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MOBILITY, PUBLIC TRANSPORT AND TECHNOLOGY FOR HEALTHY AGEING

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Abstract

The thesis analyses the key topic of healthy ageing that is gaining day by day more attention as result of the demographic trends characterizing our society. It focuses on three ways, analysed in the three main chapters, through which the well-being and quality of life of the elderly people can be substantially elevated. The framework of health ageing includes a variety of relevant domains. Nevertheless, in the current research the focus is shed on the mobility, the public transport and the technology as critical enablers of independent living and community engagement for the elderly.

The first chapter presents the wider context and motivations behind the selection of this specific research topic and stresses that the ageing of the worldwide population is a matter of urgency for the policymakers.

The first half of the second chapter is dedicated to the illustration of some basic background notions of elderly mobility (i.e. terminology, theoretical models and relationships with well-being/QoL). Additionally, the second half, gathering multidisciplinary evidence, reviews systematically the literature about the importance of mobility in later life.

The third chapter examines a crucial facilitator of the elderly mobility, i.e. the public transport system. Initially, it is introduced in a narrative way the position of the public transport in the life of the elderly people, as it has been presented so far in the scientific literature. Then, special attention is paid on the empirical association between the local public transport systems and the health status of the Italian older people. At the end of the chapter, there are presented some existing public transport policies for the elderly transport needs throughout the world.

The fourth chapter pays particular attention on the use of the Internet by the Italian older adults over 60 years old. We analyse empirical data about various online activities that are performed digitally by the elderly adults, and also, we sketch latent groups (classes) with similar online activity profiles, controlling for important socioeconomic variables.

The thesis concludes with the discussion of the main findings, underlining its innovative contribution to the scientific knowledge and providing guidance for future research contributions.

Keywords: *Health Ageing; Elderly Mobility; Public Transport; Internet; Italy*

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Varese, December 2020 Evangelia Pantelaki

Dedicated to my family

Quotes

'Old age is not an illness. It is a continuation of life with decreasing capabilities for adaptation'.

Frederic Verzar (Swiss gerontologist)

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CHAPTER 1

INTRODUCTION

1.1 Structure of the thesis

The thesis consists totally out of five chapters: (1) introduction, (2) three chapters of original research and (3) conclusions. Each one of the main chapters is considered a separate research line, giving the possibility to be read autonomously without losing any piece of information on the specific research topic. It is stressed that the connecting link between the presented topics is the highly relevant concept of *health ageing.* Appropriately, all the three chapters of the main body of the thesis are included as supportive ways of boosting healthy ageing and guidance of policy making towards this direction.

More specifically, Chapter 1 outlines the thesis and offers the framework within which it is placed. As a result, it makes the understanding of the following sessions more comprehensive. Furthermore, the research questions for each of the following chapters are illustrated analytically.

Chapter 2 focuses on the concept of elderly mobility. We live in a society which requires enough movements in order to get fully involved in any aspect of the societal activities. As a consequence, in Section 2.1, the literature on the theoretical framework of mobility is critically summarised. From a multidisciplinary point of view, it is given an indicative range of vocabulary used by the researchers, some theoretical models that have been developed to explain the drivers of mobility, empirical application of them, a framing of the different aspects of mobility and finally, a narrative review of the relationship of mobility with well-being/QoL (definitions of well-being/QoL, potential links of well-being/QoL with mobility, and causal relationships of well-being/QoL with mobility). Section 2.2 includes a published a paper. It undertakes to review systematically the scientific literature about the benefits of mobility that has been uncovered and further studied by the researchers in health, general, economic and social sciences. Since the topic is characterised by its multidisciplinary nature, the approach that is adopted in the paper confirms that characteristic. We distinguish the scientific literature in disciplines and discuss the approaches of the researchers. We find that mobility affects several pathologies, the feelings of independence and the social inclusion of the elderly people. Also, we identified a significant number of research papers in health sciences, while we found that less attention has been paid in economic and social sciences.

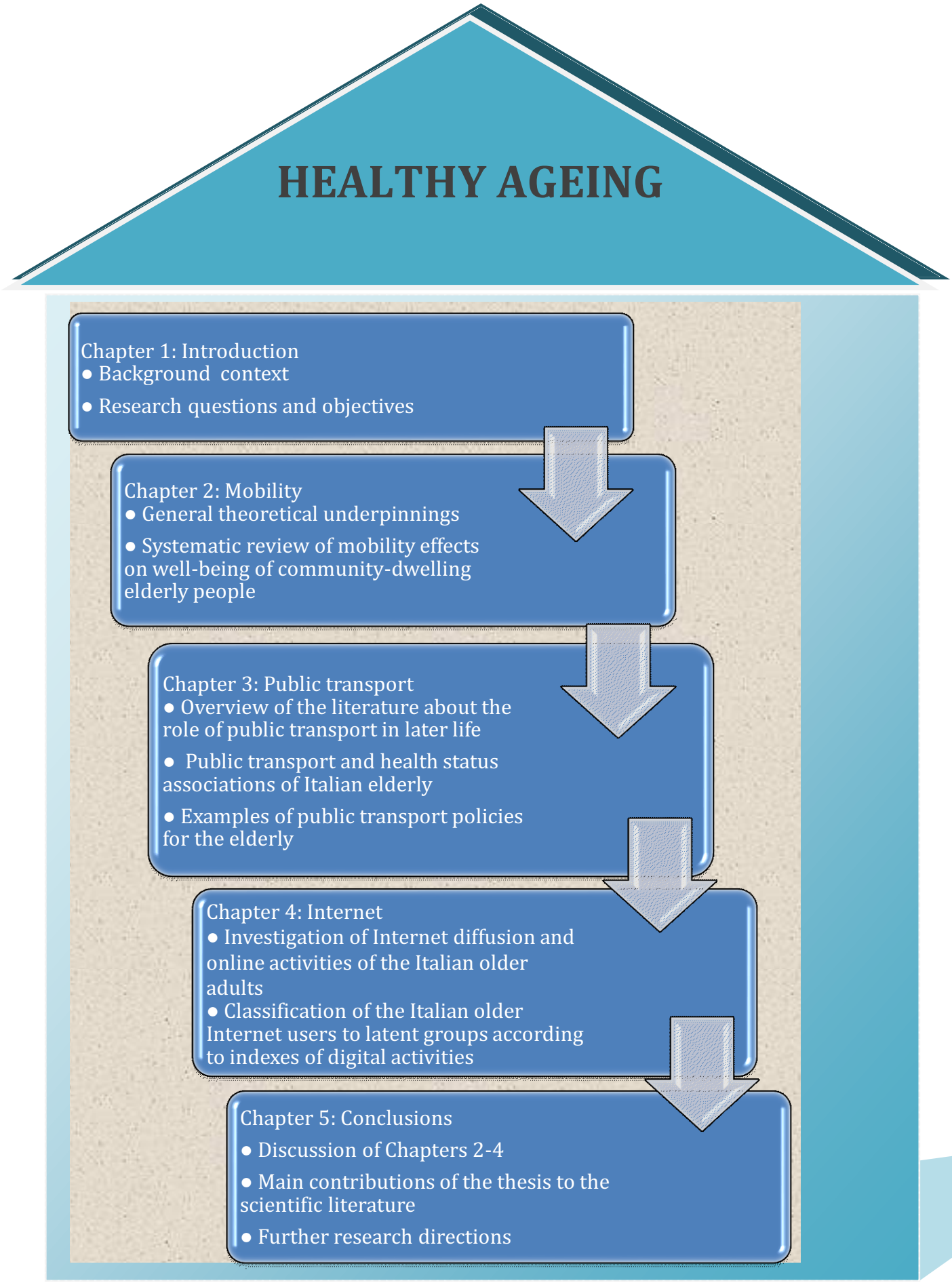
Chapter 3 examines an important facilitator of mobility, i.e. the public transport services. Initially, it is displayed the position that the public transport system occupies, as regards the formulation of human well-being/QoL (Section 3.1). Given that with increasing age the risk of driving cessation becomes higher, alternative age-friendly and sustainable transport means need to be provided in order to fill the daily mobility needs of the aged people. Section 3.2 includes a published paper. It is focused on the use of public transport services in later life and, particularly, its association with the health status of the Italian older adults. The accessibility to the local public transport and the parking space difficulties are considered obstacles for the use of the transport system. More frequent use of the public transport, was found to be closely related with health indicators. Unfortunately, we were not able to demonstrate the direction of the causality due to the cross-sectional nature of the dataset. Equally important, for these topics, are the public transport policies for the ageing population group presented in the end of Chapter 3 (Section 3.3).

In Chapter 4, we include a working paper not published or presented in conferences yet. We study the technological dimensions of healthy ageing. For this reason, we analysed a wide range of Internet activities that are performed by the Italian adults over 60 years old. Controlling for various sociodemographic characteristics, we identified profiles of Italian elderly online users. The findings showed that as the Italians age they tend to use less the Internet, except from some activities such as the communication with public authorities.

Finally, Chapter 5 summarizes the findings of the previous sections, underlines the scientific contribution and novelty of the thesis, discusses a few limitations and gives triggers for future research studies.

A brief overview of the thesis' structure is outlined in Figure 1.1.

Figure 1.1 *Organisation of the thesis*



1.2 Objective and research questions

The main objective of the thesis is to delve deeper into the issue of the ageing populations. By pinning down, as a theoretical structure, the approach of healthy ageing, it contributes to the scientific knowledge by investigating the role of mobility, public transport systems and technology in later life. Hence, the basic perspective is realised through the analysis of the following research questions:

- Chapter 2
  1. What terminology and measures are used by the researchers coming from health, general, economic and social sciences to describe elderly mobility?
  2. What existing theoretical models (and empirical applications of them) of elderly mobility drivers are met in the literature?
  3. How do the theoretical models of elderly mobility can be framed together?
  4. What is the relationship of elderly mobility with well-being/QoL?
  5. What are the effects of mobility on community living elderly people as these have been studied in health, general, economic and social sciences?
  6. What specific measurement tools of mobility have been used in the literature in order to discover the corresponding effects?

- Chapter 3
  1. How is the public transport system positioned in the daily life of the elderly people, as regards the aspects of well-being/QoL, independence and social inclusion?
  2. What is the association of public transport use with the physical, mental and self-perceived health of the Italian older people?
  3. What examples of good practices of public transport policies exist to support the transport needs in later life?

- Chapter 4
  1. How diffused (i.e. use, frequency and devices) is the Internet among the Italian older adults over 60 years old?

2. What specific online activities attract the elderly Italian people to use the Internet?
3. As many Internet activities are interrelated, how can the online activities be grouped to create indexes of digital performance that capture uniquely the digital behaviour of the elderly people in Italy?
4. Are there any latent classes (groups) among the Italian elderly people over 60's based on the online activity habits?
5. How are the socioeconomic characteristics of the older Italian people together with the digital infrastructure accessibility related to latent classes of elderly Internet users?

Therefore, at the end of the thesis, we hope the reader will have got a full picture of three crucial aspects of healthy ageing.

1.3 Background and motivation

1.3.1 Ageing trends in modern societies

Together with decreasing birth rates, advances in medicine and technology are pushing up life expectancy and are leading to ageing populations in both developed and developing countries (Cao and Zhang, 2016; Global AgeWatch Index, 2015). The projections of the international organizations such as the Organization for Economic Co-operation and Development (OECD) and the United Nations (UN) reveal a quantitative representation of the issue. In OECD countries, the population share of the people over 65 years old will reach 25.1% in 2050, from 7.7% in 1950 (OECD, 2015). Similarly, the projections of the report UN (2015) show that the share of people aged 60 or more years will increase in all continents by 2050, listing first in the rankings, the countries of Latin America and the Caribbean (the share will jump from 11% in 2015 to 26% by 2050) (Figure 1.2). Although the European countries will not face the highest percentage changes of ageing populations over time (from 24% in 2015 will reach 34% by 2050), Europe, in general, has already the oldest population with a median age of 42 years, which is expected to reach 46 by 2050 (UN/DESA, 2015).

