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Smart Furniture as a Component of a Smart City - Definition Based on Key Technologies Specification

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ABSTRACT There are dozens of definitions of Smart Furniture with meanings that vary greatly. Thus, the aim of the article is to provide an exact definition of the phrase “Smart Furniture” based on a literature and patent analysis. Why a definition? Because by providing a good definition, we have a statement that captures the meaning, the use, the function and the essence of a term or a concept and allows the impacts on stakeholders to be described. A literature search was undertaken between 20 July 2018 and 31 August 2018, and the databases searched included SCOPUS, Web of Science, and IEEE Xplore (1998 to 2017), which were searched by keywords that included the phrase “Smart Furniture”. Patent searching was performed in the ESPACENET database, where 226 articles from scientific databases and 737 patent applications were examined. After the application of strict criteria, we obtained 23 articles and six patents containing meaningful definitions of Smart Furniture. Based on the results, Smart Furniture should to be defined as designed, networked furniture that is equipped with an intelligent system or is controller operated with the user’s data and energy sources. Smart Furniture needs to have the ability to communicate and anticipate a user’s needs using a plurality of sensors and actuators inside the user’s environment, resulting in user-adapted furniture. The research results and discussion presented in this article are based on the recognition that Smart Furniture research has great policymaking, technological, and economy potential, while contributing to the user’s wellbeing and quality of life (QoL). This paper indicates that the collaboration between ICT and social-economic research has to be initiated and consolidated in sustainable way or in an environment that satisfies the needs expressed by the user.

INDEX TERMS Smart Furniture, furniture industry, wireless sensor networks, third age, sustainability, market research

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I. INTRODUCTION

The Internet of Things (IoT) [1], [2] and Industry 4.0 [3], [4] provide many opportunities for the use of new technologies. The increasing availability of high-quality data collected and transmitted in real time through inexpensive, ubiquitous hardware and connections will undoubtedly lead to scientific, technical, and commercial innovation [5]. Recently, several researchers proposed diverse systems, management processes, and technologies for managing these data. Some frequently used terms are IoT, intelligent control, home automation, energy management, wearable devices, and smart technologies [6]–[10]. All these elements can also be part of the Smart Cities phenomenon. Papadopoulos et al. 2015 [11] and Tokuda 2003 [12] understand a Smart City to be an intelligence-enabled area connected in a sustainable way that integrates all its infrastructure and services into one compact complex, where intelligent devices are used for monitoring and control to ensure sustainability and efficiency.

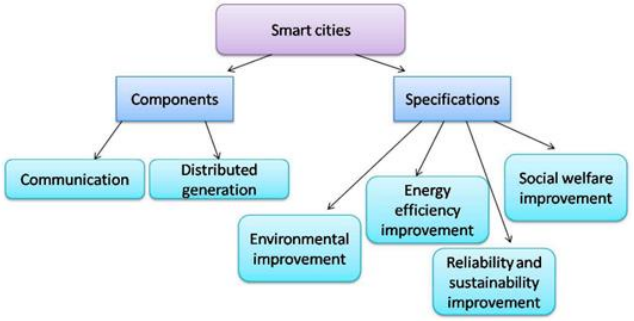

FIGURE 1: The key aspects of Smart Cities [11]

Cities/urban spaces cannot be examined in isolation from the context in which they are embedded, be it at the micro, mezzo or macro level [13].

Smart Cities mainly engage in environmental and public services (Fig. 1), but the main building block is represented as a Smart Home, [14] as the Internet of Things (IoT) is now becoming a reality.

Smart Cities are presently becoming a reality for an increasing number of people living in modern cities around the world, where various aspects of the modern city are being automated and integrated with information and communication technologies (ICT) to achieve an improved quality of life (QoL) for the residents [15].

There are 32 different Smart City definitions that can be considered relevant [16]. The term Smart City also covers the following six socioeconomic fields:

- governance
- economics
- environment
- mobility
- people
- living

The research community, however, currently uses an extended number of fields, and 13 fields can certainly be distinguished according to the type of application [17]. The authors stated that smart devices and smart environments are resource-type areas that are required in every type of smart service system. Smart {homes, energy, building transportation, logistics, farming and gardening, security, health care and management, hospitality, and education} are the business system-type areas. Smart City and government systems are defined as an umbrella system for the public administration-type areas [17]. All the aforementioned parts of Smart Cities have been described many times, and their definitions are homogenous. “Smart Furniture”, however, is not easily defined. Furniture is one of the main components of our homes, and the role of Smart Furniture is to convert a legacy non-smart space into a smart space where location-based context-aware services, service roaming, personalized services and connectivity to the Internet are ubiquitously provided, as Professor Tokuda mentions[18].

According to the research compiled by Chun in 2015 [19], the global Smart Furniture industry is expected to grow in areas such as North America and the Asian Pacific region. The industry is governed by technological developments, a growing elderly population, and the demand for automation and improved spaces. According to Wallbaum et al. [20], the total value of the global Smart Furniture industry was estimated to be USD 111.7 million in 2016, with a projected growth of 22% between 2017 and 2025. The concept of Smart Furniture stems from the IoT, smart things, or intelligent things [21], [22]. According to Li & Wang in 2009 [23], smart things are described as devices that are controlled through control processors and the Internet. The Sonos home music system, Philips colour-changing bulbs, and a revolving Italian Murphy bed and Murphy sofa are examples of devices that are controlled by information technology tools. With the development of such products, concepts such as intelligent furniture and Smart Furniture have been developed. Since the inception of Internet and information technology tools, automated devices such as smart TVs, smart washing machines, smart tables, smart beds, and smart refrigerators have been designed and are already in use [20]–[22].

All of the aforementioned areas are used in the public sector, companies, and households. As these innovations are widely used, and there is also a problem with the exact definitions of these concepts, owing to the differences in meanings. For example, a Smart Home can be described as a house that uses various types of information technology to monitor the environment, control electric appliances, and communicate with the outer world. The Smart Home is a complex type of technology; at the same time, it continues to develop. A Smart Home automation system has been developed to automatically accomplish activities performed frequently in daily life to create a more comfortable and convenient environment [24].

In addition to the well-defined Smart City or Smart Home, another area is the Smart Space Design [25], which allows an

optimal design of a user's space according to the user's needs, as well as human computer interaction satisfaction and fulfilment of other aspects of life.

Smart Furniture can be seen as belonging under the umbrella of the Smart Home and Smart City, with an overlap with the furniture sector and the IoT. All of these terms are also connected with the Industry 4.0 phenomenon, where maximum benefits are achieved through the synergies that result in ambient intelligence while creating the ubiquitous home [26]–[28]. Poslad 2009 [29] defined and describes ubiquitous computing as an umbrella term for the following three different directions: smart devices, smart environments, and smart interactions. He states, "the concept smart simply means that the entity is active, digital, networked, can operate to some extent autonomously, is reconfigurable, and has local control of the resources it needs such as energy, data storage".

The phrase Smart Furniture is used in various ways regarding connections and meanings in the design of furniture, as it needs to be smart through a connection to a wall-mounted electric socket with an Internet connection. In 2003, Ito, Iwaya et al. [30] stated, "Smart Furniture is a platform for systems to realize Smart Hot-spots. By simply placing the Smart Furniture, we can turn legacy spaces into Smart Hotspots. Smart Furniture needs to be equipped with a networked computer, I/O devices and sensors. Coordination with existing network infrastructure or user's devices are also required." Vaida, Gherman et al., in 2014 [31], provided the following definition: "Smart Furniture is the furniture which brings added value, functionality, comfort and elegance to fit every personalized requirement issued by the user". Braun, Majewski et al., in 2016 [32], provided the following definition: "Smart Furniture is able to detect the presence, posture or even physiological parameters of its occupants". According to Technavio's Smart Furniture market research report [33], "Smart furniture is powered by technological advances such as network connectivity via Bluetooth or Wi-Fi and others, which helps users enhance their furniture beyond its basic analogue functions. Smart furniture helps consumers in browsing the Internet for news feeds, weather forecast updates, listen to music. It also offers wireless charging slots for smartphones and has features like distance operation and others". Additionally, the Philips Smart Furniture project explores the ability of furniture to change its appearance by using a transparent futuristic tablet that allows users to manipulate the furniture within a room through augmented reality [34]. Several previous studies have reviewed the Smart Furniture concept and the current trends [31].

