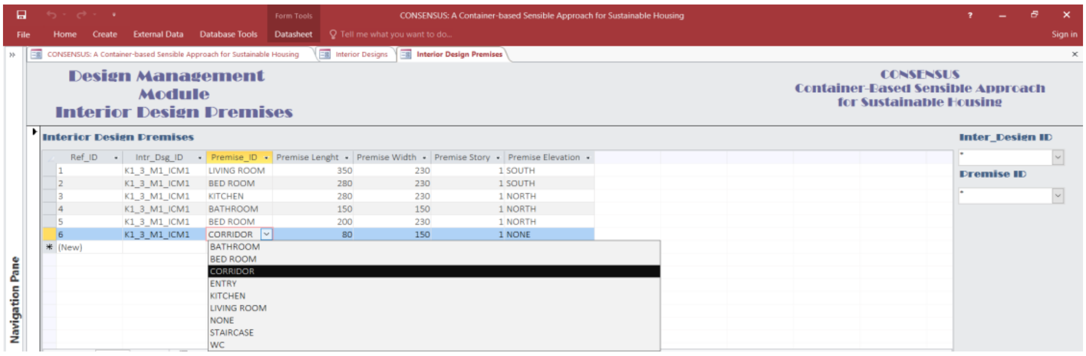

Figure 18. Identification and display interface for type and size of space of interior space organizations regarding internal architecture solutions types

The spaces and measures included in the selected interior architecture solution are defined and displayed at the interface in Figure 18 while the interior visual objects are defined and displayed at the interface in Figure 19.

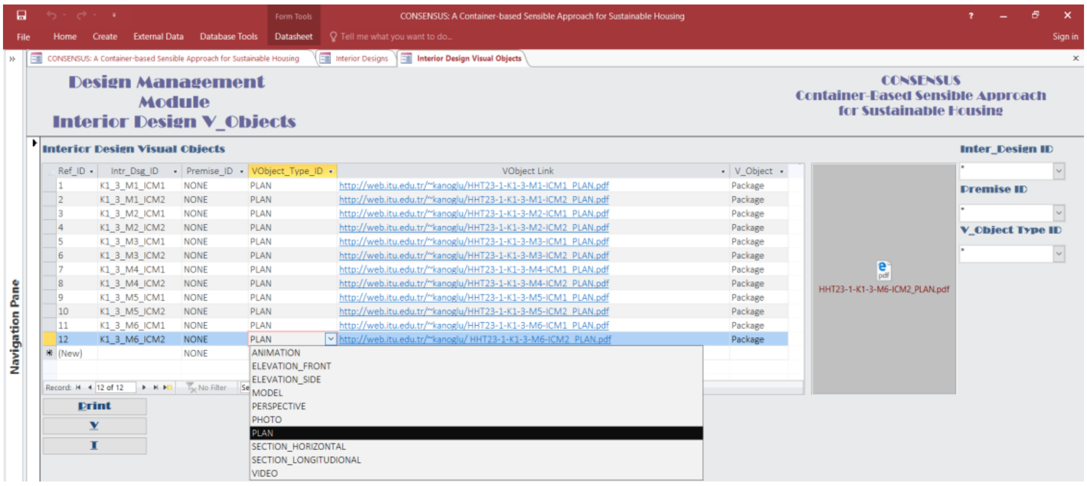

Figure 19. Identification and display interface for visual objects as to space organization alternatives regarding internal architecture solutions types

Container Identification Module

The containers produced by various manufacturers and used in the construction of architectural solution alternatives are defined in terms of their physical features in this module. In the four different tabs in the interface in Figure 20, the following data are defined:

- Dimensional measurements of the container,
- Door measurements of the container,
- Cost and other information of the container,
- Web page link of the related company where the container image is also included

The data contained in these tabs can be filtered depending on the container type and the manufacturer's parameters.

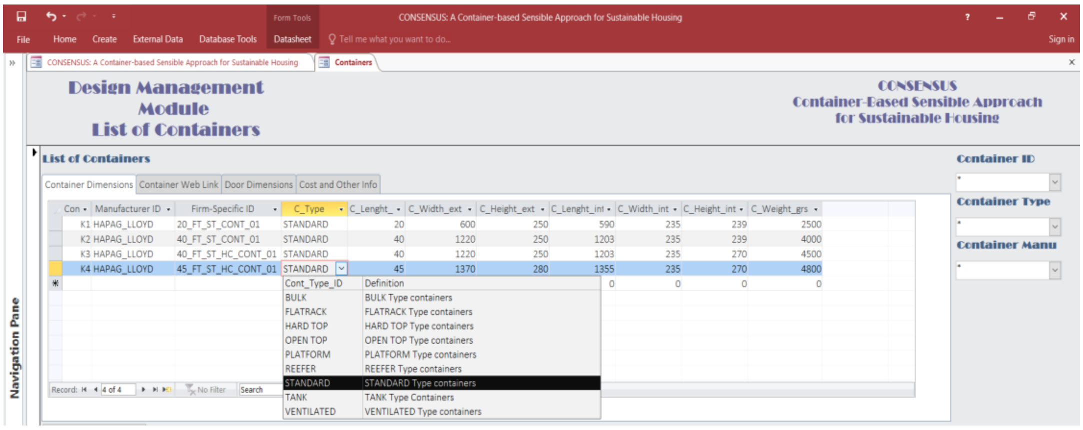

Figure 20. Identification and display interface for container alternatives

Manufacturer Identification Module

Access information regarding the firms which produce containers globally can be identified and displayed in this module (Figure 21).