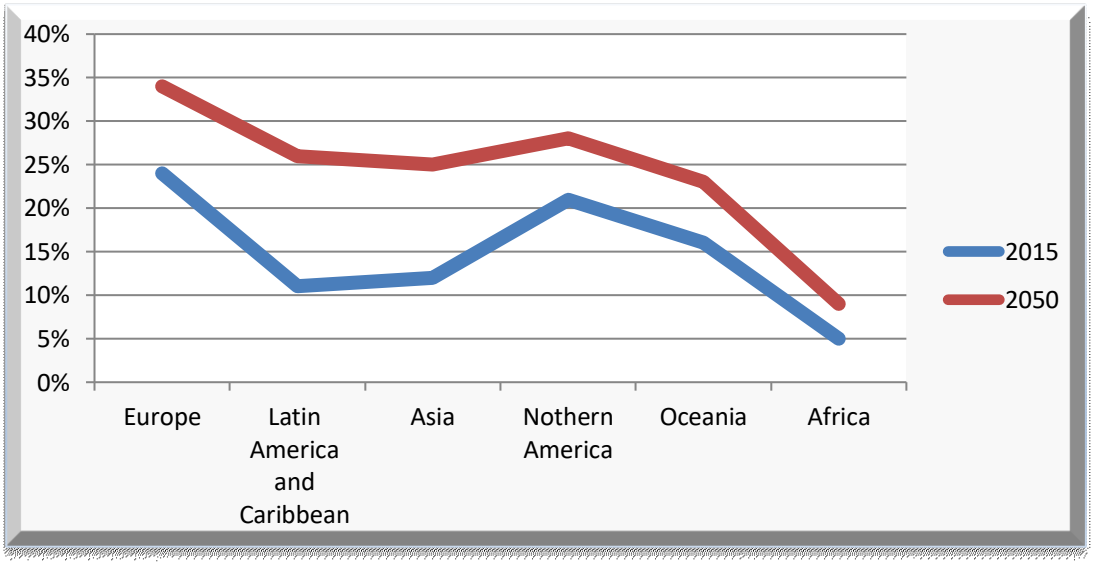


***Figure 1.2** % of population over 60 years old* (*Author's elaboration, data UN/DESA (2015)*)

Remaining in the European continent, Italy holds the sceptre among the other European countries, in terms of senility rates. In 2030, it is anticipated that the country will be in

the second position of the worldwide classification with the oldest populations, Japan will be the first, and will have a mean age of 50.8 years (UN/DESA, 2015). In 2017, all the Italian regions, except Bolzano and Campania, had more than 20% of their residents over 65 years old (calculated with respect to its region's population). Nevertheless, all the country's regions will observe the percentage of the older people to grow in the future. The projections of the Italian National Institute of Statistics (ISTAT) for 2030, reveal a tendency of more than 25% that even approaches 31% in the case of Liguria (Table 1.1). The policymakers have to consider seriously the demographic propensity during the processes of decision making, as it is expected to create an inevitable shift to the public policy priorities and initiatives. Considering these challenges, Section 3.2 and Chapter 4 of the thesis provide policy directions based on the empirical elaboration of data from Italy.

The topic of ageing might be approached under the prism of a wide range of angles. From a purely economic aspect, a substantial burden will emerge for the health care and pension systems, coming from the economic support of an increasing unproductive segment of the population (Abdullah et al., 2018; Aguiar and Macário, 2017; Metz, 2000). However, at the same time, the elderly could represent an important source of added value for the economy and several points are raised for their contribution, e.g. through the daily consumption expenditures, the participation in the employment sector (as the pension limits are going up), the participation to voluntary societal activities, the provision of assistance with childcare and the contribution to the taxation system (Mackett, 2015; Banister and Bowling, 2004). Other highly relevant parts that need to be included in this discussion, are the increased needs for age-related consumer products and services, the smooth community incorporation of the elderly people and the awareness for the environmental sustainability, as the car use is increasing substantially among the older adults (Aguiar and Macário, 2017; Metz, 2000).

Whereas in the past it seems that the issue of the ageing populations has been left in the margins, nowadays, more and more actively the scientists and the policymakers are showing their attention (Aguiar and Macário, 2017). The topic is characterised as multidisciplinary and requires the collaboration of the researchers of different disciplines, e.g. health sciences, psychology, technology, urban planning, sociology, economics and transport in order to work on the phenomenon from diverse points of view, (Chikaraishi, 2017).

Table 1.1 *Percentage distribution of the over 65's in the Italian regions (Author's elaboration, data ISTAT* http://dati.istat.it/Index.aspx?QueryId=18462*)*

Geographical Distribution	Region	% of elderly 2017	% of elderly 2030	Net result
Islands	Sardinia	22,67	30,20	7,54
South	Campania	18,20	24,19	5,99
South	Basilicata	22,28	28,17	5,88
South	Puglia	21,34	27,12	5,78
South	Calabria	20,93	26,41	5,49
North-East	Veneto	22,34	27,67	5,33
Islands	Sicilia	20,56	25,80	5,24
Center	Lazio	21,18	26,24	5,06
North-West	Valle d'Aosta	23,19	27,75	4,56
North-East	Trento	21,42	25,97	4,55
South	Molise	23,96	28,27	4,31
North-East	Bolzano	19,29	23,53	4,24
South	Abruzzo	23,27	27,42	4,14
North-West	Lombardy	22,18	26,11	3,93
North-East	Friuli-Venezia Giulia	25,74	29,61	3,88
North-West	Piedmont	25,04	28,88	3,84
Center	Marche	24,31	28,01	3,71
Center	Umbria	25,07	28,62	3,55
North-East	Emilia-Romagna	23,75	27,26	3,51
Center	Toscana	25,11	28,55	3,44
North-West	Liguria	28,35	31,23	2,88

1.3.2 Introducing the framework of Active and Healthy Ageing

Ageing is an evolving process (Klein-Hitpaß & Lenz, 2011). Notably, the meaning of getting older does not coincide with that of ageing. While getting older is just the clear increase of the chronological age as a quantitative measure, ageing is getting older at variable rates (Cooper, 2006). The perceptions about the older people have changed through the decades, from being highly experienced persons to be deemed as unproductive members of the community (Klein-Hitpaß and Lenz, 2011).

It is a fact that there are plenty of studies about the elderly people coming from scholars from very diverse scientific backgrounds. One common element to be recognised in all such papers is that the researchers have not defined yet the profile of a typical older person (Mein et al., 2014; Klein-Hitpaß and Lenz, 2011). This observation consists an obvious limitation for the accurate comparison of the results presented in the literature. Generally, the scholars (Klein-Hitpaß and Lenz, 2011) define as old, someone who has retired. However, others (Sproule, 2011) define as old someone who is near or has surpassed the average life span. Based on that idea and given that life expectancy is not similar for all the countries, WHO (2015) discriminates the meaning of ageing in developing and developed areas. According to that cut-off, the developed countries follow the age of 65 years old and the developing 50-55 years old. On the other hand, the organization of the United Nations has not adopted a specific numerical age value, according to the level of country growth, but generally uses the limit of 60+ years old. Finally, additional argument of high heterogeneity is apparent in the subgroup categorization of the elderly people. As such, a few studies (Choo et al., 2016) divide senility in early-old age (65-69 years old), middle-old age (70-74 years old), old age (75+ years old) and other (Klein-Hitpaß & Lenz, 2011) in early-old age (65-75 years old), middle-old age (75-85 years old) and old age (85+ years old).

Nowadays, since many older people live in urban areas, they require spaces and places that compensate them for the physical and social changes associated to ageing. An age-friendly neighbourhood that facilitates mobility and plays important role for the QoL of the elderly requires to have some specific characteristics. Pinto and Sufineyestani (2018) reviewed the relevant literature and provide an extensive list of requirements. They might range from the infrastructures of the built environment, e.g. cycle paths, parking and

green areas, distance from transport stations, to the availability of services e.g. supermarkets, banks, post offices, etc. Notably, Mariotti et al. (2018) analysed data from 129 community-dwelling elderly people living in 11 neighbourhoods of the city of Milan (Italy) and found that the majority of the elderly confessed not only being satisfied with their living environment but, also, preferring to age in place.

Officially, the approach of *active ageing* was first developed by the WHO in 2002 (WHO, 2018). The WHO (2007) defines active ageing as the process of optimizing opportunities for health, participation and security in order to enhance the quality of life (QoL) as people age. However, there is no consensus between the scholars on what is implied by active ageing (Johnson et al., 2017). It is related to a number of factors including both material and social which can play a key role on the individual's feelings and behaviour during the age phase of his life (WHO, 2007). The guide of the WHO (2007) about the age-friendly cities, spots eight basic domains of daily life that should be adjusted for the elderly's needs. These are the: (1) built environment, (2) transport, (3) housing, (4) social participation, (5) respect and social inclusion, (6) civic participation and employment, (7) communication, and, (8) community support and health services.

The active ageing concept has been supported until 2015 when it was replaced by the approach of *healthy ageing*. Actually, this new framework prioritizes the enhancement of functional ability by actively encouraging all relevant sectors work together (WHO, 2018). Both approaches were the inspiration for the development of the age-friendly cities, which are essential to promote the well-being of the older citizens (WHO, 2007). The age-friendly cities are those which provide care to the elderly and, at the same time, help them keep their independence (WHO, 2015). In order to promote this vision, the WHO Global Network of Age-friendly Cities and Communities was established in 2010. Its expansion was impressive from 11 cities in January 2010 to 760 cities and communities in January 2018 (WHO, 2018).

Even at the European level the ageing of the population has attracted significant attention. In 2012, the European Commission together with the United Nations Economic Commission for Europe (UNECE) defined active ageing and created the *Active Ageing Index (AAI)* as an assistive tool for the policymakers to evaluate the challenges of ageing (European Commission, 2013). In this context, active ageing is defined as the situation

where people continue to participate in the formal labour market, as well as engage in other unpaid productive activities and live healthy, independent and secure lives as they age. The established AAI consists of four domains: (1) employment, (2) participation in society, (3) independent, healthy and secure living, and (4) capacity and enabling for active ageing. Given that Chapter 3 of the thesis focuses on the public transport services, we underline that contrary to the approach of the WHO to ageing, the AAI is not explicitly addressing the transport system as part of its measurements but implicitly through accessibility to services and society participation.

As demonstrated above, the frame of healthy ageing is a widely accepted and consulted guide by the International organizations and European bodies of policy making. In line with this tendency in the ageing policy sphere, the approach of healthy ageing has been adopted as the theoretical context of the thesis and further enriched with targeted research on selected topics. More specifically, in Chapter 2 we refer to physical capability to be mobile and in Chapter 3 to the public transport services as the means of facilitating the human movements. Finally, in Chapter 4 we refer to the Internet as an element of healthy ageing. It should be noted that the scholars have identified various possible mechanisms of connection Internet with healthy ageing, e.g. improving dementia for these elderly with mild to moderate pathology levels (van de Wardt et al., 2012), promoting communication and social connectedness (Kim et al., 2016) and/or facilitating remote access to the healthcare services (Du Preez and De La Harpe, 2019). Therefore, it is crucial to comprehend the relationship of the elderly people with the Internet (what they do through it and what challenges they are facing that do not allow them to use it frequently) as is the topic of Chapter 4 of the thesis.

Abbreviations

AAI	Active Ageing Index
ISTAT	Italian National Institute of Statistics
OECD	Organisation for Economic Co-operation and Development
QoL	Quality of Life
UNECE	United Nations Economic Commission for Europe
UN	United Nations
WHO	World Health Organization

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CHAPTER 2

MOBILITY

2. Introduction

This chapter treats the research topic of the elderly mobility, as one of the key elements for healthy ageing. The purpose of this Section of the thesis is to synthesize critically the literature about mobility-related topics, identify research gaps in the existing literature and provide future research directions. Hence, more specifically, the first part of the Chapter (Section 2.1) gives some definitions of mobility (Section 2.1.1), describes existing theoretical mobility models (Section 2.1.2) and empirical applications of them (Section 2.1.3), provides a presentation of what needs to be taken into consideration by the researchers when studying elderly mobility from a more holistic viewpoint (Section 2.1.4) and synthesises critically the literature that connects mobility with well-being and quality of life (QoL) (Section 2.1.5). Finally, the second part of the Chapter (Section 2.2) refers to a systematic literature review where the intermediate links of the elderly mobility with well-being are investigated and, in the same time, they are classified on the basis of elements inspired by the Active Ageing Index (AAI). Notably, in Section 2.2 we attempt to illustrate why mobility is crucial for the aged individuals and where exactly it plays a key role in their life. This goal is accomplished through the collection of all the evidence found in the scientific literature, as it is the purpose of the systematic literature review methodology that we followed.