However, the given Smart Furniture definitions do not attempt to introduce such an approach as an integral part of Smart Cities and QoL research, despite the fact that Smart Cities and the support of QoL belong to key contemporary phenomena in developed countries.

Furthermore, they have access limitations, such as their availability is only through research database searches and patent applications are rarely taken into account, although the number of patent applications has grown rapidly in the last few years. The keywords are not connected with the term's definitions based on a study of the full texts of scientific articles.

Therefore, the aim of the paper is to provide an exact meaning of the phrase "Smart Furniture" based on a literature and patent analysis in relation to potential users.

A correct definition of "Smart Furniture" is crucial in several areas, where the definition can be seen as a benefit for the following:

1. Users of furniture products: everybody, especially, those vulnerable groups, such as older adults and disabled individuals.
2. Industry: Traditional industries, such as furniture companies, as they would be able to be more competitive and access other market segments, and ITC companies, as their products would have more applications.
3. Society in general: Considering that those vulnerable groups would be more benefitted since these technologies would allow them to live more independently at home and to continue being efficient at work for longer. Smart Furniture would contribute to the future sustainability of pensions, health care and long-care system.

The audience and the beneficiaries can be seen mainly as practitioners, industry members (furniture producers, ICT professionals, electronics manufacturers, architects, designers, construction firms and their relevant professional associations), the general public (especially the elderly, their caregivers, families, friends and any other interested platforms), education institutions, scientists, industry members working in the field, professional organizations, ministries, policy makers (European, national, and regional policy makers involved in health, sustainability, social wellbeing, etc.) and other government organizations, academics, public institutions and communities.

The furniture sector plays an incredibly important role in meeting the challenges that demographic change brings. Not only it is a critical part of the European economy, it can also significantly improve the accessibility of the built environment for older adults by improving its product offering with integrated ICT solutions, ergonomic designs, and more completely taking into account the health and safety needs of the users.

These reasons led the authors of this article to write a review that provides a current scientific and research analysis in the field of Smart Home furniture and to solve the following related problems:

(1) A definition of Smart Furniture does not exist, unlike for a Smart City or a Smart Home, which have been explicitly defined. After examining of a number of relevant database articles, we concluded that there are actually a number of definitions for Smart Furniture [11][11], [31],

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[35], [36]. These definitions are often very misleading, with meanings related only to the furniture's design. Characteristics based on functionality, in the sense of an active networked digital element, are often not present within the Smart Home concept.

(2) The customer, for example, may feel that each Smart Furniture product will be able to link to other Smart Home features, as he/she may be misled by results indicating a different purpose. In the scientific community, disunity leads to different interpretations and the creation of inconsistent concepts that deviate from the original idea.

(3) At the beginning of the Industry 4.0 era [37], sensors and actuators were envisioned as unsightly boxes mounted on apartment walls. Currently, we have the ability to buy Smart Home Control devices that connect via our Smart Phones and control a variety of home elements. A refrigerator or washing machine may even already be part of the IoT [38]. Therefore, Smart Home advancements are ongoing, and the next logical step is to incorporate electronic devices into furniture with new added value for the user. The Smart Furniture specifications involve the combination of electronics with designer furniture [33].

(4) The last few years (2015-2018) were significant regarding the increase in patent activity around the world for Smart Furniture, as shown in the figure (Fig. 2). This phenomenon requires investigation using a Systematic Literature Analysis to provide more relevant information and knowledge regarding the current meaning and exact definition of Smart Furniture.

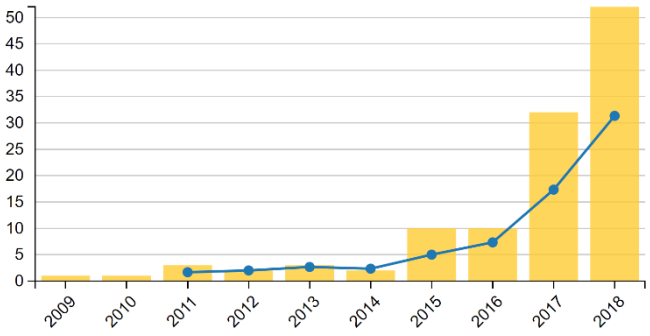


FIGURE 2. Patent activity trend for the topic "Smart Furniture" within the ESPACENET database, which includes 114 published patent applications worldwide.

Solving the abovementioned problems leads to answers to questions such as the following: Why does this investigation focus on the definition and specification of Smart Furniture and under what circumstances is this concept misused? How should the gap in the specific domain knowledge in the field of Smart Furniture be bridged?

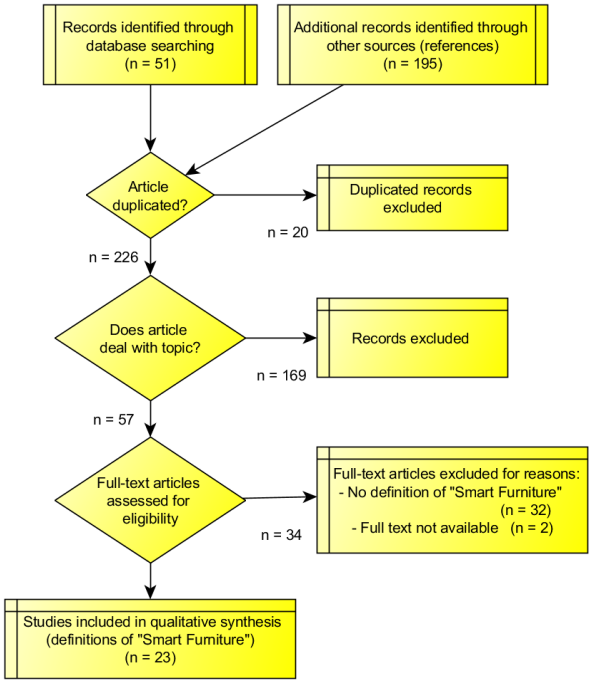
II. METHODOLOGY

Search strategy

Our search of scientific and research sources focused on scientific sources as well as on intellectual property (IP) patents.

The scoping review was performed for research papers based on PRISMA guidelines [39]. The literature search was undertaken between 20 July 2018 and 31 August 2018, to identify published peer-reviewed articles and conference papers in English. The databases searched included SCOPUS, Web of Science, and IEEE Xplore (the first source from 1998 until the last in 2017). The keywords included the exact phrase "Smart Furniture". The keywords were used in the database and journal searches. The references of the retrieved articles were assessed for relevant articles that our searches may have missed; thus, several other results were added.

Patent searching was performed in the ESPACENET database, because it covers most all of the local IP offices' databases. The search strategy was divided into two ways of searching, as we focused on the trends of the Smart Furniture sector as the first result and searched for proper definitions of "Smart Furniture". Because of the importance of the Smart Furniture sector, a search for the words "Smart" AND "Furniture" in the title or abstract of the patent was used. The seven oldest patents, i.e., from 1899 to 1995, were removed from the search results based on a quick screening of these patents. To find proper definitions of "Smart Furniture", a search for the exact phrase was performed, where the range of years was the same as for the scoping review (1998–2017). The general procedure is described in Fig. 3.



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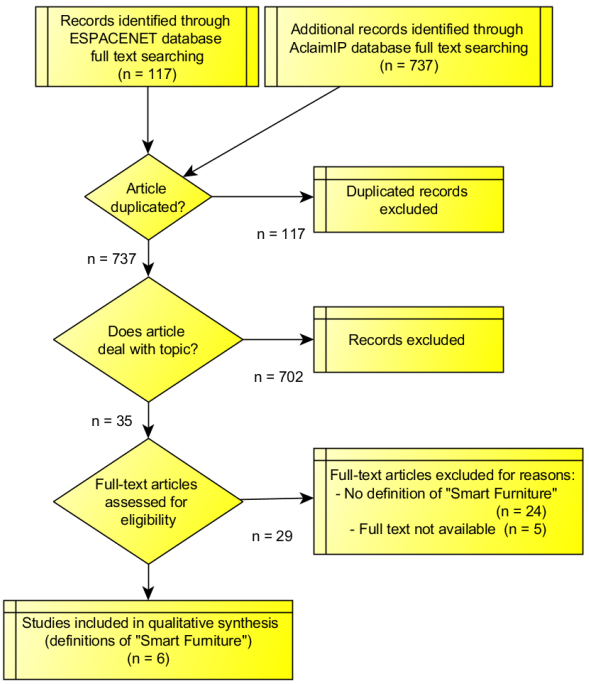

FIGURE 3. Diagrammatic representation of the study-selection flow for the systematic literature review (SLR) (upper) and systematic patent review (SPR) (lower).

