Selecting and Acquiring IoT Devices Oriented to Older People: A Systematic Literature Review

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Abstract. The devices are crucial elements in the Internet of Things (IoT) applications. The correct selection of these elements influences the quality, cost, and adequate addressing of the application depending on the needs in each of the IoT verticals. In this sense, the need for methodologies for selecting IoT devices is an exciting field to explore in research. Therefore, this paper presents a Systematic Literature Review (SLR) based on the Kitchenham and Charters methodology, as the first step for designing a methodology for the selection and acquisition of IoT devices oriented to older people. The presented SLR describes the existing methods, technical criteria, context criteria (e.g., contracts, government restrictions), and other elements considered for selecting IoT devices from 2010 to 2021 year; this from the review in digital libraries, conferences, and journals. Sixteen articles were found following the methodology of systematics review. The obtained results are made up of studies for the selection of IoT devices, or criteria for the selection of technology related to IoT, such as IoT services, IoT platforms, sensors for IoT devices, among others. Most of the found studies are not directed to a specific domain, except for a few directed to people in general or companies. Overall, the study evidences a gap in the selection methodologies for IoT devices in applications-oriented to the elderly and the presence of some context-related selection methods.

Keywords: Systematic Literature Review (SLR) · Internet of Things (IoT) selection · Internet of Things (IoT) acquisition · Methodology

1 Introduction

Healthy aging in people is nowadays one of the most important challenges for governments and healthcare institutions [1]. The improvement of health services oriented to ensure physical and mental welfare in older patients directly influences their life quality, and reduction in health services costs [1, 2]. In this sense, technology is an essential ally to reach this goal. Besides, concerning older adults, new emerging technological paradigms such as the Internet of Things (IoT), Ambient Intelligence (AmI) and Ambient Assisted Living (AAL) are focused on improving their wellbeing [3–5].

The ideal field of application in for elderly-oriented solutions is AAL which is defined by [6, 7] as technical systems developed to support elderly or people with diseases in

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their daily activities giving them independent life as long as possible and improving their quality of life. Here exist a wide range of IoT applications (e.g., elderly care monitoring, chronic patient health monitoring, recognition of human activity, clinical applications), and all of them depending of the quality of the used devices to improve their impact [8]. In this sense, the IoT device selection is overriding to achieve an adequate technological solution for elderly-oriented or context needs. Therefore, having a structured method that considers steps such as mapping of requirements, classification, and weighting for choosing IoT devices is needed.

In this context, to know advances within this field of study and to establish a starting point to develop the bases to support the development of these kinds of methodologies, a Systematic Literature Review (SLR) is an ideal means to identify, evaluate, and interpret all the advances in this domain [9]. Although some research presents literature reviews about the acquisition of devices, there is no register about the presented in this paper which is n SLR to look for methodologies for selecting and acquiring IoT devices oriented to older people. The SLR follows three stages: i) Planification, ii) Execution of the review process iii) Report of the results, as suggested by Kitchenham [9].

This paper's remainder is organized as follows: Sect. 2 discusses the background, including existing SLRs or methodologies in this domain. Section 3 and Sect. 4 discusses an explanation of the research method and the systematic review results. Finally, a discussion of the results, methodology validation, and future work.

2 Background

This section gives initially an overview of the IoT application fields to create solutions for older people. Then, are discussed some important criteria and methodologies in selecting IoT devices that can be applied in solutions oriented to elderly.

In the last years, the needs in elderly care field have been addressed by technology. In this context, the IoT and AAL paradigms have applications or solutions-oriented to improve the quality of life in the elderly such as:

- *Elderly care monitoring.* These applications include devices that primarily intended to improve quality of life and promote safe and independent living. Examples include devices in AAL environments, active aging, therapy and entertainment, communication and social activities, health monitoring and diet [8].
- *Chronic patient health monitoring.* These applications include IoT devices specialized in monitoring and supporting older people with chronic diseases or disabilities, such as diabetes, Alzheimer's, among others [8, 10].
- *Recognition of human activity:* These applications include devices for constantly monitoring the elderly activities to detect abnormal conditions and reduce the effects of unpredictable events such as sudden falls [11]. This category also includes devices for the elderly location, navigation assistance and object locators.
- *Clinical applications.* These applications include IoT devices for the detection, diagnosis, prediction, and treatment of diseases (e.g., seizure detection) [8, 12].
- *Emergency conditions.* These applications include fall detection devices, fall risk management, emergency responses, and categorization of emergency patients according to their level of severity [8, 13, 14].