2.1 Some theoretical reflections

2.1.1 Terminology and definitions of mobility

The mobility of the elderly people is a research topic that is studied separately by researchers from a variety of disciplines and subfields of them. Nevertheless, a multidisciplinary approach has the advantage to reveal several aspects of the topic that otherwise may remain hidden (Murray, 2015). Given the focus of each scholar when studying elderly mobility, we stress that although all researchers are talking about this topic, in reality, it is not conceived on a similar perspective. We found that in the scientific literature the terminology exhibits substantial variation. Figure 2.1 presents a sample of the diversity of the terms that can be found in the literature. Additionally, more details about the exact matching of mobility measures used by the researchers with their terminologies is provided in Tables 2.1, 2.2 and 2.3, and also, the matching is divided on the basis of the disciplinary-specific perspectives. We should underline that the diversity

of the vocabulary presented in this Section, has been mainly extracted by the included papers in the systematic review of Section 2.2 and complemented with a few definitions that has been identified while studying the literature about elderly mobility. As such, Section 2.1.1 can offer us only insights about the terminology used by the researchers when discussing the topic. It cannot be considered an exhaustive list, considering the selection criteria used for the inclusion of the papers in the systematic review and the scope of the study. Thus, further research in the future could build on the current basis and enrich the vocabulary that is collected here.

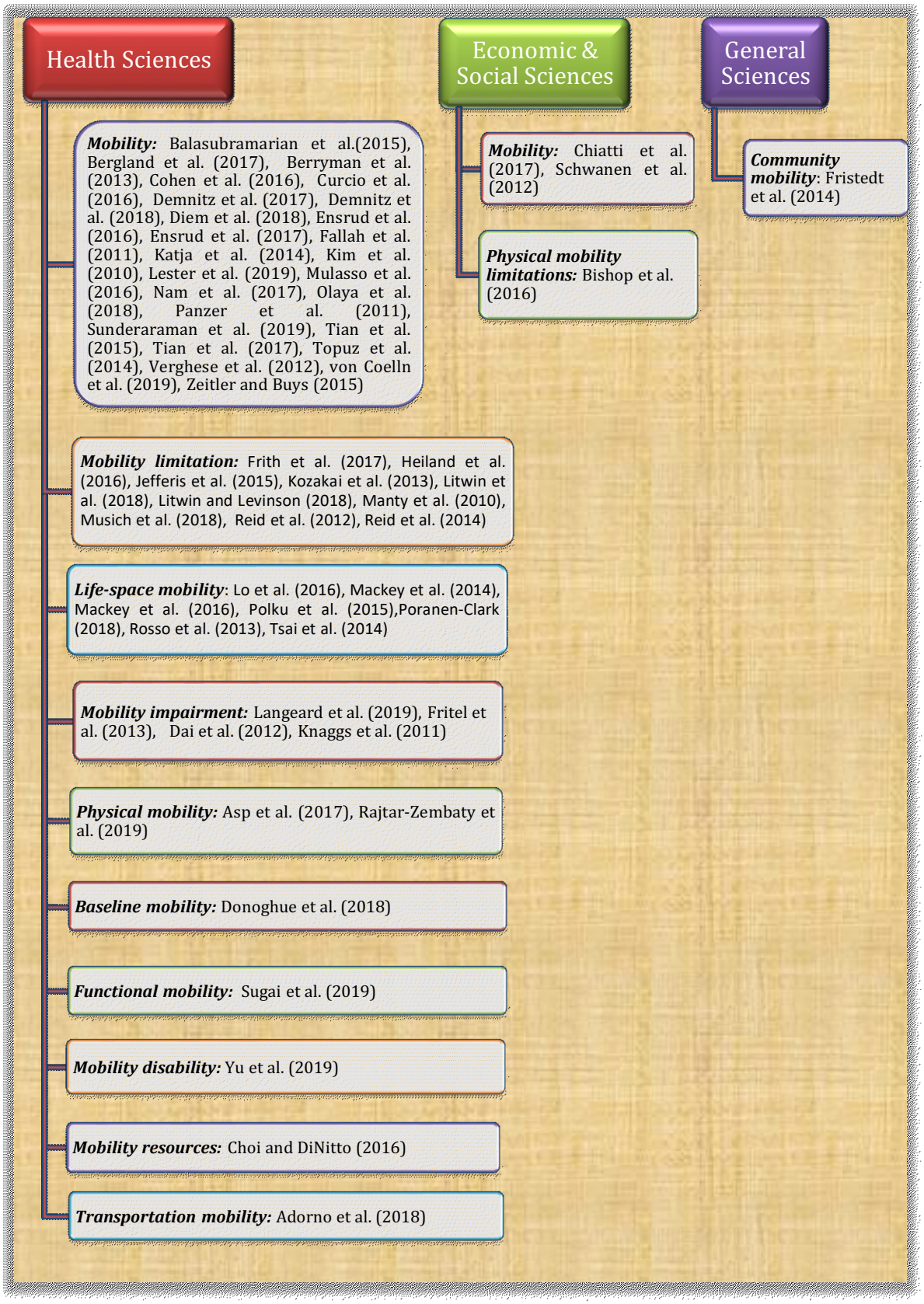
Health sciences

Whereas the generic term *mobility* is used across almost all the disciplines, instead, we notice how a quite various collection of *mobility* interpretations referring to the elderly's ability to move occurred among researchers, especially within the domain of health sciences (See Table 2.1 for more precise information). The language used in health sciences betrays that the scope of the research is basically to investigate the capability of the elderly to be mobile or, in some cases, to assess the hardships that discourage the elderly from the physical movement. Thus, *mobility* in such terms, is appraised through medical tests: Performance Oriented Mobility Assessment (POMA), Timed Up and Go (TUG), Short Physical Performance Battery (SPPB), walking time in order to cover various distances, time in seconds required to keep a balanced position and self-reported mobility measurements, where the older people are asked to assess their capabilities to walk indoors, outdoors, and climb stairs.

Additionally to the most commonly met term of *mobility*, other types of mobility were found in the health-targeted literature. Specifically, the assessment of *mobility limitation* has been performed through self-reported answers among a list of mobility difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, the SPPB test, the measurement of the one-leg balance stand test and the walking speed[1]. Another characterisation of mobility in the scientific literature is that of *life-space mobility.* For its evaluation, it has been adopted by the scholars the methodology proposed by Baker et al. (2003) or a slightly modified version of it in Rosso et al. (2013). Baker et al. (2003) measures mobility based on self-reported questions regarding the movement to specific life-space ''levels'' ranging from within one's house to beyond one's town, the frequency of movements and the use of assistance (i.e. equipment or persons). All

[1] In Heiland et al. (2016) it has been used the cut-off of walking distance less than 0.8 m/s on a 2.4 or 6 meters in order to characterize an individual as mobile limited.

Figure 2.1 *An indicative multidisciplinary wordbook of mobility (Authors' elaborations)*



the information collected are combined to a composite measure called the *composite measure of life-space (LS-C).*

For the appraisal of *mobility impairment,* the tests included a timed 6-meter walk test, the TUG test, a test measuring the time taken to get up from a chair and sit down again five times without using the arms, self-reported difficulties in walking ¼ mile, getting up from a chair, climbing a flight of stairs, or performing light housework and assessment of mobility scores (i.e. Gait Composite Score, Balance Composite Score and Physical Capacity Score). As regards *physical mobility,* it has been tested through the question 'Can you walk upstairs without difficulty (for example getting on a bus or a train)?' and 'Can you take a short walk (about five min) at a reasonably fast pace?' The participant was considered having physical mobility if he/she answered yes to both questions. More, other researchers applied the TUG test and the 6 Minute Walk Test. The *baseline mobility* was evaluated through TUG test, Usual Gait Speed (UGS) test, and Dual-task Gait Speed test (DTGS). For the *functional mobility, it* was mainly used the TUG test while for m*obility disability,* the gait speed (time to walk 2.4 meters at usual pace).

Finally, although the effects of urban transport and/or travel habits were excluded from the review, from a public-health perspective, an article about *transportation mobility* was found which refers to the general perception of utility coming from the access to destinations for the elderly. Additionally, other than the terminology explained so far, in health sciences researchers have evaluated the *mobility resources* by questioning the persons about how (other than driving) they got to places outside their home during the preceding month. They could choose more than one of the following means: (a) getting a ride from a family member, friend, or someone paid to help, (b) walking or using a wheel chair or scooter, (c) taking public transportation, (d) using a van or shuttle service provided by the place where the sample persons lived, (e) using a van or shuttle service for seniors or disabled persons, (f) taking a taxi, and (g) using other means.

Table 2.1 *Mobility vocabulary and measurement tools in health sciences (Author's elaborations)*