Analysis

The analysis was performed based on a combination of reviews, original articles, conference papers, (afterwards referred to as articles), and patent applications (as patents). Articles and patents were included in the selection and review based on the following inclusion criteria.

- Ordinary results in a 20-year window: 1998–2017.
- Reviewed full texts of articles or patents in English.
- The aim of this research is to analyse the potential uses of different types of Smart Furniture, innovation research, or perceptions of future potential users.
- The output of the articles included both descriptions of specific Smart Furniture solutions and an analysis of the state of the solution and an effort to define the concept of Smart Furniture.
- Articles where is possible to describe some of the following variables are associated with aim of the paper, i.e., to provide a definition with respect to binding and target groups of users: device types, actuator types, processing type and user identification (personal identification and use-cases).

The results that were gradually eliminated from the analysis were done so for the following reasons:

- Written in a language other than English.
- Results that were focused only on the description of the concrete technological / technical solutions of the selected Smart Furniture elements; even in the theoretical background, there was no meanings given for these concepts.
- Results that were closely related (only included a description of the technical solution) to the technological solution.
- Results addressing the area of sustainability of development and the impacts of these elements on the environment.
- Results in which "Smart Furniture" was only mentioned but not further defined.

III. RESULTS

A. SMART FURNITURE – TERM SPECIFICATION, SPECIFICATION, AND CHARACTERISTICS IN THE LITERATURE

The most active main authors for the topic “Smart Furniture” in the ISI WOK database are Tokuda H. (6x), Brooks J.O. (4x), Papadopoulos I. (4x), and Braun A. (4x). The authors focus on how to define the term and how to specify the properties of Smart Furniture. Table 2 contains 12 frequently used keywords from the area of IT; the keyword for the design area is the only one used 16 times. Table 1 shows that the frequency of occurrence is based on 23 studies that were screened based on the exclusion and inclusion criteria (Fig. 2).

TABLE I
FREQUENCY AND TOP WORDS FOR ANALYSED LITERATURE.

Word	Occurrences	Frequency	Rank
smart	77	5.9%	1
furniture	68	5.2%	2
user(s)	22	1.5%	3
space / environment	21	1.4%	4
control(ler) / automated	18	1.4%	5
data / information	18	1.3%	6
system(s)	17	1.3%	7
sensor(s)	16	1.3%	8
design	16	1.2%	9
Intelligent(ce)	16	1.1%	10
according	14	1.1%	11
technology	12	0.9%	12
things / objects	12	0.9%	13
wireless networks	10	0.4%	14
table(s)	10	0.9%	15
functionality	9	0.4%	16
devices	9	0.4%	17
computer	8	0.4%	18
Internet	8	0.4%	19
interaction	5	0.2%	20

Based on these keywords, the authors propose a definition of Smart Furniture and, to a greater extent, describe the characteristics of Smart Furniture.

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Term specification for Smart Furniture

In 2004, Tokuda [18] stated that Smart Furniture is a product that has the ability to change the residential space into an intelligent space through the use of information technology. Additionally, in 2004, Tokuda [18] further defined the concept of Smart Furniture as a platform that uses smart hot-spots, which use sensors, computing devices, and computer networking facilities to transform the private space into an intelligent space. On the other hand, in 2015, Panda & Goel [40] asserted that Smart Furniture is based on informational technology devices, such as sensors and computing networks, that aim at providing comfort to the users within the human environment. The core concept of Smart Furniture is that objects can be equipped with information technology capabilities, which can allow them to communicate with the devices through the use of sensors and computer networks through the Internet [19], [34], [36], [41]. Consequently, this allows the integration of real-life data with the virtual environment's information. According to Collins English Dictionary, "Furniture consists of large objects such as tables, chairs, or beds that are used in a room for sitting or lying on or for putting things on or in". Oxford Dictionaries defines furniture as "The movable articles that are used to make a room or building suitable for living or working in, such as tables, chairs, or desks". The meaning of this word is well known, as there is no difference between the different meanings. The Oxford dictionary provides different meanings for the adjective, verb, and noun. Collins English Dictionary provides the definition of Smart Home as "a dwelling equipped with systems and appliances that can be operated remotely using a computer or mobile phone", but for the simple word smart, it provides ten examples of its usage and many synonyms. As asserted by Li & Wang [23], intelligent furniture consists of conventional furniture and information technology, which emphasizes creating a "dialogue between the human being and the furniture". The literature suggests that the term Smart Furniture is a relatively new term [20]–[22], [42]. However, a previous work by Maskeliunas & Raudonis (2013) [43] also reveals that the term intelligent furniture is used to describe automated furniture, which has the ability to collect data through sensors, which transmit it to the controller [43]. The controller is responsible for processing the information according to the encoded procedures to automate the furniture's control process. Another term used in the literature is smart things, which is used to describe objects with sensing, processing, and networking capabilities and are autonomous in nature [21]. Tang, He & Wu in 2013 [42] asserts that smart things have the ability to connect the virtual and real environments for automation and monitoring; they operate from networks through the use of web services. Technologies such as sensors, Bluetooth technology, ambient intelligence, Web 3.0, Wi-Fi, and ZigBee are used to connect the physical and virtual environment [42].

Specification of Smart Furniture

In 2014, Vaida et al. [31] provided 14 Smart Furniture characteristics; based on a survey, they determined that five of them can be considered more valuable than the others, with an overall importance of almost 50%. The most important criteria for customers are design, functionality, safety in use, customization, and structural design [44]. In 2014, Probst et al. [45] stated that functional furniture aims at improving its users comfort through the use of intelligent systems. In 2018, Pan et al. [46] stated that Smart Furniture is based on an intelligent system that aims at increasing the value, comfort, and functionality of the furniture for the user. As asserted by Panda & Goel in 2015 [40], Smart Furniture is characterized by its ability to execute several applications at the same time, their ability to support customization and mobility, and the capability to connect the remote service and operate as per user input. According to the work of Papadopoulos, Karagouni & Trigkas in 2016 [11], the characteristics of Smart Furniture vary according to individual needs and requirements. These are discussed as follows.

(1) Style: Smart Furniture design is accommodated according to individual requirements. It can be novel, traditional, or extravagant [11].
(2) Space: Space has been identified as an important factor that affects the design of the Smart Furniture. Space requirements can include ample open space, some space, or restricted space [41].
(3) Functionality: According to the work of Papadopoulos et al. in 2015 [38], Smart Furniture design is highly dependent on functionality. Smart Furniture can be designed to act as a space saver or to have a multipurpose function.

Smart Furniture has several capabilities. In 2013, Maskeliunas & Raudonis [43] asserted that smart furniture is designed for user detection and establishing social connections between users. Chun, in 2015 [19], stated that Smart Furniture's main capabilities are to retrieve user data and analyse the user network's topology, settings, and characteristics. According to Jianping & Haibin's work in 2012 [34], the Smart Furniture's capabilities are characterized by their ability to collect user data, coordinate the data to the control unit, and provide the output based on the data collected. The Smart Furniture architecture requires hardware and software platforms that must connect the physical environment, the virtual environment, and the wireless network [36]. The architecture needs to support customization, perception, and physical output based on the artefact type; therefore, it needs an adaptable configuration system, control unit, and support for sensor modalities, based on user requirements [34], [41]. In 2004, Tokuda et al. [18] stated that the Smart Furniture design was based on previous designs proposed by Tokuda in 2003 and 2004 [12], [30], which proposed a Smart Furniture model. The proposed design was based on human-computer interaction through the use of hardware and software technologies. The term smart hot-spot services was proposed

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by researchers, which acted as a computer network to offer functionality to the end-user. The hardware requirements of the Smart Furniture include a controller, actuator, sensor, and hardware circuit. The software requirements serve as the main operating system that is responsible for collecting data [14, p. 2], [18]. The intelligent behaviour of the Smart Furniture is used by the consumers through user interaction with the computer interface. Through the interface circuit, the control commands are transmitted to all parts of the furniture. The application programme is responsible for the collection of data, which can achieved either through speech recognition, touch-screen technology, or somatosensory technology [36]. The data are then moved to the sensor. The sensor is responsible for creating awareness in the physical environment, which requires the communication of objects to create the virtual presence that make it a part of the network. The communication requirements essential to establishing a connection include local transmission support of information to the objects that are nearby and quick response to network changes without the need for user interaction [23]. Consequently, the objects need to be highly efficient, compact, and lightweight. Once the data are retrieved by the sensor, they are processed and analysed by the cloud technology database.