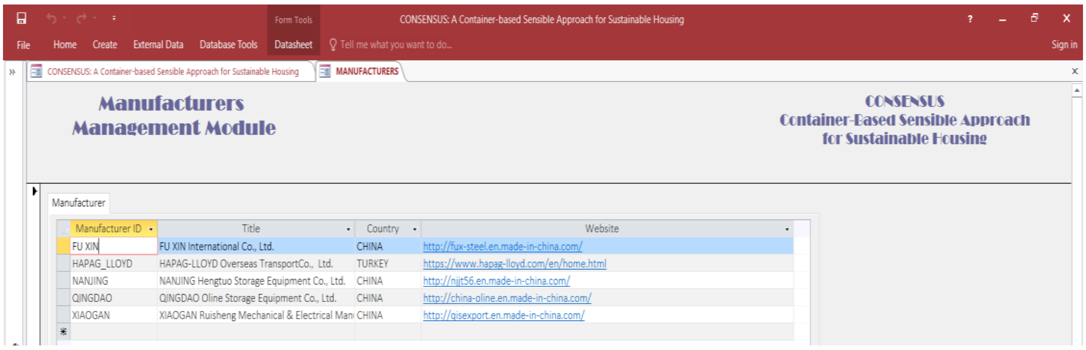

Figure 21. Identification and display interface for manufacturer companies

Coding Module

The coding systematic related to the entities required in the various modules can be diagrams are defined in the following tabs placed in a single interface in this module:

- Description tab for container type codes,
- Description tab for individual disabilities,
- Description tab for individual type codes,
- Description tab for container layout codes,
- Description tab for location type codes,

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- Description tab for visual object type codes

All the data displayed in the above interfaces can be prepared as a report in the print environment through the model. For example, the print report as to total solution sets is given in Figure 22.

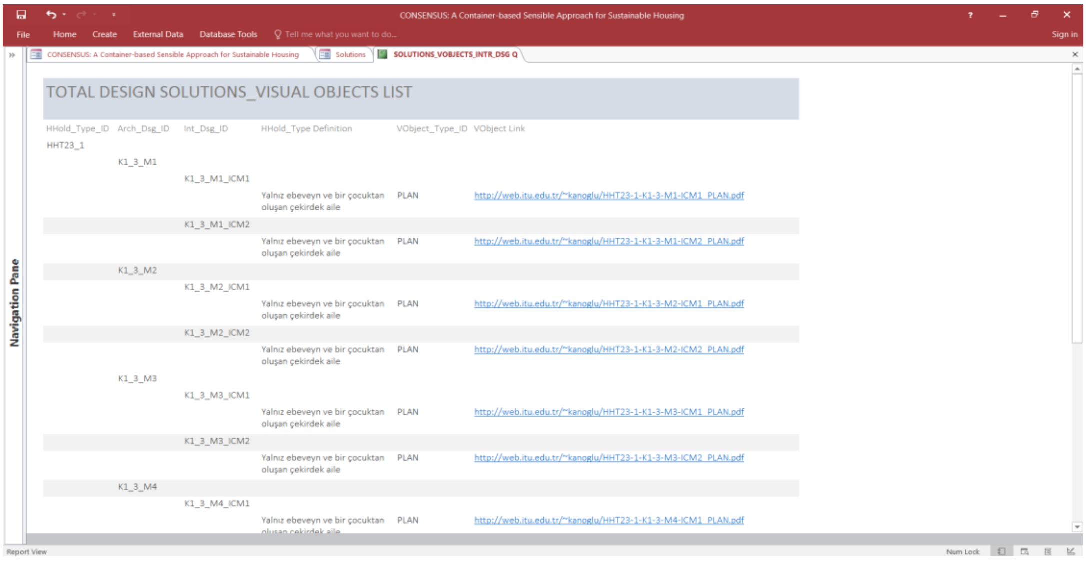

Figure 22. Example of Print reports; set of total design solutions

RESULTS AND DISCUSSION

A database model which can be turned into a clear source for architects, interior architects, civil engineers and companies using containers in housing production in the sector was developed within the scope of the study. This data base model is collectively diversifiable and can offer numerous design alternatives and access to container manufacturers for professionals by virtue of architectural and interior architectural solutions produced from the combination of different types of containers. Professionals are able to quickly access many alternate databases in accordance with the specified criteria, and see spatial limitations of these alternatives and interior architecture solution alternatives particularly in the case of time constrained productions such as container cities to be set up in disaster areas.

Architectural and interior architectural solutions can be detailed and diversified according to these criteria by adding different criteria such as location, social and cultural necessities and user ages to this data model which is clearly designed to be developed for different purposes. In this way, it is possible to have access to a large number of solutions accesses that respond personally to the needs of users, in other words, personalized solutions, thanks to this database model. Moreover, a variety of data such as detail drawings, material information and furniture alternatives to be used, can be integrated into the database model, which can be extended from the city and district planning scale to the product design scale. Furthermore, information such as cost and time planning, contractor alternatives can be added to the database model for each design alternative. In addition to all these, the database model proposed within the thesis study will constitute an example for conduction of similar studies for structures with different functions such as office, education and health care structures.

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