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility	Public Health & Health Services	TUG, DGI, SPPB, and CB&M	Predicting falls for ambulatory community-dwelling older adults requires assessments both of mobility and balance and targeting cutoff scores. CB&M scale identified both fallers and recurrent fallers on the basis of their fall history while (CB&M, ABC, DGI, and BBS) discriminated recurrent fallers from those with fewer or no falls.	Balasubramanian et. al (2015)
Mobility	Public Health & Health Services	TUG test	TUG test is a valid measure of mortality for both genders.	Bergland et al. (2017)
Mobility	Public Health & Health Services	TUG test and 10m walking test	Faster individuals in the mobility tests used demonstrate higher neuromuscular performances as well as higher aerobic capacity and better cognitive flexibility.	Berryman et al. (2013)
Mobility	Clinical Medicine	TUG test	Deficits in visuomotor performance were associated with slow TUG performance, whereas verbal episodic memory deficits were associated with less upright posture.	Cohen et al. (2016)
Mobility	Public Health & Health Services	POMA	Tinetti Mobility Test score, together with muscle strength and evaluation, can preventively detect sarcopenic elderly subject at risk of falls.	Curcio et al. (2016)
Mobility	Clinical Medicine	Walking time (2.44 m) course, balance time in one-legged stand (cut-off 30s) and chair stands tests	The objective measures of mobility used related poor mobility to poorer cognitive function, e.g. processing speed, markers of decreased GMV and white matter microstructure.	Demnitz et al. (2017)
Mobility	Clinical Medicine	Walking time 4 m course, balance time in one-legged stand (cut-off 60s) and chair stands tests	Cognitive measures were significantly associated with mobility measures.	Demnitz et al. (2018)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility	Public Health & Health Services	Walking speed (m/s) at 6 m	Mobility and cognition in community dwelling older women are each strong independent predictors of the maintenance of independence i.e. living in the community and performing most basic ADLs without assistance.	Diem et al. (2018)
Mobility	Public Health & Health Services	SPPB	There was not strong evidence of an interaction between mobility and cognition for prediction of mortality risk. Mortality risks were increased among women with intermediate and poor after considering cognition and other mortality risk factors.	Ensrud et al. (2016)
Mobility	Public Health & Health Services	SPPB	Reduced mobility and poorer cognition were each associated with higher inpatient health care utilization.	Ensrud et al. (2017)
Mobility	Clinical Medicine	Rapid gait test: back-and-forth walk over the 20-ft course as quickly as possible	Mobility was significantly associated with frailty status, but not with mortality.	Fallah et al. (2011)
Mobility	Public Health & Health Services	Self-reported information – Questions on ability to walk indoors, outdoors, and climb stairs	Mobility mediated part of the association between social activity and mortality.	Katja et al. (2014)
Mobility	Clinical Medicine	TUG test, 5-chair STS test, alternate step, TRG test, UGS test	The four mobility performance tests, except the 5-chair STS, proved to have the potential of discriminating the older women at high and low risk of frailty. The TRG test, at the cut point of 6 s, had the highest sensitivity and specificity in identifying high risk of frailty.	Kim et al. (2010)
Mobility	Clinical Medicine	SPPB, FSST, gait speed and DeMMI	The worse an older person's objectively measured mobility scores, the greater their use of community services to remain living in their rural community.	Lester et al. (2019)
Mobility	Public Health & Health Services	TUG test	The Tilburg Frailty Indicator was significantly associated with falls whereas the TUG test not.	Mulasso et al. (2016)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility	Public Health & Health Services	POMA and self-reported information – If help is needed from another person or special equipment or a device for a walking across a small room	The assessment of mobility using POMA and ADL tests is an effective predictor of mortality.	Nam et al. (2017)
Mobility	Public Health & Health Services	Self-reported information – Difficulties in the previous 30 days in 15 different mobility-related situations	High physical activity and mobility levels are both significant predictors of survival among older adults, and their effects are independent of physical, cognitive, and mental health functioning.	Olaya et al. (2018)
Mobility	Public Health & Health Services	Composite scores of individual mobility variables such as quiet standing, maximal lean, sit-to-stand, gait, turn, step-in-tub and downstairs	Mobility measurement variable sets distinguished falls-status and showed the same results POMA and Computerized Dynamic Posturography Sensory Organization Test.	Panzer et al. (2011)
Mobility	Clinical Medicine	TUG test and Gait assessment	Among healthy individuals, relatively lowered cognitive performance may be linked to increased risk of gait alterations during the performance of these complex motor functions, or that lowered cognition may represent a higher vulnerability to gait disturbances. The study does not support the cause-effect relationship due to cross sectional nature of the data.	Sunderaraman et al. (2019)
Mobility	Public Health & Health Services	400-m walk test and usual gait speed for a 6-meter course	Higher lap time variation may be an early indicator of executive function decline independent of mean lap time.	Tian et al. (2015)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility	Clinical Medicine	400-m walk test and, usual gait speed to the nearest 0.1 second was measured or on a 6-meter course. The average speed in m/s over two trials was used for analyses	Among initially unimpaired older adults, the temporal relationship between usual gait speed and executive function is bidirectional, with each predicting change in the other, while poor fast walking performance predicts future executive function and memory changes but not vice versa.	Tian et al. (2017)
Mobility	Public Health & Health Services	TUG test, Timed Chair Stand test, Functional Reach test, One-Leg Balance test, and lower limb muscle strength	The mobility and activity levels of the elderly living in a retirement village and in community were found to be significantly different, in terms of falling and fear of falling, there were no remarkable differences. Therefore, the life status should be considered in order to reach safe conclusions.	Topuz et al. (2014)
Mobility	Clinical Medicine	WWT test, Speed (cm/s) during normal pace walking, SPPB	The WWT test is a robust predictor of risk of frailty, disability, and mortality in high-functioning older adults. Comparing WWT with SPPB, the first may better predict frailty whereas the second may better predict disability.	Verghese et al. (2012)
Mobility	Clinical Medicine	modified TUG, 32 ft. walk, Standing Posture	The mobility measures have potential to enhance risk stratification of older adults who may develop Parkinson.	von Coelln et al. (2019)
Mobility	Public Health & Health Services	GPS tracking and daily travel diaries	Age-friendly means of transportation enhance older people's activity engagement in community. The findings also suggest the need for further research into this relationship between transportation and participation within the community environment.	Zeitler and Buys (2015)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility limitation	Clinical Medicine	Self-reported information – Difficulty walking without special equipment use; walking 0.25 miles (to convert to kilometer, multiply by 1.6); walking 10 steps without stopping; stooping, crouching, or kneeling; walking from one room to another on the same level; standing up from an armless straight chair; or standing or being on their feet for 2 hours	Individuals suffering both from reduced cognition and mobility were at the highest risk of all causes of mortality. These presenting either cognition or mobility deficit are also at risk of mortality. Comparing the groups (either cognitive or mobility deficits with the co-existence of pathologies group) no statistically significant results arise.	Frith et al. (2017)
Mobility limitation	Clinical Medicine	One-leg balance stand and assessment of walking speed (m/s) of 2.4 or 6 m walk	Mobility tests can indicate hierarchical risk of disability in older adults.	Heiland et al. (2016)
Mobility limitation	Clinical Medicine	Self-reported information – Reported grade of difficulty (no difficulty vs some difficulty, moderate difficulty, severe difficulty) getting about outdoors	Associations between baseline physical activity levels (step counts, sedentary time, light PA, and MVPA) and number of falls differed y presence of mobility limitations.	Jefferis et al. (2015)
Mobility limitation	Clinical Medicine	Self-reported information-Difficulty in walking 2 km and climbing one flight of stairs without resting	Mobility limitation (vs. intact mobility) at 5.8 years prior to death markedly increases the need of inpatient care in the last year of life among men.	Kozakai et al. (2013)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility limitation	Public Health & Health Services	Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	Social networks are especially important in the promotion of activity participation among older adults with mobility limitations. The co-presence of mobility limitation and social isolation brings this group in a more disadvantaged position compared to only mobility limited elderly.	Litwin and Levinson (2018)
Mobility limitation	Public Health & Health Services	Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	Fear of falling predicts falling only for the elderly who present low to moderate mobility limitations while for highly limited elderly it is not the case.	Litwin et al. (2018)
Mobility limitation	Clinical Medicine	Self-reported information – Perceived difficulty and task modification in advanced mobility regarding the 2-km walk	Indications of mobility decline together with history of falls increased the risk of future falls.	Manty et al. (2010)
Mobility limitation	Clinical Medicine	Self- reported information - Questions on difficulties with walking or climbing stairs	Moderate and severe limitations demonstrated significantly increased falls, decreased preventive service compliance and increased healthcare utilization and expenditures as mobility limitation severity increased.	Musich et al. (2018)
Mobility limitation	Clinical Medicine	SPPB	The contractile properties of surviving muscle fibers are maintained in older adults with overt mobility impairments in an attempt to preserve overall muscle function.	Reid et al. (2012)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility limitation	Clinical Medicine	SPPB	The major finding of this investigation is that lower extremity muscle power deteriorates at the same amount but with different physiological mechanisms over a 3-year interval in healthy and mobility-limited older groups.	Reid et al. (2014)
Life-space mobility	Clinical Medicine	LSA test (Baker et al., 2003)	Associations were found between neighborhood disadvantage and falls and between life-space and after controlling for relevant covariates.	Lo et al. (2016)
Life-space mobility	Clinical Medicine	LSA test (Baker et al., 2003)	Life-space mobility can be a predictor of the risk of mortality in addition to that provided by gait speed, which is widely recognized as the strongest physical performance predictor of mortality in older adults.	Mackey et al. (2014)
Life-space mobility	Clinical Medicine	LSA test (Baker et al., 2003)	Life-space scores of 60 or less were associated with mortality in older women independent of other strong risk factors.	Mackey et al. (2016)
Life-space mobility	Clinical Medicine	LSA test (Baker et al., 2003)	The associations between life-space mobility and different dimensions of depression were partially mediated through different factor. Differences appear between men and women in these associations. Cross sectional data are used thus not permitting to conclude on the temporal dimension.	Polku et al. (2015)
Life-space mobility	Public Health & Health Services	LSA test (Baker et al., 2003)	Since better EF at baseline predicted higher life space mobility at follow but baseline life-space mobility did not predict EF at follow-up the authors concluded that executive function was a determinant of life-space mobility.	Poranen-Clark et al. (2018)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Life-space mobility	Public Health & Health Services	LSA (Baker et al., 2013) modified	Low mobility is associated with low social engagement even in the absence of disability; associations with disability differed by type of social engagement.	Rosso et al. (2013)
Life-space mobility	Clinical Medicine	LSA test (Baker et al., 2003)	Participants with a restricted life space were less physically active and about 70% of them had exceptionally low values in daily step and moderate activity time.	Tsai et al. (2015)
Mobility impairment	Clinical Medicine	TUG test	Balance and mobility testing should be a priority in fall screening and the TUG is a good functional screening tool for mobility and fall risk.	Dai et al. (2012)
Mobility impairment	Clinical Medicine	TUG test, a timed 6-m walk test and a test measuring the time taken to get up from a chair and sit down again five times without using the arms	The study shows a strong proportional relationship between motor functional problems and urinary incontinence (urge urinary incontinence but not stress urinary incontinence) for the elderly women.	Fritel et al. (2013)
Mobility impairment	Clinical Medicine	Self-reported information – Difficulty in walking ¼ mile, getting up from a chair, climbing a flight of stairs, or performing light housework	Compared to normative values, metabolic costs of daily activities are substantially different in older adults and having mobility impairments increases this metabolic cost.	Knaggs et al. (2011)
Mobility impairment	Clinical Medicine	TUG test and Mobility Scores (Gait Composite Score, Balance Composite Score, Physical Capacity Score)	In older adults with fear of falling cognitive impairment significantly distinguishes fallers and non-fallers, whereas mobility impairment does not.	Langeard et al. (2019)

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Physical mobility	Public Health & Health Services	Self-reported information – Ability to walk upstairs without difficulty (for example getting on a bus or a train) and take a short walk (about five min) at a reasonably fast pace	Association between physical activity and obesity was found only among the physically mobile elderly and not among those with impaired mobility suggesting the existence of complexity between physical activity, physical mobility, and obesity.	Asp et al. (2017)
Physical mobility	Clinical Medicine	TUG test and the 6 Minute Walk Test	The results reveal that higher levels of global cognition were related to the better physical mobility performance after controlling for age, sex, body mass index, medication use, depressive symptoms, and health characteristics.	Rajtar-Zembaty et al. (2019)
Baseline mobility	Clinical Medicine	TUG test, UGS test, and DTGS test	Cognition did not variate much within the follow up period of 5.9 years, thus not permitting the association with mobility. Further research for longer periods is needed.	Donoghue et al. (2018)
Functional mobility	Public Health & Health Services	TUG test	The causes of kyphosis progression are not fully understood. However, this paper finds that the elderly who performed low at the TUG test, their incidence of kyphosis progression was 34.5%, whereas it was 11.4% among those with normal mobility.	Sugai et al. (2019)
Mobility disability	Public Health & Health Services	UGS test: time to walk 8 feet (2.4 m)	Mild cognitive impairment predicted mortality. Developing first mild cognitive impairment and then mobility disability doubled the risk of death. The reverse order did not affect the risk.	Yu et al. (2019)
Mobility resources	Public Health & Health Services	Self-reported information - How people (other than driving) got to places outside their home during the preceding month	Non-drivers who walked for transport had lower depressive symptoms than those who did not walk at either T1 or T2, and perception of transportation barriers to visiting friends/family was associated with higher depressive symptoms at T1 only.	Choi and DiNitto (2016)
Transportation mobility	Public Health & Health Services	Means of transport broadly	Transportation mobility facilitates independent living, accessibility to health care, goods, services, family involvement and social networks.	Adorno et al. (2018)

Economic and Social Sciences

When talking about the term *mobility,* the scientists in Economic and Social Sciences (Table 2.2), mean the actual and potential embodied movement through physical space (Schwanen et al., 2012) or consider mobility-related study variables i.e. ability to walk 500 meters or more, accessibility to private car, use of private car, bus stop distance from home and use of the public transport (Chiatti et al., 2017). Additionally, when considering *physical mobility limitations*, Bishop et al. (2016) refer to them through self-reported information (see Table 2).

Table 2.2 *Mobility vocabulary and measurement tools in Economic and Social Sciences (Author's elaborations)*

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Mobility	Economics & Business	Self-reported information – Frequency of walking 500 m or more, access and use of private car, bus stop distance from home and use of public transport	Higher physical and mental self-reported health is associated with walking more than 500 m on a daily basis, use of a private car and frequent engagement in social activities. Access to the car is only associated with physical health. Mental health scores are significantly lower among those living far from the closest bus stop and never using public transport.	Chiatti et al. (2017)
Mobility	Social Sciences	Actual and potential embodied movement through physical space	Independent mobility is a fuzzy concept and in this study it is conceived by the participants as avoiding lifts provided by next of kin, friends or others for getting around.	Schwanen et al. (2012)
Physical mobility limitations	Social Sciences	Self-reported information - Difficulty in stooping or crouching, climbing one flight of stairs without resting, climbing several flight of stairs without resting, moving large objects, sitting in a chair for two hours, getting up from a chair after sitting for long periods, lifting weights more than 10 pounds, raising arms above shoulder level, walking one block, walking several blocks, and picking up a dime	Better cognitive health was related to fewer mobility limitations, and faster decline in word recall was associated with more rapid increase in mobility limitations over the 10 years of aging observed.	Bishop et al. (2016)

General Sciences

In General Sciences (Table 2.3), the term *community-mobility* is used, associated with the response to the question "*Are you able to transport yourself to places beyond walking distance*", i.e., Community mobility (CM) by private or public transport, and including walking to and from the vehicle at origin and destination (Fristedt et al., 2014).