- *Mental health.* These applications include devices for the detection, prediction, and care of mental illnesses in elderly (e.g., dementia, depression) [8].
- *Movement disorders.* These applications include devices for continuous analysis or training of patient balance and gait based on portable sensors [8, 12].
- *Rehabilitation.* These applications include IoT devices to provide rehabilitation services and/or to generate feedback to patients and their caregivers about the progress of the rehabilitation process (e.g., exoskeletons) [8, 15].
- *Accessibility to health services.* These applications include devices that allow the generation of requests for health services, generation of information related to health areas, good habits promotion, and self-control in certain diseases [2, 8].
- *Accessibility for caregivers.* These applications include devices that allow remote monitoring and treatment of patients by healthcare providers [2, 8].

As presented, some of the applications are criticism due to its direct relationship with wellbeing and healthcare. Therefore, the quality of the devices directly influences the proper addressing of the solution. Hereof, an adequate selection of the devices depending of the context and the specific needs of the application is necessary.

The literature about IoT technology selection present some elements to consider when choosing adequately devices. On the one hand, the selection criteria, grouped into fifteen categories: *technical characteristic* [16–18]*, device quality* [17, 19, 20]*, safety* [17, 21]*, sensors* [22, 23]*, services* [22, 24]*, software* [25]*, communications* [17, 22, 26]*, data type* [27–29]*, IoT platforms* [28, 30]*, patient needs* [31–33]*, ethical considerations* [34]*, marketplace* [19, 35]*, contracts negotiation* [17, 21]*, governmental regulations* [31, 36, 37]*, and acquisition or fabrication* [38–40].

On the other hand, the IoT technology selection methodologies such as: *Analytical Hierarchical Process (AHP)* [41]*, Analytical Network Process (ANP)* [42]*, Additive Relationship Assessment (ARAS)* [43]*, Decision Making Testing and Evaluation Laboratory (DEMATEL)* [44]*, Elimination and Election Reality (ELECTRE)* [45, 46]*, Convolutional methods* [47]*, Primitive Cognitive Network Process (PCNP)* [48, 49].

Overall, there have been swiftly presented some specific elderly-oriented application areas, selection criteria for IoT technology and some selection methodologies. In the next section, these considerations are the starting point to the SLR.

3 Systematic Literature Review (SLR) Research Method

A Systematic Literature Review (SLR) lets obtaining, evaluating, and interpreting state of the art into primary studies about research questions related to a specific area of interest. These goals are reached by applying a scientific methodology that provides an objective assessment of the research topic in a reliable, repeatable, and replicable manner. Therefore, this paper applies the methodology proposed by Kitchenham et al. (Kitchenham & Charters, 2007a), to carry out the SLR.

The selected methodology consists of three stages, as shown and described in Fig. 1.

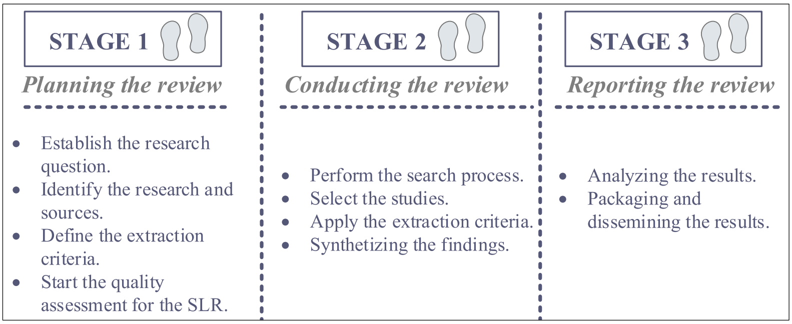

Fig. 1. Stages for the execution of a Systematic Literature Review according to Kitchenham.

3.1 Planning the Review

This stage defines the SLR protocol and research question to perform the review. Before beginning the review, it is necessary to verify the non-existence of similar previous works to avoid duplicating work. In this sense, a first search was carried out for SLRs related to the selection and/or acquisition of IoT technology and specialized in elderly-related aspects. As a result, the search did not return similar studies; for this reason, planning for the revision continues. Also, the guidelines proposed by Kitchenham [9] suggest the information extraction by considering several aspects as shown in Table 1.

Table 1. Extraction aspects during the SLR.