B. SMART FURNITURE IN PATENT DATABASES

The first patent containing the words Smart Furniture is from 1998, when inventor W.D. Gilbert of the Powerdesk company mentioned that a card can be a smart card and the computer and card-reader can be integrated into an item of furniture, e.g., a desk or writing table [47]. The next invention by Doughty [48] described intelligent furniture equipped with a set of sensors and an intelligent processor. The Smart Furniture patenting activity trend for these years was increasing. The first patent containing the exact phrase "Smart Furniture" in the body is a patent application from Nokia Corporation from 30 April 2002, granted 27 March 2007 [49]. Unfortunately, this patent only used "Smart Furniture" as one of the many references in the text, while the application theme is not connected to the searched topic. The first relevant patent application in history dealing with the phrase "Smart Furniture" is the "RFID smart office chair" by Hagale et al., from the IBM Corporation in an application on 5 August 2004 [50], granted on 15 November 2005. This patent application contains the phrase "Smart Furniture" 71 times (4 times in the Abstract, 40 times in the Claims, and 27 times in the Description). This patent is also the most cited patent (71 times by other patents) for all patents covered by a search in the ESPACENET database for the phrase "Smart Furniture". The total distribution by country is shown in Table II.

TABLE II
APPLICANT COUNTRIES IN THE PATENT DATABASES ESPACENET AND ACCLAIMIP FOR THE PHRASE SMART FURNITURE ("SF").

Country (applicant)	ESPACENET "SF" in topic	AcclaimIP "SF" in topic	ESPACENET "SF" anywhere	AcclaimIP "SF" anywhere
United States	6	6	60	95
China	17	61	24	819
World	4	4	10	22
Taiwan	1	1	1	13
Korea, Republic of	2	3	2	8
Romania			7	6
EU			6	5
India				4
Canada			3	2
Japan	1	1	1	1
Mexico	1	1	1	1
United Kingdom			1	1
Australia			1	
Total	32	77	117	977

There are seven companies around the world whose name contains "Smart Furniture", and they have 20 active patent applications. These patents do not contain information related to the definition of "Smart Furniture", but they are also taken into account due to the company name.

The most used keywords that were included in the patent databases for Smart Furniture are specified in Table III.

TABLE III
FREQUENCY AND TOP WORDS FOR PATENTS.

Word	Occurrences	Frequency	Rank
Control (ler) (ing) / monitoring / processing / Automatic (ally)	139	3.9%	1
Smart	122	3.8%	2
Furniture	93	3.2%	3
plate / table / lamp / bed / light / equipment / television	90	2.5%	4
Device(s) / terminal / machine	83	2.2%	5
module	58	2%	6
data / information	51	1.4%	7
user / body	50	1.0%	8
Remote / mobile / central	43	0.9%	9
Home / indoor	35	0.7%	10
Connected (ion) (ing)	32	0.6%	11
wireless network	32	0.6%	12
arranged	30	0.5%	13
system	27	0.5%	14
Surface / material	27	0.5%	15
signal	16	0.3%	16
installed	13	0.3%	17
recognition	12	0.2%	18
connector / sensors	12	0.2%	19
Electric / power	12	0.2%	20

Based on the available options from the analytical solutions presented in patents, we selected the two most relevant circle graphs based on the most frequently used nouns in the results

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from the ESPACENET database (Fig. 4) and the most frequently used assignees from AcclaimIP (Fig. 4). The most used nouns highlighted several parameters that define Smart Furniture, as follows.

- several types of furniture
- current state of furniture
- hardware solution which is embedded in Smart Furniture
- identification of user by plurality of parameters
- use of a personal profile by secure communication

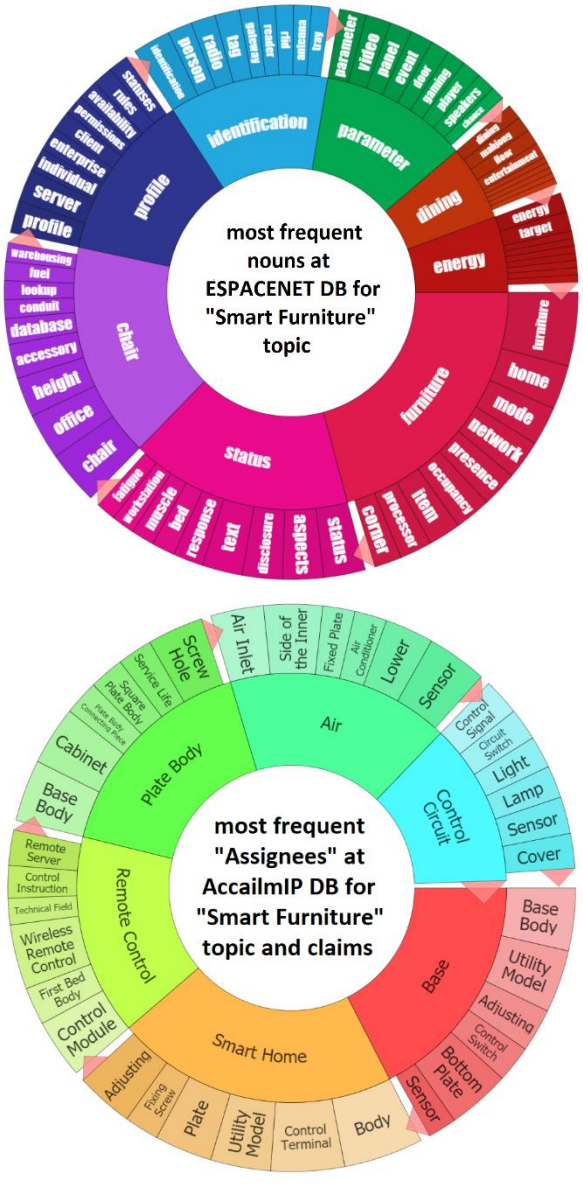

FIGURE 4. Most frequent "nouns" and "Assignees" found in the patent applications in the ESPACENET (upper) and AcclaimIP databases (lower) for the phrase "Smart Furniture" in the topic (117 patents and 217 patents, respectively).

A summary of selected patent applications performed by Hagale [50] resulted in the most frequent nouns and assignees (Fig. 4). It is evident from the most used words that Smart Furniture must be designed as furniture with some connection to user data for suitable adjustment of Smart Furniture items to fit to a user's needs.

Term specification for Smart Furniture based on patent databases

Inventors [50] also stated that "Smart Furniture can include a reader for the identification device to identify a person using the piece of furniture. The Smart Furniture may also include storage in which settings profiles of users are stored. The Smart Furniture may then receive a profile that matches the person using the furniture and set adjustable features according to the profile. Settings profiles may be uploaded to or downloaded from a remote storage using a wireless communication interface, such as a wireless network interface". Such a network is described as an Internet connection to provide even worldwide connections as well as propagation to any other Smart Furniture capable of communicating and applying these settings. The last-named ability is very important because it confirms the need to reconfigure the functionality of the Smart Furniture to fit the user's needs or preferences. As the last parameter, the priority of each Smart Furniture item is declared to be equipped. The next interesting patent application dealing with some definition of Smart Furniture in connection with a Smart Home router was from China in 2016 [51]. The inventors provided a description of "Smart Furniture" that is almost up to date. The invention discloses "a Smart Home router which is capable of achieving self-adaptation of the IoT" [51]. They also state that "different Smart Furniture devices are controlled through various apps installed in the router in advance to be connected into the network in a wired or wireless mode". They are also controlled by users using a "connection according to the protocol and encryption authenticated hardware in intelligent furniture", which indicates the security level for this home equipment. Smart Furniture, according to this patent application, is also part of the IoT, as they declare that "Various kinds of Smart Furniture can be connected into the IoT through a cloud tool or a desktop end and mobile terminal APPs, and the user does not need to conduct complex configuration; meanwhile, due to the fact that an encryption and decryption hardware chip is arranged internally, the home network is safer and not likely to be attacked" [51]. The emphasis given to the security level of this invention is significant, as they plan to use a HW crypto solution.