Table 2.3 *Mobility vocabulary and measurement tools in General Sciences (Author's elaborations)*

Mobility vocabulary	***Field***	***Mobility measure(s)***	***Findings***	***Author(s) (year)***
Community mobility	General Science & Technology	Self-reported information – Ability to transport yourself to places beyond walking distance", i.e., community mobility by private or public transport, and including walking to and from the vehicle at origin and destination	Community mobility among men was associated with higher ratings of subjective health for both genders. Men, on the one hand, reported more involvement in sport activities while women, more instrumental activities of daily living outside the home.	Fristedt et al. (2014)

Other definitions of elderly mobility

Apart from the mobility terminology, as it has been recorded so far in the previous paragraphs, while studying the literature about elderly mobility we have spotted a few other conceptualization directions. For the sake of a more comprehensive illustration, we propose grouping the definitions of mobility on the one hand to quite brief and simple, while on the other hand there are others complex attempting to cover the term from too many perspectives.

Some of the simple definitions attribute three dimensions to mobility, i.e. the space of movement, the purpose, and the supportive means that facilitate the displacement. For instance, in Banister and Bowling (2004) mobility is the ability to get out and about. Also, Musselwhite and Haddad (2010) highlighted that mobility is the amount of travel, whereas

Spinney et al. (2009) expressed it as the time voluntary spent outside of one's home. Additionally, Wallace and Franc (1999) adds the reason of moving as part of the mobility definition. According to that approach, mobility is the ability to move from one place to another for purposes of meeting personal, social, employment or recreational needs and desires.

In other cases of defining mobility, the means were found to be of high importance, either referring to a particular transport mode or, more generally, to transport means availability. In this sense, the definition provided by Webber et al. (2010) stresses not only the spatial dimension of mobility but also the means used to achieve mobility. Thus, it is defined as the ability to move oneself (either independently or by using assistive devices or transportation) within environments that expand from one's home to the neighbourhood and to the regions beyond. Accordingly, Fristedt et al. (2014) define mobility as moving (ones) self in the community and using public or private transportation. Furthermore, Windle and Burholt (2003) consider mobility of older people in the context of transport opportunities and provision. Finally, in Aguiar and Macário (2017) mobility is characterised by the capacity to travel by all modes of transport, including walking, cycling, driving his own vehicle or use the public transportation.

As the factors that affect mobility are characterised by complexity, the concept of mobility is better understood multidimensionally (La Grow et al., 2013; Webber et al., 2010). A few definitions of mobility aimed at capturing its complexity. In Prohaska et al. (2011), all the three aforementioned aspects of mobility (i.e. space, purpose and means) are considered. As such, mobility implies the movement within and between environments and includes transferring from bed to chair, walking, engaging in leisure activities, biking, driving and using different means of transport. Feeling mobility as a human experience, Metz (2000) argued that it captures the specific five elements:

- travelling to achieve access to desired people and places;
- psychological benefits of movement i.e. "getting out and about";
- exercise benefits;
- involvement in the local community - yielding benefits from informal local support networks;
- potential travel - knowing that a trip could be made even if it is not actually undertaken.

Considering the several aforementioned approaches to define mobility, a quite clear observation that emerges is the evident diversity of terminology and mobility definitions used by the scholars. However, working towards an accurate conceptualization of a universally operational definition will yield two benefits (Metz, 2000). First, it will allow the precise measurement of mobility decrease as people age. Mobility may be a more representative predictor (with respect to the Activities of Daily Living (ADL)) of the disabilities experienced by the older people and lowers the older people's QoL (Fagerström and Borglin, 2010). According to Wallace and Franc (1999), whereas in the geriatric and gerontological literature, mobility is often confused with disability[2], instead, in the literature of disabilities among older persons, mobility is mainly used to indicate ambulation or other lower extremity activities such as transferring from a bed to a chair within a room, walking across a room, climbing stairs, jogging, moving furniture, and so on. Mobility, in this context of *disability*, is characterised as mobility impairment and it is defined as the disabilities that affect the ability to move, manipulate objects, and interact with the physical world (Esmat and Hussein, 2012). Furthermore, in medicine it is often called *impaired physical mobility* a state in which the individual experiences, or is at risk of experiencing, limitation of physical movement but is not immobile (de Paula et al., 2013).

Secondly, a well-defined mobility term will permit the evaluation of the impact of mobility-related measures in order to improve the movements of the elderly. Mobility limitations are related to a variety of unwanted health outcomes in later age. A very recent review on this matter (Freiberger et al., 2020) found that mobility restrictions are quite common for about 35% of the 70's and for most of the over 85's.

Finally, regarding both reasons mentioned above. as it is underlined in the literature that mobility is related to increased fall risk, hospitalization, decreased QoL, and even mortality, being able to assess the impact of the adopted therapies, we can get insights about which is the most effective approach to follow. More, if the definition/conceptualisation of mobility starts from the same underpinnings, the comparison of the studies could be rendered more valid.

[2] The authors use the disability definition of the WHO (1993): abnormalities in the function of limbs or other body parts due to illnesses or anatomic abnormalities.

2.1.2 Theoretical mobility models

Additionally to the terminology diversity of elderly mobility, the absence of inclusive theoretical foundations is firmly underlined in the literature. Usually, the issues that are evolving around it are discipline specific *(*Webber et. al, 2010*).* Nevertheless, there have been limited noteworthy attempts to build some theoretical models, briefly presented in Table 2.4. All these efforts share a common goal: to determine key factors and drivers of mobility.

A very frequently cited model in the elderly mobility literature is that of Webber et al. (2010) (Figure 2.2). With the aim to depict a conceptual mobility framework in gerontological studies, the authors developed a model in which the elderly mobility aspects are represented with a conical form. The cone is divided into horizontal pieces and every horizontal slice is devoted to a different sector/domain of the physical space. Within each physical space level, different aspects (i.e., financial, psychosocial, environmental, physical, cognitive, gender, cultural and biographical) are investigated. Thanks to this structure, the model manages to capture the heterogeneity and complexity of the factors affecting elderly mobility. However, using exclusively as a criterion of the assessment the perspective of travel needs' satisfaction, the model has been criticised by Musselwhite and Haddad (2018) as being mainly focused on utilitarian transport needs rather than higher order daily demands e.g. independence, self-esteem or life enjoyment.

Table 2.4 *Theoretical models of mobility and empirical testing of them*

Author(s)	***Model description***	***Mobility determinants***	***Results empirical testing***
Franke et al. (2019)	The authors extend the model of Webber et al. (2010). The principal factors of mobility are classified to three large categories: (a) contextual, i.e. economic, environmental and cultural factors, (b) subjective, i.e. personal psycho-related factors and norms, and (c) physiological, i.e. physical health status conditions.	Contextual (i.e. economic, environmental and cultural factors), subjective, (i.e. personal psycho-related factors and norms) and physiological, (i.e. physical health status conditions).	Not Tested
Musselwhite and Haddad (2018)	Extended version of Musselwhite and Haddad (2010) model with the sole difference that the aesthetic needs have been further disaggregated to kinaesthetic mobility (i.e. just being mobile) immersive mobility (i.e. to reach beauty) and imaginative mobility (i.e. recalling mobility).	The level of needs' satisfaction: primary (or utilitarian), secondary (or affective) and tertiary (or aesthetic defined as kinaesthetic, immersive and imaginative).	Not Tested
Musselwhite and Haddad (2010)	The model is built on the hierarchy of elderly needs satisfied through mobility. Three levels of needs are identified: primary, secondary and tertiary, the motivations/reasons for mobility rather than the capabilities of the elderly, or the wider environmental context in which they are called to move and satisfy their needs.	The level of needs' satisfaction: primary (or utilitarian), secondary (or affective) and tertiary (or aesthetic).	Not Tested
Musselwhite (2016)	The design is rooted in the ecological models' approach. An age-friendly transport system needs to examine at first place individual factors, like the health conditions, the needs and motivations, then, to consider the neighbourhood characteristics, afterwards, the accessibility of the public transport, and finally, all of the aforementioned elements need to be derived from properly outlined public policy planning.	The transport mobility of the older people is affected by individual factors (e.g. health conditions), their needs and motivations, the neighbourhood characteristics, the accessibility of the public transport, and finally, the public policy planning.	Not Tested
Ormerod et al. (2015)	The model has been inspired from the ecological models. The individuals are surrounded by four subsystems: the microsystem, the mesosystem, the exosystem and the macrosystem. All the four systems are placed on the chronosystem axis.	Microsystem contains all the factors that affect directly the individuals (i.e. family, peers, built environment), mesosystem refers to the connections of two types of mesosystem, exosystem regards the regulation (i.e. policy, rules, laws), macrosystem (i.e. customs and ideologies of culture) and the chronosystem captures the variations of time.	Not Tested
Webber et al. (2010)	The model is represented graphically by a conical form. The cone is divided into 7 horizontal pieces which depict the levels of the physical space, i.e. room, home, outdoors, neighbourhood, service community, surrounding area and world. Every horizontal slice is split into 6 determinant factors, i.e. financial psychological, environmental physical, cognitive, and gender, cultural, and biographical influences.	Financial, psychosocial, environmental, physical, cognitive, and gender, cultural, and biographical influences.	Meyer et al. (2014): Personal and community mobility are separately related with all drivers of mobility. When both mobility types were incorporated in the same model, psychosocial and financial variables are not statistically significant. Ullrich et al. (2019): The older adults who suffer from cognitive deficiencies presented restricted mobility space with respect to the healthiest elderly.

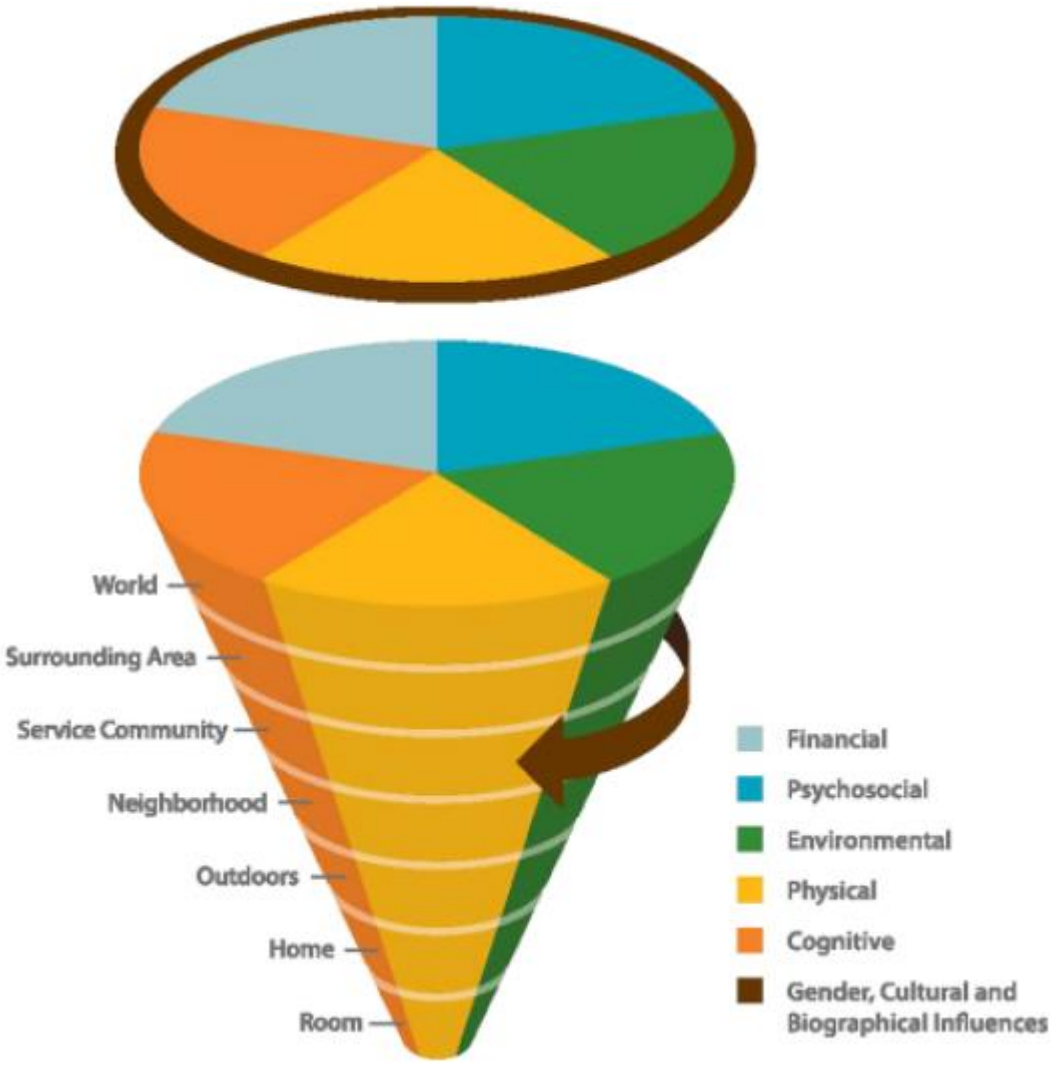


Figure 2.2 *Webber et al. (2010) model*

An adapted version of the Webber et al. (2010) model is developed by Franke et al. (2019). Whereas this model loses the conical depiction, instead it builds further on the determinants' level representation. The factors influencing the elderly mobility are elaborated in depth and some extra are added. Here, the segmentation of the key factors of mobility is done with respect to three large categories: (a) contextual, i.e. economic, environmental and cultural factors, (b) subjective, i.e. personal psycho-related factors and norms, and (c) physiological, i.e. physical health status conditions. Taking into consideration the role of ageing on changing the strength of the main factors in each space level, certain age discrimination points are added to show the younger, adult and aged life periods.