Aspect	Description
Population	Studies related to methodologies for selecting/acquiring IoT devices oriented to older people. Also, there are considered methodologies for selecting IoT devices
Intervention	The study contains a group of aspects related to the selection of devices
Comparison	This study aims not to compare the different aspects to be addressed when designing a methodology for selecting IoT devices oriented to elderly
Outcomes	To identify the main aspects addressed during the design of methodologies and aspects considered for the selection of IoT devices
Context	This study is developed in a research context, where the experts in the domain present primary studies

Afterward, are defined the research protocol steps from identifying the research question to the release of the results in order to carry out an orderly and systematic review. In addition to the data extraction and synthesis of studies.

Research Question. The overall objective of this review is to identify:

RQ: *What factors are considered for proposing methodologies for the selection and acquisition of IoT technology?*

Moreover, Kitchenham suggests dividing the main question into sub-research questions. In this case, the following were defined:

- *RQ1: What aspects are considered for selecting / acquiring existing IoT technology?*
- *RQ2: What domains are the selection and acquisition methodologies for IoT technology-oriented?*
- *RQ3: What method is used to weigh IoT devices?*
- *RQ4: How is research on methodologies for acquiring IoT technologies carried out?*

Research Strategy. According to the technological and medical field of the research, the libraries considered for the search were ACM, IEEE Xplore, ScienceDirect, and PubMed. The search string to submit to these sites is defined in Table 2.

Table 2. Search string.

Concept	Sub-string	Connector	Alternative terms
Internet of things	Internet of things	OR	
IoT	IoT	AND	
Acquisition	Acquisition	OR	
	Selection	AND	
Methodology	Method*	AND	It includes methodology, method
Search string	*(Internet of Things OR IoT) AND (Acquisition OR Selection) AND Method**		

In order to select the studies, there are considered the publications in the period 2010-January 2021. The selection is based on the IoT emergence milestone by 2008–2009 as presented in [50]. Therefore, it is expected that by 2010 there may have already been the first formal studies in this domain. In addition, manual searches of conferences and journals related to IoT applied in health and/or care of the elderly are included in SCImago Journal & Country Rank, Core Conferences, and Google Scholar.

Data Extraction Criteria. In order to extract data from the primary studies, a set of criteria is established for each research sub-question as set out in Table 3. These criteria are reviewed in each study to facilitate their classification.

3.2 Conducting the Review

This second stage starts with selecting and assessing the primary studies, then the monitoring and extraction by following the alignments such as the research questions and protocol proposed in the planning stage.

Table 3. Criteria to be analyzed for each research sub-question.

RQ1: What aspects are considered for selecting and/or acquiring existing IoT technology?			
EC1	*Analysis criteria*	*Technical characteristic* *Quality* *Safety* *Software* *Final user* *Device market* *Contracts* *Government regulations*	*Sensors* *Manufacturing* *Business* *IoT platforms* *Data* *IoT services* *Communications*
RQ2: What domains are the selection/acquisition methodologies for IoT technology-oriented?			
EC2	*Domains*	*Elderly* *People (in general)* *Enterprises* *None in specific*	
RQ3: What method is used to weigh IoT devices?			
EC3	*Methods*	*AHP (Analytical Hierarchical Process)* *ANP (Analytical Network Process)* *ARAS (Additive Relationship Assessment)* *DEMATEL (Decision Making Testing and Evaluation Laboratory)* *ELECTRE (Elimination and Election Reality)* *IPM (Multiple Information Process)* *Convolutional methods* *PCNP (Primitive Cognitive Network Process)* *Others (algorithms, models, etc.)*	
RQ4: How is research on methodologies for acquiring IoT technologies being carried out?			
EC4	*Focus*	*General IoT device selection* *Selection of IoT devices for medical use* *Process automation with IoT* *Sensor selection for IoT devices* *Wireless technology selection for IoT networks* *Selection of IoT services* *Selection of IoT platforms* *Selection of IoT systems* *General technology selection*	

Primary Studies Selection. The search string was applied in the metadata of title, abstract and keywords of the selected digital libraries. Then, since the results, the titles and abstracts were evaluated to filter the articles that did not align with the research question. Studies that at least comply with the selection or acquisition of IoT technology or analysis of aspects of IoT were kept. Introductory documents, same works in different sources, Not English written articles, books, workshops, and posters were excluded.