The use of Smart Furniture for one of the original purposes defined by Tokuda [12] is declared by another patent application, "Wireless network distribution method applicable to smart furniture device" by Chuan et al. [52], where the inventors stated that "The invention belongs to the field of smart furniture, and provides a wireless network distribution method applicable to a smart furniture device".

The next invention, named "Smart Furniture" by Yang, 2017, is based on the use of standard home equipment, such as a bed, sofa, or chair, with detection sensors to measure the health data

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of the user [53]. They described Smart Furniture as "a furniture article designed for being used by a user and a smart system which includes a detection module built-in with the furniture article for detecting health data of the user when the furniture article is used". They suggest the use of a plurality of sensors, which need to be "located at a user supporting surface of the furniture article for collecting health data of the user" [53]. The measured user health data are then analysed to ensure that the user is using the article of furniture properly [53].

C. SPECIFICATION OF TYPES AND USES OF SMART FURNITURE IN THE LITERATURE AND PATENT DATABASES

Wide-ranging studies have discussed the design and possible uses of Smart Furniture to improve living standards, promote user safety, promote energy efficiency, and save operational and maintenance costs [11][11], [36], [40], [41], [46].

As previously mentioned, the first patent with the phrase "Smart Furniture" was filed by Hagale et al. of the IBM Corporation in August 2004 [50]. They used several possible descriptions of what Smart Furniture is and what role it can play. They first stated the following: "Smart furniture is provided that automatically adjusts to a person's preferences based on an identification of the person. A person may be equipped with an identification device, such as a radio frequency identification device" [50]. This definition is still valid and up to date. Smart Furniture needs to adjust to user preferences once the user is identified by the device. At that time, a radio frequency identification device (RFID) [54] was one of the common possible options; now, any personal mobile smart device, such as a Smartphone, can easily be used for this purpose; however, they cannot use them exclusively thanks to their start-of-market penetration beginning in 2005. In 2012, Bleda et al. [35] asserted that the use of Smart Furniture aided by sensors and ambience intelligence systems offers several benefits. Ambience intelligence systems with sensors can be integrated into the furniture and, because they are small and lightweight, the user cannot feel them. The potential use of ambience technology allows a ubiquitous computing environment. Another potential advantage of this technology is that it can help elderly people execute daily operations [20], [22]. In 2003, Ito et al. [30] suggested that users can use Smart Furniture as a gateway to the cyber world, as a service operator, or as a service receiver. As asserted by Tokuda in 2004 [14, p. 2], mirror-type Smart Furniture could be used "as a personal reminder or a controller for various appliances at home". In 2011, Brooks et al. [41] conducted a study to present the concept of Smart Furniture. Their study emphasizes using nightstands based on intelligent systems. The nightstands had embedded sensors and smart features and were primarily used by senior citizens. The researchers focused primarily on the design and function of the nightstand. The capabilities of the nightstands included the ability to move up and down and the interactions were voice-activated [41]. The nightstand design was based on a contemporary design with additional storage facilities. Furthermore, the researchers proposed another Assistive Robotic Table [41]. Its capabilities included smart storage and a smart table surface. The smart table surface could fold and extend through automated control. Furthermore, the modified robotic nightstand had an automated headboard with interactive functionality [41].

In countries such as China and Japan, Smart Furniture is being used in commercial buildings and public spaces to improve user comfort, improve functionality, and save space. The use of smart office furniture in commercial offices includes office controlling systems and intelligent file cabinet systems [22]. In healthcare, the Smart Furniture pieces developed by researchers include a smart medicine cabinet that has the ability to identify expired medication, automated smart tables whose height can be adjusted based on user requirements to relieve exhaustion [20]. For residential units, the types of Smart Furniture are wide ranging. Tables with built-in light systems have been developed. These tables have the ability to detect the luminosity based on user's requirement and can provide the required amount of light within a short time to reduce visual exhaustion. Furthermore, these tables have light sensation controls, on/off lighting capabilities, and time-switching capabilities [42]. Magnetic induction installations in the tables offer temperature regulation, which ensures a constant room temperature.

Study furniture for children has been designed with smart capabilities. According to Pan et al. in 2018 [46], study-type furniture has been designed to adjust the study-table height according to the user's requirements. A project by Maskeliunas & Raudonis in 2013 [43] developed a human–computer interaction sofa with the following three technologies: gaze tracking, hand touch, and speech recognition. The proposed design demonstrates the efficiency of the three technologies combined. An intelligent sofa has been designed with welcoming speech capabilities [19]. Another recently developed Smart Furniture design is smart bookcases that signal the user if the load of books on it exceeds its limit. A smart chest has been designed with disinfection and dehumidification functionalities. The design of Smart Furniture is not limited to living room and bedroom furniture. According to Papadopoulos, Karagouni & Trigkas [11], smart kitchen cabinets and stations have been designed to regulate the temperature, the fire intensity of the cooking range, and recreational facilities, such as watching videos and listening to music.

Key Technologies of Smart Furniture

Since the year 2003, when the phrase "Smart Furniture" was initially coined by Ito et al. [30], a number of technologies have been described within this domain. A summary table (Table IV) was prepared to provide a list of technologies used in the Smart Furniture phenomenon as well as the advancements in recent years in the given domain.

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In 2004, Tokuda et al. [18] proposed a Smart Furniture design with Internet accessibility through the use of a smart hot-spot that has access to the Internet. The design principle of this Smart Furniture based on a smart hotspot was to improve the user's functionality and comfort. The researchers used computer networks, sensors, and devices that allowed the user to use the Smart Furniture to access a virtual environment by acting as service operators. Based on the proposed system, they designed a cylindrical lamp and a mirror-type Smart Furniture product that contained an iPAQ and Linux operating system. The cylindrical lamp had six LED lights that operated alternatively. The mirror-type Smart Furniture product had an iPAQ with a wireless LAN and a Linux operating system.

In 2012, Bleda et al. [35] reviewed the existing wireless communication standards in the automation and control field that were suitable for a larger network of communication nodes. Among the main standards were X10, LonWorks, and KNX, and the ZigBee, a standard of IEEE 802.15.4, was found to be the most suitable standard for Smart Furniture [35]. They also reviewed low power microcontrollers, which are needed to provide sensor nodes with low power consumption. The main microcontrollers are MICA/MizaZ, Tyndall, Telos/TelosB, and Movital/Jennic. The microcontrollers resolve the problem of the quality loss of the communication link when a sensor network is deployed in the furniture of a house with respect to signals at 2.4 Ghz, which are used in ZigBee, for example. Therefore, the higher power consumption that results in decreased battery life is also a common problem. The materials tested, starting with those that introduce lower power losses (plastics, PVC, bamboo) and ending with materials with greater power losses (cardboard, aluminium and steel), have been reviewed [35].

The design of Smart Furniture was also investigated by Tang, He & Wu in 2013 [42]. The researchers emphasize the benefits of using wireless networking for a Smart Home's control system [42]. The key features of the system included motor driven windows and an on/off control system for the gas tank. There is an emerging trend of using new technologies for sensor nodes and end point HW controllers as well as using the new standards in wireless communication covering the well-established WiFi and RFID or ZigBee standards. The new standards also covered Bleda et al. in 2012 [35] and their use of the Internet of Things (IoT), Web of Things (WoT) and Wireless Sensor Networks (WSNs) as the umbrella system.

Vaida et al. 2014 [31] contributed to the Smart Furniture topic with a study covering 30 participants, where they determined that 5 of the most valuable Smart Furniture characteristics of the 14 available are as follows:

(1) Design
(2) Functionality
(3) Safety in Use
(4) Customization
(5) Structural Design

The design of the Smart Furniture is its most important feature, as every user needs to use the furniture for its primary purpose. The second and fourth characteristics, "Functionality" and "Customization", however, require more specific information, which characterizes the ability of the user to satisfy his/her declared and nondeclared needs. The user's needs should be transferred to the Smart Furniture by HW equipment, which allows the detection of identified or anonymous users. A number of possibilities are available to enable a user identification system, as shown in Table IV.