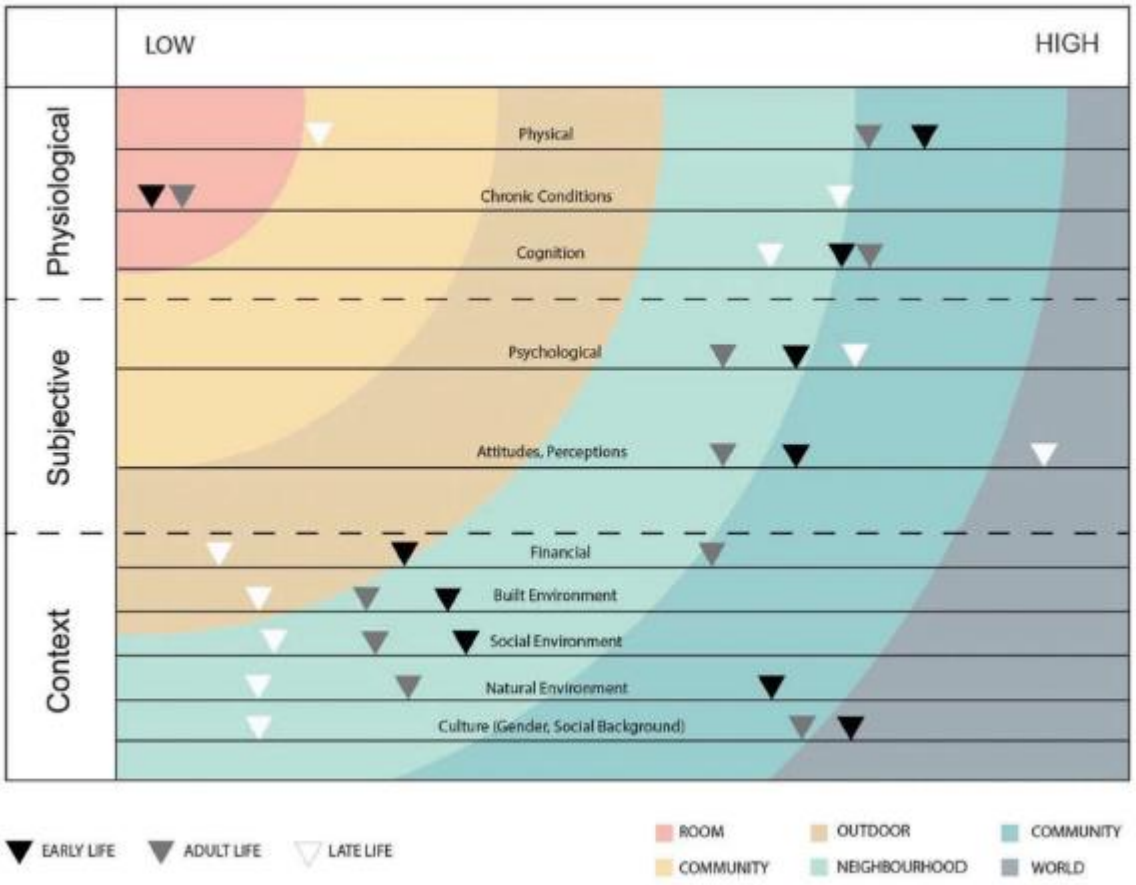


Figure 2.3 *Franke et al. (2019) model*

By advocating the transferability of their model in different disciplines and for various participants groups, the authors suggest the adoption of a more precise arithmetic time spectrum of mobility, ranging from a scale between 1 and 10, positioned with respect to the life course of the elderly people. More specifically, it means that the authors suggest for further research the substitution of the early, adult and late life with more precise measurement as it is the numbering of the life course from 1 to 10. This extension will place elderly mobility to a more individual specific level and will illustrate exactly its evolving nature.

Keeping a purely transport approach, Musselwhite and Haddad (2010) built on the hierarchy of needs satisfied by the elderly mobility. Their idea forms three levels of priority for the travel needs: primary, secondary and tertiary (Figure 2.4).

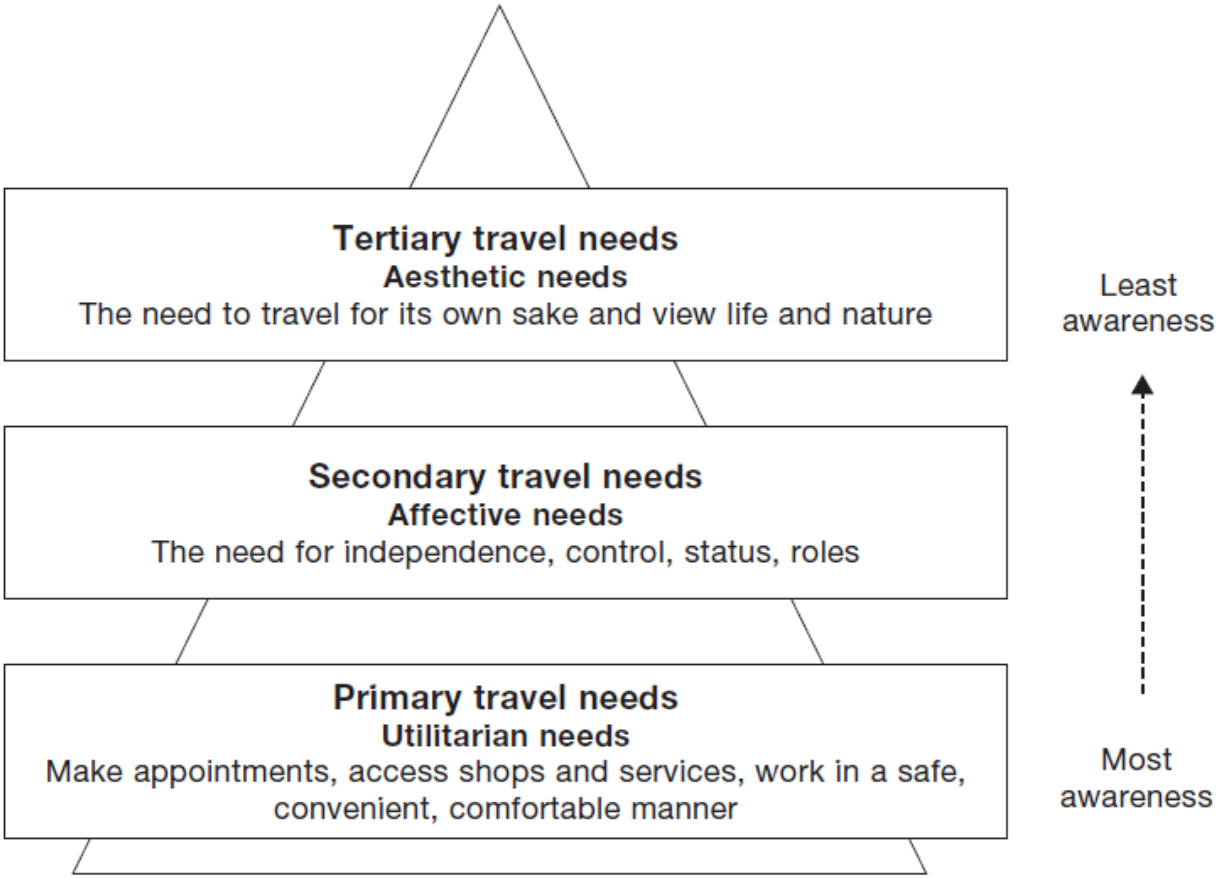


Figure 2.4 *Musselwhite and Haddad (2010) model*

As primary (or utilitarian) mobility needs, they consider those that aim to cover basic daily survival needs like access to local food shops and services, going to work, visiting friends and making medical appointments. The secondary (or affective) travel needs fulfil the need for independence, control, status and roles. Finally, the tertiary (or aesthetic) level covers just the need to travel for its own sake to enjoy life and nature. Their approach focuses on the motivations/reasons for mobility rather than the capabilities of the elderly, or the wider environmental context in which they are called to move and satisfy their needs. Despite the notional utility of the theoretical base of the model, it cannot be considered an inclusive theoretical model, as this work does not consider time-based elements and the dynamic dimensions of mobility in later life. Thus, it would need further extensions and research with the scope to take into account the complexity of mobility.

Ten years after the introduction of the Musselwhite and Haddad (2010) model, the authors evaluated its use in the literature during this period (see Musselwhite and Haddad, 2018). The feedback collected from the implementation of the model in different contexts (rural/urban

country-specific, transport mode used) yielded directions for future research and an adapted version emerged (Figure 2.5). Hence, the authors judged that the aesthetic needs require further disaggregation as follows:

1. kinaesthetic mobility: interpreted as just being mobile;
2. immersive mobility: to reach beauty;
3. imaginative mobility: recalling mobility.

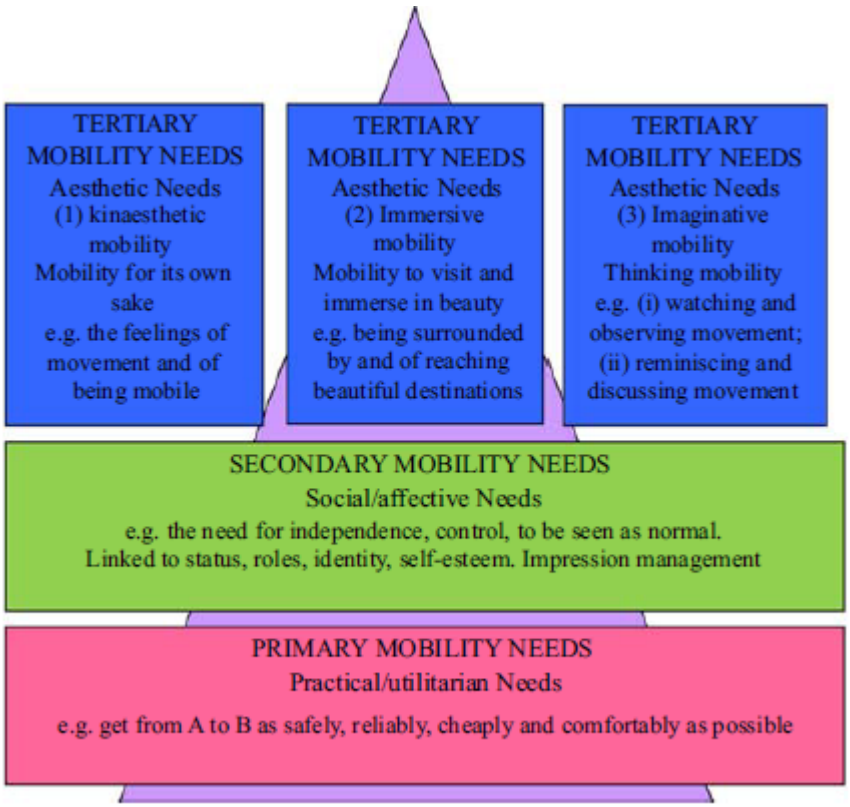


Figure 2.5 *Musselwhite and Haddad (2018) model*

Always from a transport point of view, Musselwhite (2016) introduced a second model of mobility and transport in later age (Figure 2.6). The individuals lay in the centre of the model and given that the design is rooted in the ecological models'[3] approach, separate external layers of determinant factors encircle them. As such, an age-friendly transport system needs to examine at first place individual factors, like the health conditions, the needs and motivations, then, to consider the neighbourhood characteristics, afterwards, the accessibility of the public transport, and finally, all of the aforementioned elements need to be derived from properly outlined public policy planning.