Quality Assurance of Primary Studies. Since the number of obtained results and that most of these have no more than three years old since their publication, it was decided to filter the papers published in an indexed journal or library. As a result of the search and filters described above, were obtained the following presented in Table 4.

Table 4. Automatic search results in digital libraries.

Search engine	Results	Just conferences and journals	Since 2010
IEEE Xplore	495	469	468
ACM	104	97	97
Science Direct	70	60	60
PubMed	42	40	40
		Total	665
Removing repeated			641

As a next step, the titles and abstracts of the 641 results were analyzed to extract only the articles that contribute to the research questions; thus, obtaining only two papers (*S01* and *S02* of Appendix 1). Additionally, 15 more reports were obtained from the manual search, giving 17 articles useful for research as total (*S03–S16* of Appendix 1).

3.3 Reporting the Review

The final stage presents the core of the SLR since the extraction criteria, the selection mechanism, and thus the current state of the art in this domain. All the researches were tabulated following the criteria to obtain a data summary. The summary results are in Table 5; where most of these do not have a specific domain orientation even to the elderly. Concerning current studies, it highlights the IoT sensors and platform selection.

Table 5. Results obtained by criterion of each sub-question.

Extraction criteria		#	%	Papers
RQ1: What aspects are considered for selecting and/or acquiring existing IoT technology?				
Analysis criteria	*Technical characteristic*	*5*	*31%*	*S01, S04, S07, S09, S16*
	Quality	*5*	*31%*	*S01, S03, S04, S08, S11*
	Safety	*7*	*44%*	*S03, S04, S08, S11, S13–S15*
	Software	*0*	*0%*	
	Final user	*5*	*31%*	*S02, S04, S08, S09, S11*
	Device market	*3*	*19%*	*S02, S04, S11*
	Contracts	*0*	*0%*	
	Government regulations	*3*	*19%*	*S02, S08, S11*
	IoT services	*1*	*6%*	*S01*
	Communications	*4*	*25%*	*S01, S03, S04, S11*
	Sensors	*1*	*6%*	*S07*
	Manufacturing	*2*	*13%*	*S01, S16*
	Business	*4*	*25%*	*S03, S04, S08, S11*
	IoT platforms	*3*	*19%*	*S02, S14, S09*
	Data	*3*	*19%*	*S11, S14, S09*
RQ2: What domains are the methodologies for selecting/acquiring IoT technology-oriented?				
Domains	*Elderly*	*0*	*0%*	
	People (in general)	*2*	*13%*	*S08, S11*
	Enterprises	*1*	*6%*	*S03*
	None in specific	*13*	*81%*	*S01, S02, S04–S07, S09, S10, S12–S16*
RQ3: What method is used to weigh IoT devices?				
Methods	*AHP*	*5*	*31%*	*S01, S03, S06, S09, S16*
	ANP	*2*	*13%*	*S11, S13*
	ARAS	*1*	*6%*	*S08*
	DEMATEL	*1*	*6%*	*S13*
	ELECTRE	*1*	*6%*	*S16*
	Convolutional methods	*3*	*19%*	*S12, S14, S15*

(*continued*)

Table 5. (*continued*)

Extraction criteria		#	%	Papers
	PCNP	*1*	*6%*	*S05*
	Others (algorithms, models, etc.)	*6*	*38%*	*S01, S02, S04, S07, S10, S15*
RQ4: How is research on methodologies for acquiring IoT technologies being carried out?				
Focus	*General IoT device selection*	*3*	*19%*	*S06, S09, S12*
	IoT device selection for medical use	*2*	*13%*	*S08, S11*
	Process automation with IoT	*1*	*6%*	*S03*
	Sensor selection for IoT devices	*3*	*19%*	*S04, S07, S10*
	Selection of IoT services	*1*	*6%*	*S13*
	Selection of IoT platforms	*3*	*19%*	*S02, S14, S15*
	Selection of IoT systems	*2*	*13%*	*S01, S16*
	General technology selection	*1*	*6%*	*S05*

Afterwards, from the obtained results, the trends in each sub question are shown. Figure 2 presents the analyzed criteria dispersion regarding the IoT device selection. Here highlight as most common criteria the quality, security and communications.