Identification is mostly performed by the user's smart device, a RFID in earlier years, or by a proximity sensor if anonymous users are allowed. Using a camera for identification is also a new trend because, with the increasing processing power of node controllers, it is possible to detect the face of a user for identification.

Thus, the definition of Smart Furniture is now more focused on furniture with interfaces for entering commands rather than furniture with interfaces that actively transform the furniture.

With the goal of providing a correct "Smart Furniture" definition, the key technologies have to be studied in detail [55], [56]. The key technologies needed to exploit Smart Furniture can be summarized as a network of physically connected devices, such as vehicles or home appliances, that enable these 'things' to connect and exchange data. This connectivity, in turn, creates never-before-seen opportunities to converge the physical and the digital – via data analytics – to improve efficiency (both in the public and private sectors), drive economic benefits and improve livelihoods.

The most used and, therefore, the key technology for Smart Furniture, as described by research articles and patents (Table IV), includes any type of ambient (embedded) sensor (9 studies). The second most used technology includes any type of actuator, where visualization is most often used, but the trend is towards using a microprocessor unit with a high-level programming language (7 studies). Some studies (7 studies) include Wireless Network communication, which is needed to connect all types of Smart Furniture with the nodes and main stations, such as Raspberry, Arduino or a microprocessor unit in the case of a final commercial product. Smart Furniture nodes interconnected by any type of wireless technology require a processing unit, as presented in the literature six times. The processing speed of the unit depends on the purpose of the Smart Furniture, and the current trend is to use an embedded PC type tablet.

Another interesting phenomenon is the presence of Ambient Assisted Living (AAL) [57] or monitoring (4 studies) due to the connection of the Smart Furniture to a Smart Home system with some level of (artificial) intelligence. Studies have also covered the ethical issues regarding monitoring (either with active or passive (PIR sensors)) or personal identification (6 studies).

TABLE IV

Smart Furniture characteristics according to sensor/device types, actuator types, processing types, personal identification and use-cases

		Sensor/device types			Actuator types		Processing types		Person detection and recognition			Use-cases	
Authors	**Title of study**	**Wearables/ phones/ tablets**	**Ambient sensors (embedded)**	**Wireless Network**	**Wi-Fi Access Point**	**Electrical / mechanical**	**Processing on local computer or ad hoc**	**Cloud based processing / online service / server**	**Identification by device/tag**	**Identification by ambient recognition**	**Anonymous person identification**	**Monitoring**	**Experimental study**
Ito et al. in 2003 [30]	Smart furniture: improvising ubiquitous hot-spot environment	X	touch, voice	RFID, Wi-Fi, IrDA	X	X, display, speaker, light, LCD, lamp	X		X	X			
Tokuda in 2004 [14]	Sf2: Smart furniture for creating ubiquitous applications	X	touch	RFID, Wi-Fi, IrDA	X	X, display, speaker, light, LCD, lamp			X	X		X	
Hagale et al. 2004 [50]	RFID smart office chair	X	X	RFID, Wi-Fi	X	X		X	X				
Brooks et al. in 2011 [41]	Toward a “Smart” Nightstand Prototype: An Examination of Nightstand Table Contents and Preferences		X, voice			X				X		AL, rehabilitation	28 participants (adult patients), 36 students & 36 older people
Bleda et al. in 2012 [35]	Evaluation of the Impact of Furniture on Communications Performance for Ubiquitous Deployment of Wireless Sensor Networks in Smart Homes	X, WSN, IoT, WoT	X, temp, humidity, luminosity	ZigBee, 6LoWPAN, GLoWBAL			X	X		X		AAL	
Tang, He & Wu in 2013 [42]	Design and Implementation of the System Based on the Mechanical Topology Smart Furniture		X	RF		X, ATmega16L, on/off windows & gas tank	X, ATmega16L	X			X	X, PIR	

Maskeliunas & Raudonis in 2013 [43]	ROBOSOFA-Low cost multimodal I/O fusion for smart furniture		voice, touch, gaze, camera, accelerometer				X		X	X			10 participants (adult)
Wallbaum et al. 2016 [20]	RemoTable: Sharing Daily Activities and Moods Using Smart Furniture		proximity	RFID, Wi-Fi		X, Arduino Mega, LED	X, Raspberry Pi				X		14 participants (adults)
Papadopoulos, Karagouni & Trigkas in 2015 [11]	Techno-economic Analysis of Furniture Innovation: Developing a Green and Smart Furniture for Mass Production	X	camera	X		X, mirror	X, tablet, PLC			X			

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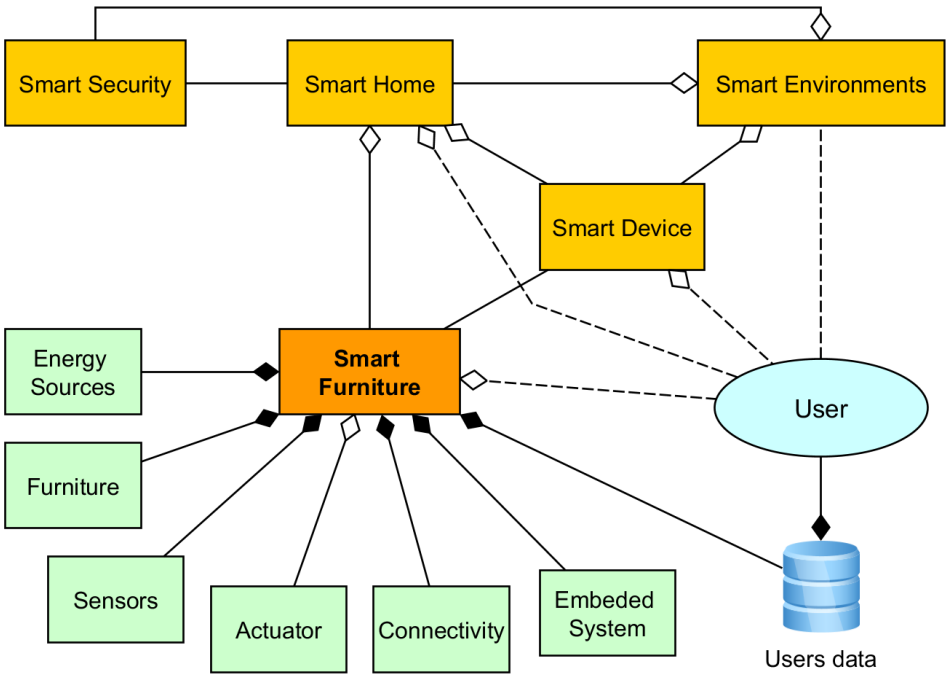

FIGURE 5. **Role and position of Smart Furniture within the Smart City umbrella according to the UML design.**

Based on the analysed research projects, studies and patent applications, Smart Furniture can be described in the context of Smart Homes, Smart Devices, Smart Environments and Users, as well as with the basic building blocks of the Smart Furniture concept which are as follows: furniture, sensors, connectivity, embedded systems, energy sources and actuators (Fig. 5). The role of the user is also important, and it needs to be stated that users can interact with other components of the Smart Home, not only with the Smart Furniture.

D. A SUGGESTED DEFINITION OF SMART FURNITURE BASED ON THE LITERATURE AND PATENT ANALYSES

Based on the frequency of keywords used in the literature and patent databases and based on the examination of the content of the studies and patents included in the selection based on the exclusion and inclusion criteria, the authors suggest the following definition of Smart Furniture.

Smart Furniture is designed, networked furniture that is equipped with an intelligent system or controller operated with the user's data and energy sources. Smart Furniture is able to communicate and anticipate the user's needs using a plurality of sensors and actuators inside the user's environment, resulting in a form of user-adapted furniture or an environment that satisfies the user-declared needs and non-declared needs for the purpose of improving their quality of life in a smart world.