[2] The ecological models couple the reactions of the individuals according to the external environment in which there are called to live (Ormerod et al., 2015).

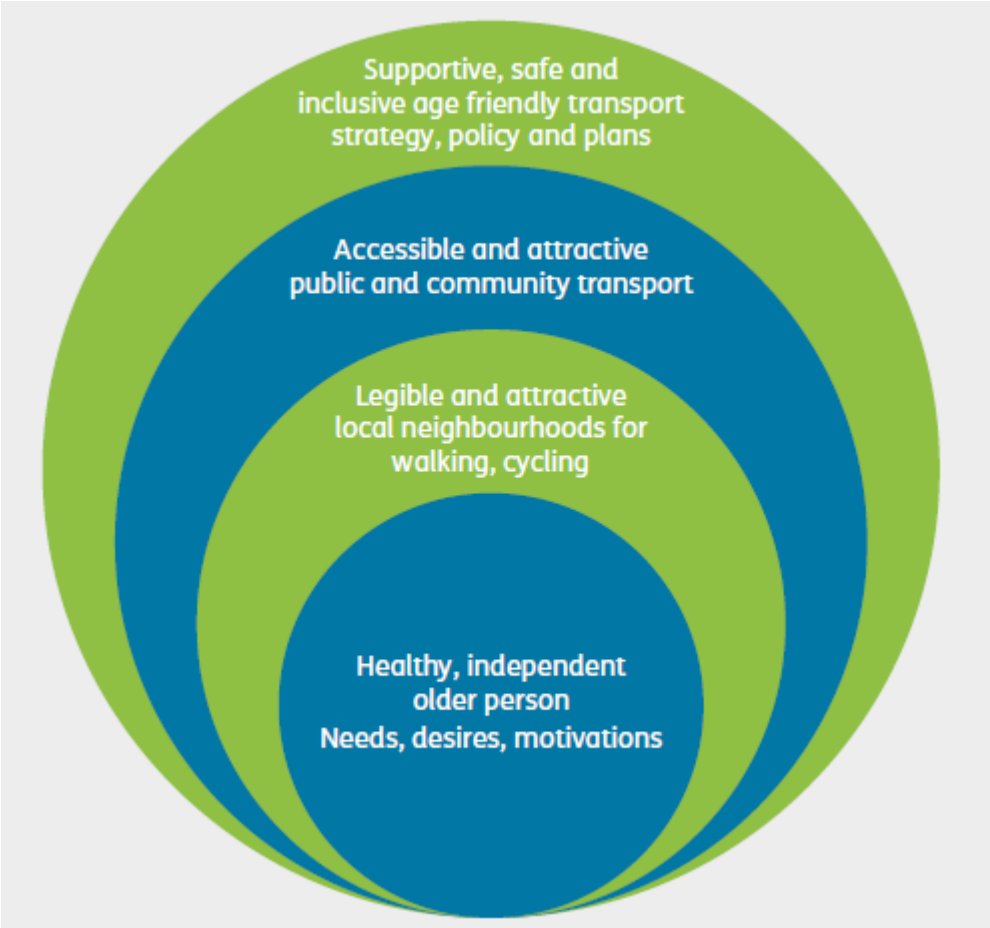


Figure 2.6 *Musselwhite (2016) model*

As mobility exhibits a dynamic nature, it should be seen to unfold not only in different levels of space but also in time, during the life of the older adults. Taking inspiration from the ecological models, Ormerod et al. (2015) provide an explanation of this double direction development (Figure 2.7). The model places the person in the core of the approach and around it there are met four subsystems: the microsystem, the mesosystem, the exosystem and the macrosystem. All the four systems are placed on the chronosystem axis with the scope to denote that the systems are not fixed but there are temporal dimensions evolving. Within the various subsystems, which practically are the levels of the environment within which mobility can be achieved, they identify a number of determinant factors that can affect mobility. Importantly, the progress of mobility problems is shaped by a handful of components i.e. sociodemographic determinants, health-related aspects, the style of living and the daily environment (Sakari, 2013).

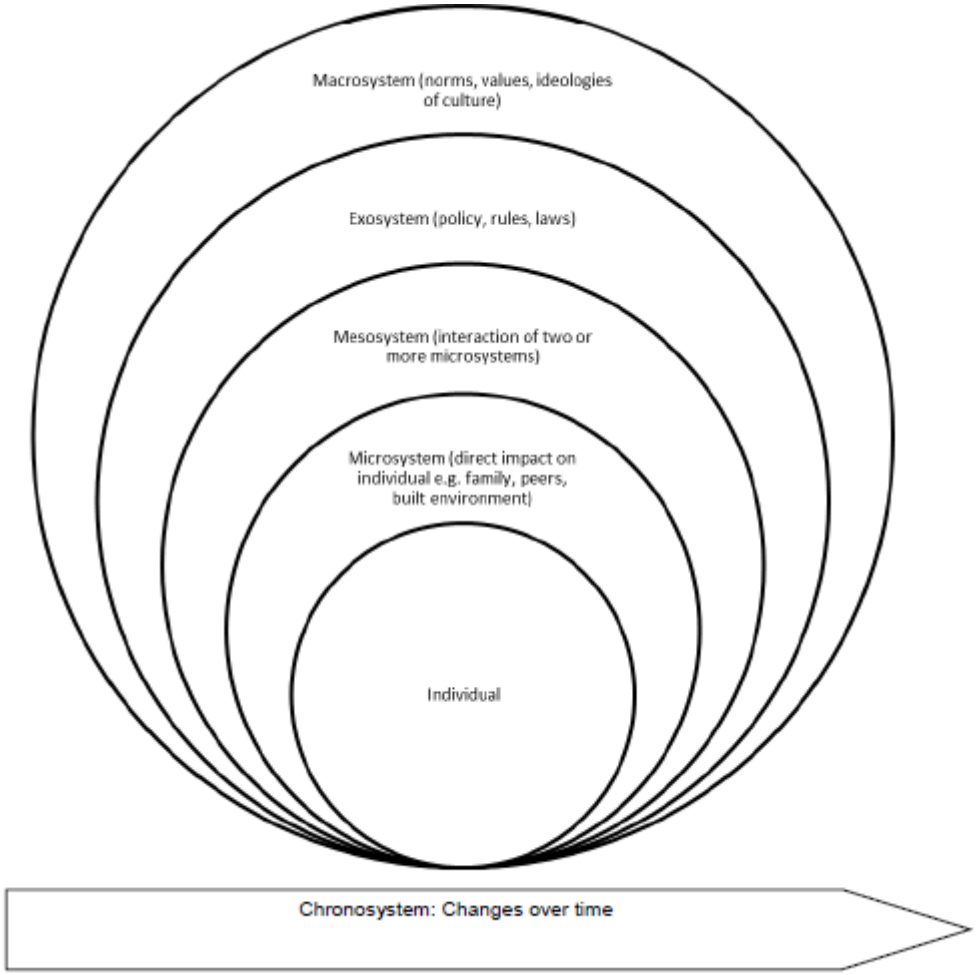


Figure 2.7 *Ormerod et al. (2015) model*

In sum, all the models that we found in the literature show a collection of vastly non-identical number of parameters, with the exception of Franke et al. (2019) and Musselwhite and Haddad (2018) that have extended pre-existing models (Webber et al. (2010) and Musselwhite and Haddad (2010)). Generally, it cannot be said that one model is capturing more robustly than the other the elderly mobility. Definitely, each one of them investigates a separate side of the topic.

Under the prism of a more critical analysis, the design of the Webber et al. (2010) model (and also Franke et al. (2019)) incorporates a range of determinant mobility-related factors on the physical space. On a completely different logic, Musselwhite and Haddad (2010) (and Musselwhite and Haddad (2018)) pay attention only to the reasons of mobility, ignoring completely possible obstacles or incentives. On the other hand, Ormerod et al. (2010) couples the mobility parameters with the time dimension. Differently from the aforementioned models' rationality, Musselwhite (2016) focuses exclusively on crucial components of mobility

without studying temporal or spatial hypothesis. On combining the uniqueness of the approach of each model, we suggest that the reader refers to Section 2.1.4, as there we put forward a framework that brings together elements that describe elderly mobility from a more inclusive optique.

2.1.3 Empirical applications of theoretical mobility models

Considering all the theoretical models analysed in the previous section (Section 2.1.2), we have noticed that there is very limited empirical evidence of them in the literature. Interestingly, the Webber et al. (2010) model has already been tested empirically in diverse cultural contexts. Meyer et al. (2014) have analysed data from a representative sample of 6,112 American adults aged over 50 years old (mean age: 74.74) in the Health and Retirement Study. Using the methodology of structural equation modelling, the authors appraised several relationship links as they have been hypothesized in Webber's et al. (2010) model for two types of mobility, the personal and the functional one, and two indexes have been created respectively. For the first mobility type there were included a few questions about the ability to: (a) walk one or several blocks, (b) jog one mile, (c) ability to sit for 2 hours, (d) to get up from a chair, (e) climb stairs or only one flight of stairs, (f) stoop, (g) reach arms, and (j) pull/push objects. For community mobility, the participants have been asked whether they: (a) were able to drive? (b) have driven in the past month? (c) had a car available and (d) have limited their driving to nearby places or could also drive on longer trips. Their results retained the expected theoretical predictions when each mobility type was assessed separately. This finding implies that each mobility type is separately related with all drivers of mobility. On the contrary, when both mobility types were incorporated in the same model, psychosocial and financial variables did not appear to be statistically significant.

More recently, Ullrich et al. (2019) tested Webber's et al. (2010) model with data collected from a cross-sectional randomized controlled trial (RCT) process. The participants were older German patients (≥65 years old) with mild to moderate cognitive impairments. In fact, the authors verified that compared to healthier individuals the older adults who suffer from cognitive deficiencies present a confined mobility space to a smaller extent. Consequently, they highly encourage the experts to target the improvement of physical functioning capabilities and social interactions for this group of the population.

2.1.4 Framing together the different aspects of mobility

So far, all the models presented in Section 2.1.2 show that mobility cannot be fully studied without taking into consideration multiple aspects. Still further research is needed to contribute towards more inclusive theoretical frameworks that will allow us to comprehend deeply the topic.

Firstly, we stress that the starting point needs to be the conceptualisation (see for details Section 2.1.1) of elderly mobility in such a way as to incorporate:

(a) the physical capability to be mobile as we found it to be studied mainly in health sciences (see for example Balasubramanian et al., 2015);
(b) the physical displacement on the space as it is studied in social sciences (see for example Schwanen et al., 2012);
(c) the use of transport means that facilitate reaching destinations as studied basically in the transport literature (see for example Banister and Bowling, 2004).

Secondly, synthesising the current literature as it has been presented in Section 2.1.2, *six basic pillars* of determinant factors emerged that need to be examined by the scholars when studying elderly mobility: 1*. life course, 2. trip purpose, 3. transport system, 4. space level, 5. individual characteristics and 6. environmental elements*. Briefly, they are included in Table 2.4 (Section 2.1.2). As Figure 2.8 shows, a first basic element that needs to be included in the research of elderly mobility is the *life course* of the older adults. This key observation has been underlined by Franke et al. (2019). Notably, as the elderly people are a very heterogeneous age group[4] (Shrestha et al., 2017; Somenahalli et al., 2016), usually in the literature we find age slot classifications that describe their life phase e.g. younger-old, middle-old and older-old adults (Klein-Hitpaß & Lenz, 2011). Because with increasing age the physical capabilities tend to decline, it is critical to incorporate the age in the analysis, as an indicator of the changes of the time.

[4] With respect to their health status and wealth (GOAL, 2012).