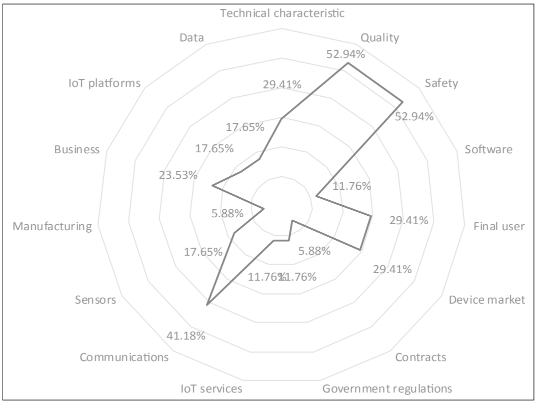

Fig. 2. Analyzed criteria trends to IoT device selection.

Figure 3 shows trends about used methodologies. It presents AHP as the most used. Then, are shown the Linear Convolution Method (LCM) and proportional method.

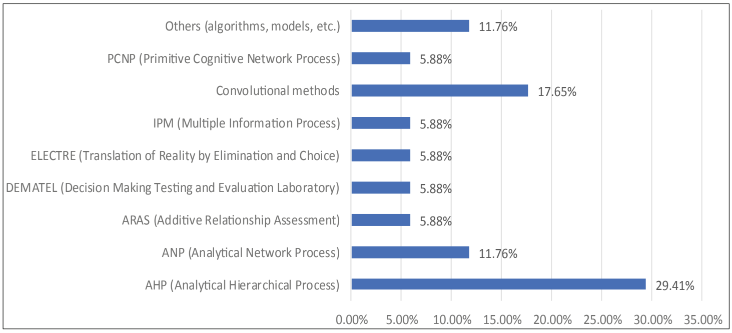

Fig. 3. Analyzed criteria trends to IoT device selection.

4 Results of the Systematic Review

This section presents a summary of the results from the searches about studies related to IoT devices selection both specialized in a single specific criterion, and multi-criteria selection methods. These results were complemented with research related to IoT technology such as the selection of IoT platforms or services, to obtain a broad set of criteria that will form part of a methodology for selecting IoT devices aimed at the elderly.

The range of the publications is 2013 to 2020 (Table 6). From 2013 to 2015, there is the least number of investigations (12%); where the selection of technology through selection methodologies (*S05*) or the search for sensors for middleware with IoT devices (*S07*) is already appreciated. Besides, in the period from 2016 to 2017, investigations reached 26%, where more specialized works in the selection of IoT devices can be observed, highlighting the *S04*, dedicated to the selection of IoT devices evaluated from the criteria of RFID and sensors; and *S06*, which proposes a multi-criteria decision model adaptable to different selection models in the search for the most convenient IoT devices. For the 2018 to 2020 period, the related jobs raise up to 63%, where 2019 has most publications (13). In this period, the research aimed at the selection of IoT platforms (*S02, S14, S15*) and the selection of IoT devices aimed at medical solutions (*S08, S11*) stand out. It is worth highlighting the importance of the S11 research that is oriented to the use of IoT for the implementation of Intensive Care Units (ICU) solutions.

EC1 Analysis Criteria. 75% of the studies include one or more technical criteria for the selection stage. The number of criteria is very dispersed and has different levels of abstraction. Within the range greater than 40% are the security criteria such as *S13* research, specialized in a security framework for evaluating IoT services; or *S03* research where a method for selecting IoT devices including security analysis criterion is proposed. In the range of 20 to 40% are the Quality, Technical Characteristics and Communications criteria, such as the research *S04* that analyzes the characteristics of radiofrequency sensors and identifiers (RFDI) in IoT devices from the quality view, technical characteristics, communications, among others. Another example is *S01* that includes these criteria for designing IoT ecosystems. In the 10 to 19% range are the Data, Manufacturing, and IoT Platforms categories such as the research *S16* that suggests some criteria for the IoT systems development; or the research *S14* that includes the criteria

Table 6. Research classification according to year of publication

Year	Papers	Year	Papers	Year	Papers
2013	1	2018	3	2019	2
2015	1	2018	2	2020	4
2016	2	2018	1	2020	2
2016	1	2019	4	2020	1
2017	2	2019	4		
2017	1	2019	3		

related to data management in IoT platforms. Finally, the range below 10% present the criteria for sensors and IoT services (*S07, S01*). None of the studies considers specific software criteria. Table 7 shows the papers' technical criteria classification.