Smart Furniture must be put into the context of other related consequences and used concepts. As the user lives in the real environment (lower level at Fig. 6), which is equipped with a number of sensors and actuators, a unique ubiquitous environment [58] surrounds the user (Fig. 6, 7). The physical environment is used to provide the actual presence of the user for the digital–ubiquitous environment of which a Smart Home as well as Smart Furniture is a part. Smart homes need to analyse (in real time) the presence of a digital user to provide a relevant decision about which action needs to be taken in the physical environment. Most important, the action needs to be determined based on personalized settings, which need to be delivered to the Smart Furniture as well as the whole Smart Environment, which is used by a recognized user (Fig. 6).

The visualization presented in the figure (Fig. 6) shows a user entering a Ubiquitous Environment [29] (upper level at Fig. 6). The user is detected via a Smart Device, while the digital representation of the user is updated to the Smart Home system. Based on predefined settings stored in or generated by the Smart Home system, the Smart Chair (as an example of Smart Furniture) updates its setting to fit to the identified user. The personal settings of the Smart Chair can be pre-set by the user or updated based on experience from sensors embedded within the Smart Chair [50] (Fig. 6). The digital user representation as well as the historical trends of real user behaviour can be shared from the Smart Home system to the

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Smart City environment where they can be used, e.g., for energy consumption predictions.

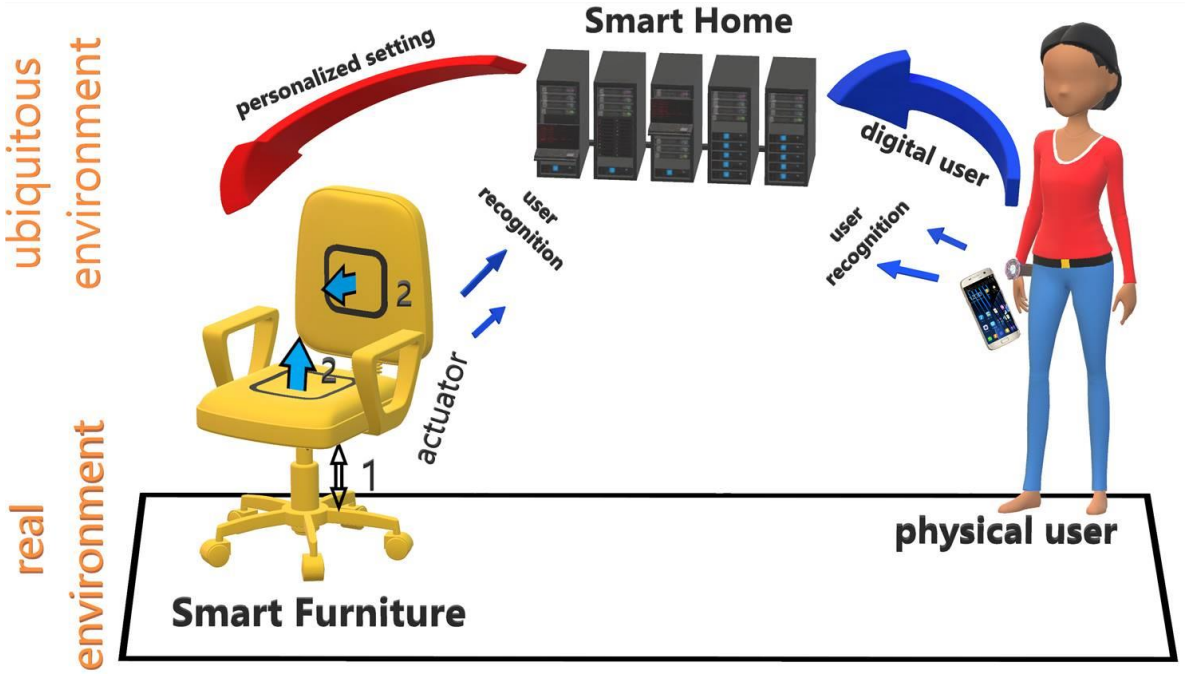

FIGURE 6. **Smart Furniture in the context of a Ubiquitous Environment (Smart Home, Ambient Assisted Living [57]).**

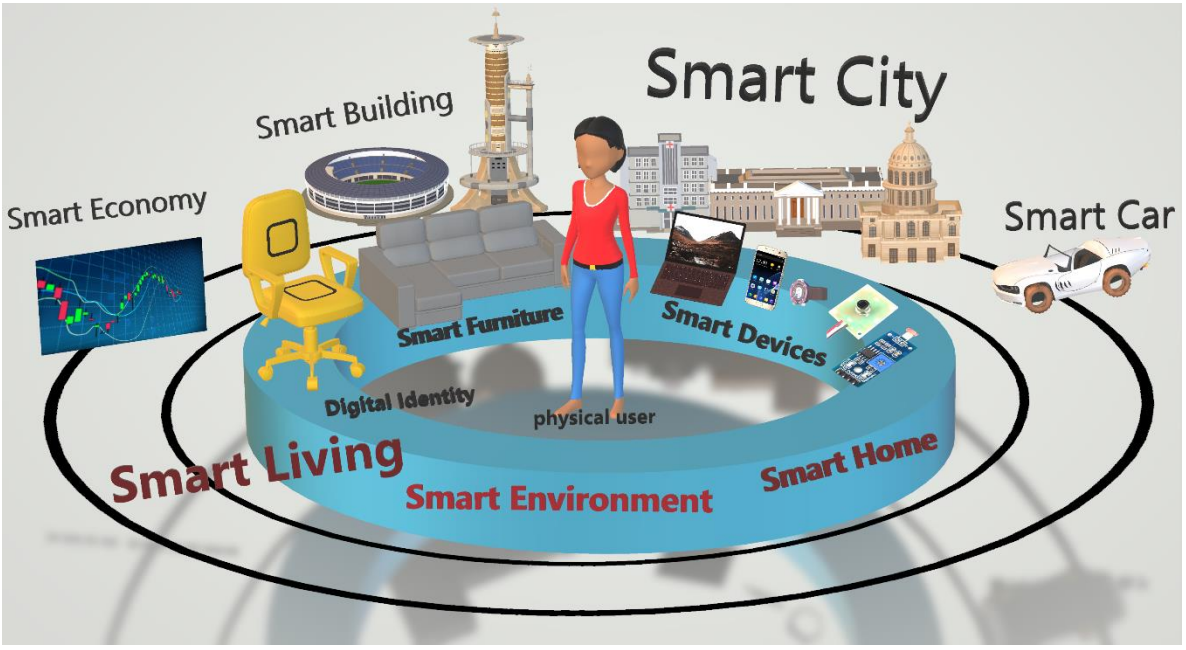

FIGURE 7. **A user in a digital world of smart concepts (living, furniture, devices, home, environment, car, building, city, economy, etc.).**

User life is becoming increasingly digital; the connection to the digital world is ubiquitous. The internet accompanies the user all day through the use of smart devices, while the digital ID exists even if the physical user is sleeping. The smart world is full of smart concepts in various areas (Fig. 7).

Future trends of smart concepts, however, need to be oriented towards the non-obtrusive behaviour of a ubiquitous environment to target the real need for help by the user [58].

IV. DISCUSSION

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A. RESEARCH MOTIVATION

The given definition opens the Smart Furniture concept to a new generation of ICT-enabled Smart solutions in the context of a Smart City. Its content suggests that more organized and result-oriented discussion among a variety of stakeholders is required, which will lead to global and sustainable polices for research on Smart Furniture. It also highlights that this discussion should be enriched by means of the collaboration with users to improve their wellbeing and QoL. By emphasizing the variety of research to Smart Furniture's policymaking, the given definition represents a starting point to discuss technological and policymaking research issues existing on the micro, mezzo, and macro level, as proposed in [59].

The integration of technological, policymaking and user's requirements indicates the need for a new approach at all levels. The given Smart Furniture definition is one of the first attempts to introduce such an approach as an integral part of the Smart Cities and QoL research [59]. While many research organizations and business partnerships compete to develop smart city applications, the given definition of Smart Furniture encourages a scientific discussion about the convergence of technological, economic and user requirements within this context. Having in mind the final vision of Smart Furniture, this definition indicates that a holistic approach is required to integrate the Smart Furniture research into the advanced theories of technological innovation and socially inclusive economic growth. Defining Smart Furniture will aid the adjustment and adaptation of our environment to the future extended working older population surroundings and thereby contribute to economies worldwide, given that there is an increased worry over the ageing population trend and its impact on economies. However, this requires a joint effort of all stakeholders included in the technological and social-economic development of Smart Furniture.

Since the given definition of Smart Furniture follows the nested-cluster model [13], it allow us to argue that sustainability depends on strategic alignment and integration of the five clusters (i.e., policymaking; services; industry; resources; research, education, innovation). The research, education, innovation cluster has a central role in drawing the research agenda and vision of the user-oriented and personalized development of Smart Furniture that opens communication among its stakeholders, which is beneficial for all them.

Smart furniture is also associated with significant concepts, such as IoT and artificial intelligence (AI).

IoT is defined as the extension of Internet connectivity into physical devices and objects of daily use [60]. IoT also play a role involving active objects with some type of adaptation to user needs. Such a specific form of the IoT vision is in close connection with the Smart Furniture definition and specification, which can be seen as an IoT object represented visually as a piece of furniture. To reach the Smart Furniture concept, some type of real-time analytics or machine learning as a part of Artificial Intelligence (AI) needs to be embedded into the solution. Considering the first and the most cited patent application of a Smart Chair [50] and the current trend in using IoT as well as cutting prices for any sensors and actuators from the IoT family, the most room to improve can be seen, for example, in office chairs and Smart Working Spaces, in general. Wider penetration of the IoT and AI into Smart furniture can improve the home and working environment and quality of life.

The result of this work is a precise definition for Smart Furniture. Why define Smart Furniture? A definition is a statement that captures the meaning, the use, the function and the essence of a term or a concept. Good definitions are a valuable asset and allow us to assess a situation better to make better decisions. A truly good definition is generative and creates value beyond its intended purpose of effectively describing something. By defining Smart Furniture, we are participating in the debate regarding its role in a Smart City.

The Smart City has the potential to improve the QoL and provide convenience at work, safety protection, among many other possible uses, as Deng et al. 2019 and Islam et al. 2017 stated [61], [62]. Namely, Smart Cities focus on ICT as a key enabler to fulfil the objectives of wellbeing and sustainability. Smart Furniture is an integral part of the Smart City concept, as recently proposed by Visvizi & Lytras [13], [59], [63] and in accordance with our definition; it relies on ICT solutions and is intended to improve wellbeing.

From an economics point of view, Smart Furniture is conditioned by the operation of five clusters (i.e., policymaking, services, industry, resources, and research, education, and innovation), which are described in the nested clusters model proposed by Visvizi & Lytras [13], [59], [63]. Each of these clusters is embedded in Smart Furniture as an integral part of Smart Cities, where ICT solutions advance the performance of these clusters. Their strategic alignment and functional connections define the sustainability of Smart Furniture because the inclusion of strategy and policymaking considerations makes the smart context holistic, scalable, and human-centred. The nested clusters model, which was introduced in the Smart Cities research, encourages a more structured discussion focused on the sustainable development of Smart Furniture. Additionally, highlighting the policies and strategies suitable for providing users with the ability to profit from and contribute to Smart Furniture development makes a case for pragmatic and demand-driven research dedicated to improving QoL.

B. RESEARCH CHALLENGES

Smart Furniture has entered a new stage of development that is distinguished by an inter- and a multi-disciplinary approach. There are many open technological and policymaking research issues, which should be discussed on the micro, mezzo, and macro levels and are in line with the conclusions

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provided by the abovementioned authors that all the spaces in the Smart City concept (Smart Furniture is one of them) cannot be examined outside of the context in which they are embedded, i.e., micro, mezzo, or macro. Additionally, Smart Furniture is a part of all the considered cases of the proposed framework, i.e., data aggregation, analytics, cloud blockchain, innovation and socially inclusive economic growth and sustainability, in all three layers.

However, most of the ***technological issues*** in the Smart Furniture research can be identified at the micro level. These issues are mainly directed at user profiling, taking into the account the semantic annotation of Smart Furniture services, interoperability between distributed Smart Furniture services, integration with single-point-of-access Smart Furniture services, and location- and geospatial-aware Smart Furniture. A crucial requirement is the establishment of advanced networking technologies and the implementation of an integrated-data warehouse. The unified approach to data management demands, on the one hand, enables novel analytics of Smart Furniture efficiency, and on the other hand, enables artificial intelligence for real-time processing of big data for any purpose. To promote the new approach to financial stream management, blockchain technologies should be utilized in this smart context. Last, but not of least importance, is the awareness and training of users in Smart Furniture skills; their competence will contribute to improving overall wellbeing and QoL.

The technological issues in the Smart Furniture research at the mezzo and macro levels are related to issues in the Smart Cities research. At the mezzo level, these issues refer to the adaptive design of data crawlers, which will be exploited for data, services and decision-making. Different business intelligence and analytic applications will be explored along with approaches to increase the flexibility of the establishment and management of Smart Furniture services. At the macro level, technological issues are associated with data management, which utilizes intelligent, interoperable agents for real-time data extraction. Advanced analytics should be exploited to monitor and predict indicators related to innovation, socially inclusive economic growth, and sustainability.

Beyond the technological issues in Smart Furniture research, ***strategies and socially aware policymaking*** should be covered by future research activities. Smart Furniture strategies should consider research into sustainable innovations, case studies of smart furniture research, caring communities and integration. Social awareness issues should be discussed in terms of smart communities, linked data for Smart Furniture as an integral part of Smart Cities, and security and privacy issues in smart service provision. These strategies and policymaking considerations will create connections between the normative and the empirical in Smart Furniture as an integral part of the Smart Cities research, with the ultimate goal to achieve better wellbeing and QoL.

In relation to the Smart Solution concept, the most frequently mentioned ***risks are privacy and data protection***. In this respect, public attitudes, opinions and behaviours will be critical as far as privacy and data protection are concerned [73]. Privacy and obtrusiveness issues appear to be the most important factors that affect the adoption of Smart Home technology [74]. A multicentre smart-home project indicated that privacy and choice were the major areas of ***ethical focus in the design*** and implementation of Smart Home health technologies. While actual respect is clearly ethically important, favourable end-user perceptions are essential for public acceptability of new technologies and ensuring that their benefits are spread equitably. Even where researchers were able to ensure adequate data privacy, the lack of a commonly agreed concept of privacy could mean that, even with sustained attention, privacy is limited in its ability to be solved as an ethical problem [75].

C. RESEARCH RECOMMENDATIONS

As mentioned above, the definition of Smart Furniture is connected with technological, risk and privacy, ethical, and economic issues. In future research, the key functionalities of Smart Furniture need to be outlined to determine the main characteristics of the furniture of the future and which design aspects should be satisfied and addressed (multi-functionality [63], ecology [64], security [65], education [66], health [67], [68], leisure [69], social interactions [70], governance [71], [72], etc.).

Second, these main characteristics and functionalities should contribute to, and improve, at least one dimension of QoL so that the Smart City concept will be meaningful.

The third direction involves synchronization and synergy with other smart world concepts, such as Smart Homes, Smart Ageing and so on, which means that Smart Furniture should sometimes provide input to other smart concepts. Sometimes, these aspects should rely equally on each other to progress, while in other situations, other smart concepts should support Smart Furniture.

A combination of these factors should result in a framework and synergy for shaping future Smart Furniture solutions.

V. CONCLUSION

In the context of current changes and trends, such as the IoT phenomenon, rapid technological developments, when different technology solutions are being made available to wider groups of users, or within the increasingly high quality of life in developed countries, it has been explored how and for whom the smart furniture solution can benefit, and what solutions exist in relation to selected target groups (as mentioned in the inclusion criterion section of the method). At the same time, we wanted to identify and distinguish between sensor / device types, actuator types, processing types, personal identification and use cases.

The research results and discussion presented in this article are based on the recognition that the Smart Furniture research has great policymaking, technological, and economy potential while also contributing to user's wellbeing and QoL. This paper indicates that the collaboration between the ICT and social-economic research has to be initiated and consolidated in sustainable way. This is motivated by the conceptual work that queried the interdisciplinary nature of the Smart Cities research [63], which may include the specificity of furniture to start a discussion into the Smart Furniture research. Similar to the wider research agenda proposed in [59], this paper implicitly highlights the importance of integrating the Smart Furniture research with policymaking designed for innovation, socially inclusive economic growth, and sustainability. Finally, the future research should place the scalability of the Smart Furniture research and policymaking considerations in the wider context of the inter-disciplinary discussion.

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