Table 7. Research classification according to the technical criteria

Technical aspects	# Papers	% Papers	Rank	% Tech. aspects
Security	7	43.75%	>40%	75.00%
Technical characteristics	5	31.25%	20 to 40%	
Quality	5	31.25%		
Communications	4	25.00%		
Data	3	18.75%	10 to 19%	
IoT platforms	3	18.75%		
Manufacture	2	12.50%		
Sensors	1	6.25%	<10%	
IoT services	1	6.25%		
Software	0	0.00%		
None	4	25.00%	–	25.00%

EC2 Domain. In the results, 81% of the studies do not specialize in a specific domain. Only 13% are oriented to people in general, such as *S08* focused on patients requiring physical rehabilitation, or *S11* on people requiring hospitalization in an intensive care unit. 6% to a business vision (such as *S03* oriented to the automation of processes within a company). Besides, there is no study focused on the selection of IoT devices oriented to the elderly. Figure 4 shows the papers' classification according to the domain.

EC3 Methods. The studies found a wide variety of methods used for the selection of criteria. Of these, AHP stands out as the preferred one with 31%, made up of *S01, S03, S06, S09*, and *S16*. The next rank consists of the works that use convolution methods

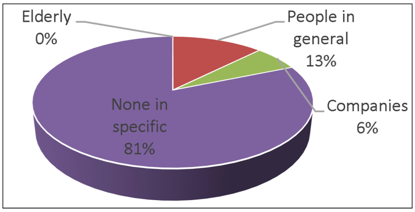

Fig. 4. Research classification according to the domain

with 19%. In this rank, the *S12*, which applies the Linear Convolution Method and the Ideal Point Method, stands out; and the researches *S14* and *S15* that apply the Linear Convolution Method. As the third most used methodology is ANP with 13% (*S11* and *S13*). We obtained 38% of studies that do not apply selection methodologies as such, but different options such as algorithms, metamodels, or simply do not specify a specific methodology. Within this range, the research *S01* stands out, which establishes a metamodel for the design of IoT ecosystems that allows the use of different selection methodologies such as AHP or ELECTRE. Table 8 shows the classification of the papers according to selection methods.

Table 8. Research classification according to selection methods

Methods	# Papers	% Papers	% Selection methods
AHP	5	31.25%	62.50%
Convolution methods	3	18.7n5%	
ANP	2	12.50%	
ARAS	1	6.25%	
DEMATEL	1	6.25%	
ELECTRE	1	6.25%	
PCNP	1	6.25%	
Others	6	37.50%	37.50%

EC4 Focus. There is no significant difference between the approaches of the studies, however, there are 3 trends: 19% of the studies have approaches to the selection of IoT devices in general, sensors for IoT devices or IoT platforms. Within this range, the research *S09* stands out, which presents a multi-criteria decision model for IoT device selection from different selection methodologies. 13% of the studies have approaches to the selection of IoT devices for medical use or selection of IoT systems such as those previously described: *S08*, *S11*, *S01* and *S16*. 6% of the studies focus on process automation with IoT, IoT services selection or technology selection in general such as the research *S03* that establish a selection method for IoT devices focused on process automation. Table 9 shows the classification of the papers according to selection methods.

Table 9. Research classification according to focus

Focus	# Papers	% Papers	Rank
General IoT device selection	3	18.75%	~19%
Sensor selection for IoT devices	3	18.75%	
Selection of IoT platforms	3	18.75%	
Selection of IoT devices for medical use	2	12.50%	~13%
Selection of IoT systems	2	12.50%	
Process automation with IoT	1	6.25%	~6%
Selection of IoT services	1	6.25%	
General technology selection	1	6.25%	

5 Conclusions and Further Work

The purpose of this work is to know the scientific advances regarding the offer of methodologies for the selection or acquisition of IoT devices to address contextual needs of older adults. After conducting the SLR, it is observed that, despite having achieved a significant number of valid initial studies (more than 600 papers), the number of valid papers for the purpose of the study was very low (16), which reflects that there is not much research about selection methods for IoT devices, even though IoT technology has been in existence for more than 10 years. In that way, there is no evolution of the studies that delve into any specific domain and focus. Hence, it is concluded that most of the reviewed articles focus on the selection of sensors or IoT platforms; Furthermore, a large percentage of studies have focused on AHP, a method that offers advantages such as considering all possible alternatives, encouraging reflection, and achieving an objective and reliable result. However, there is an absence of methods for the acquisition of IoT devices aimed at older adults; therefore, it is suggested to work in methodologies that consider aspects of this age group to set up high quality AAL.

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Appendix 1

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