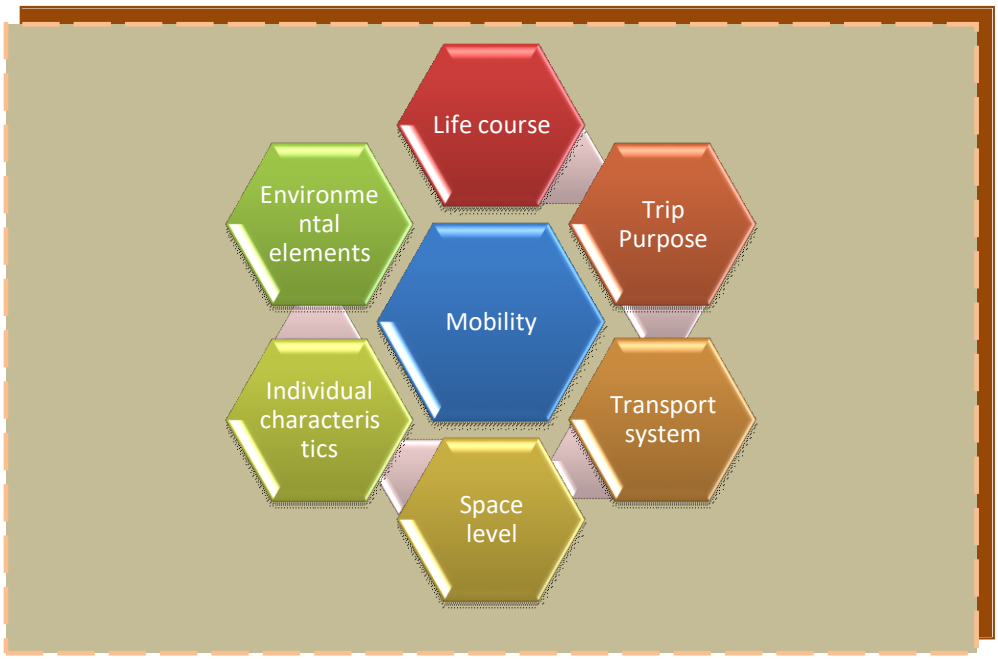


Figure 2.8 *An inclusive framework of elderly mobility (Author's elaboration)*

Following what has been proposed in the model of Musselwhite and Haddad (2010), the older people move in order to satisfy various types of needs, as such the *purpose of the trip* does not need to be neglected from a complete approach of mobility research . As the authors stress, each movement can satisfy a different level of the human needs and, in the same time, underline that all of them are necessary for the improvement of the overall well-being. That said, the existence of the *transport system* is crucial in meeting the ageing mobility needs as a critical facilitator or barrier in reaching important activity destinations of the welfare space, (Musselwhite, 2016). For instance, Johnson et al. (2017) have highlighted eleven quality dimensions of an age-friendly transport system (refer to Section 3.3.1 for more details).

In the model of Webber et al. (2010), the *space* is arranged in levels of proximity with respect to the place of residence of the elderly. Their approach evidences that for each space level there are various factors that can influence mobility. As the people age, they tend to reduce their activity space but this does not necessarily mean that they enjoy lower well-being (Kamruzzaman and Hine, 2011), especially nowadays with the tendency of the "15 minutes

cities"[5], where it is attempted to provide all the essential services within a 15 minutes walking distance.

Apart from the aforementioned parameters, that are quite relevant for the study of elderly mobility, the models analysed in Section 2.1.2 have highlighted many *individual characteristics* that play an important role in shaping the way elderly mobility is influenced. First and foremost, considering that as age increases the health status deteriorates, it has been recognised by the scholars that it is particularly crucial for the older people. In fact, it is mentioned in some of the theoretical mobility models, under the terms physiological (Franke et al., 2019), healthier older person (Musselwhite, 2016), physical and cognitive (Webber et al., 2010). Additionally to the health conditions, other individual characteristics participate on shaping elderly mobility. Franke et al. (2019) call them subjective, i.e. personal psycho-related factors and norms, Musselwhite (2016) needs, desires and motivations and Webber et al. (2010) financial, gender, psychosocial and the life history. Basically, all these characteristics have one common element: they derive from and are related to the individuals rather than on the environment.

Finally, the elderly people are inevitably affected by diverse *environmental elements* external to their nature. Thus, the researchers who would like to incorporate any part of the complexity of elderly mobility need to be aware of them. The environmental factors can be distinguished in three levels: (a) the built, (b) the social, (c) the cultural and (d) the regulatory environment. More analytically, the scholars recognise the importance of the built environment for the daily movements, especially for the elderly people. The physical barriers found on the space such as not well-maintained pavements or not accessible public transport are considered seriously by the older people themselves when deciding for their mobility. As regards the social environment (Ormerod et al., 2015; Webber et al., 2010), it has been referred to as the power of the family and friends to influence the levels of mobility. For example, if the family leads a more active lifestyle there are higher probabilities for the elderly people to increase their mobility. The cultural environment is equally relevant and has been included by the researchers in the theoretical mobility models. It influences the way people behave with respect to their social relations, the level education and the type of occupation

[5] A few European cities/countries have proposed "15 minutes city" plans, and especially after COVID-19 pandemic, such as Milan (Comune di Milano, 2020), Paris (https://eurocities.eu/latest/parisians-will-live-within-a-15-minute-radius/) and the Netherlands with the Integrated Service Areas (Singelenberg et al., 2020).

(Webber et al., 2010). Also, Ormerod et al. (2015) refer to it as norms and values, implying that we adopt behaviours that are passed to us from the previous generations. Lastly, the regulatory environment contains the rules that are set by the policy makers according to the goals they want to achieve. Musselwhite (2016) and Ormerod et al. (2015), specifically, pay attention to the age-friendly transport policies and plans which can support and facilitate healthy ageing (see Section 3.3 for examples of transport policies). Concluding, when the scientists will manage to include all the parameters analysed in this section, we believe that the topic for elderly mobility will have been studied to its full potential, at least with respect to the current theoretical contributions.

2.1.5 Connecting mobility with well-being and QoL

In this section, it is provided a critical overview of the current literature about the association of mobility with well-being/QoL. This narrative review has been performed with the scope to identify patterns and trends about the research topic in the literature, find research gaps and seek new lines of inquiry. The articles presented throughout the section have been collected, mainly, through the online library *Google Scholar*, searching for combinations of the keywords *mobility, older/older people/elderly, well-being/quality of life, literature review/review* in the titles of the papers. Furthermore, additional relevant to the topic papers have been collected from the references of them collected studies.

Definitions of well-being and QoL

In this section, it is presented the conceptualization of well-being and QoL and, furthermore, their relationship with elderly mobility. Both the concepts of well-being and QoL are widely used within the literature of elderly mobility. However, they represent concepts with definitions and theoretical landscape that tend to mix and provide similar takeaways. That is the reason why, in this section, we analyse them together. Sometimes the two concepts are used interchangeably (see Nordbakke and Schwanen, 2014) or in some cases are given different meanings (see Delbosc, 2012). Nordbakke and Schwanen (2014) conceive them as being the same because they admit that have many parts in common. More generally, the authors discover that well-being is not conceived the same by the researchers of the various sciences and observe three main dichotomies of it:

1. Subjective vs. Objective;
2. Hedonic vs. Eudaimonic;
3. Universalist vs. Contextualist.

Principally, the studies about subjective well-being (SWB) refer to it as how people evaluate their own lives and what they personally call happiness or satisfaction (Diener et al., 2003). Under this logic, Delbosc (2012) uses the terms well-being, life satisfaction and happiness interchangeably. Hence, SWB can include both emotional (feelings of joy and gratification) and cognitive aspects (satisfaction and fulfilment in various life domains such as marriage, work, and leisure time) (Diener et al., 2003).

Similar with the case of well-being, several dimensions either subjective or objective have to be considered about the QoL, e.g. physical, psychological and social components (Abdullah et al., 2018; Aguiar and Macário, 2017). Diener et al. (2003) argue that SWB is one measure of QoL for the individuals and the societies. As a consequence, SWB is necessary to achieve high QoL of individuals and communities but not sufficient (Diener et al., 2003). The WHO (1997) characterises the complex interactions of six domains in the definition of QoL: the physical and psychological health, the levels of feeling independent, the social relationships, the environment, and the spiritual, religious or personal beliefs.

More specifically, when referring to the QoL in later age, Boggatz (2016) sustains that for the older adults this is formed by the extent of satisfaction with life conditions, the SWB and the subjective fulfilment of life dimensions. In addition, Banister and Bowling (2004) support that the older people perceive QoL more spherically as:

- ✓ the people's standards of social comparison and expectations of life;
- ✓ a sense of optimism and belief;
- ✓ having good health and physical functioning;
- ✓ engaging in a large number of social activities and feeling supported;
- ✓ living in a neighbourhood with good community facilities and services (including transport);
- ✓ feeling safe in one's neighbourhood.

Nevertheless, QoL refers to the total outcome of positive and negative events experienced over the life course (Esmat and Hussein, 2012). As these factors are not stable over the time but depend on social, cultural, legal, economic, and historical elements, the researchers fail to reach a common place and build comprehensive QoL theoretical models. This is basically attributed to the plurality of the domains that they select to include each time in the evaluations (Esmat and Hussein, 2012; Skevington et al., 2004). This challenge is evident in several research fields. For instance, Cao and Zhang (2016) call for a robust set of QoL indicators in land use and transportation studies, whereas De Paula et al. (2013) (by spotting sixteen QoL measures) reveal that this is an issue in health sciences as well. Unless the QoL toolkit becomes more universal, the comparison of the different studies could not be rendered quite accurate (Cao and Zhang, 2016).

Potential links of well-being/QoL with mobility

As a specific theoretical framework for the design of the relationship between mobility and well-being is lacking (Nordbakke and Schwanen, 2014) and the exact causal link is rather unclear (Delbosc, 2012), the scholars tend to propose very diverse explanations. Table 2.5 presents briefly the empirical studies included in this Section about the relationship of elderly mobility with well-being/QoL. Generally, it is rationalized in the literature that the possession of personal and mobility resources is associated with higher personal well-being (Gagliardi et al., 2010). Some researchers argue that mobility facilitates accessibility to services and activities, increasing levels feeling independent and, also, social interactions with people (Fristedt et al., 2014; Delbosc, 2012; Ziegler and Schwanen, 2011; Whelan et al., 2006). Nordbakke and Schwanen (2014) record some examples of potential causal links as identified in a wide range of disciplines. A quite interesting approach is the utility theory diffused in economics. It suggests that even the potential movement (motility) enhances the ability and opportunities to satisfy desires and preferences, while the actual access to destinations can actually fulfil desires and preferences. Also, assuming that the whole journey provides utility to the people (see for this topic Mokhtarian and Salomon, 2001), the procedure of travelling per se can be part of the desires' fulfilment.

While cognitive problems and physical impairments cause frequently mobility limitations to the elderly (Lodovici and Torchio, 2015), it does not necessarily mean a decline of their overall QoL (de Paula et al., 2013; Hudakova and Hornakova, 2011). Losing mobility implies decreasing independence[6] of the elderly which in turn needs substitution from other individuals' support (Ormerod et al., 2015). The older people with mobility problems cannot easily enjoy neither an independent life nor participation in social and physical activities (social inclusion) (Ormerod et al., 2015; Rantakokko, 2011). Esmat and Hussein (2012) interviewed 199 mobility impaired Egyptian older adults (aged 60 years or above) about a few dimensions of QoL (physical aspect, psychological well-being and social concern). The results showed that 29.2% were suffering from arthralgia, 66.8% had continuous pain, 58.2% lived in houses with poor kitchens and toilets (in terms of safety measures) and 80.9% were

[6] The fuzzy concept of independence can be interpreted either as autonomy in trip-making, freedom in action performance. (Schwanen et al., 2012) or the ability to perform activities of daily living without relying on others assistance (WHO, 2002). Notably, the independence is often confused with autonomy, translated as the perceived ability to control, cope with and make personal decisions about how one lives on a day-to-day basis, according to one's own rules and preferences (WHO, 2002).

unable to prepare their food. Additionally, two aspects of social connectedness have been verified. 61.8% of the participants were not able to participate in social activities and in subjective level (psychologically) 54.3% of the participants were feeling hopelessness. Similar findings have been found in Risser et al. (2010), showing that immobility may enhance depression, lack of motivation and fear of loneliness.

Few years ago, Metz (2000) argued that, although there is a general acceptance about the intimate relationship of mobility with QoL, it was not well-described and it was largely supported by common sense interpretations. Following this ascertainment, a few papers targeting an in depth understanding of that interaction are detected. The study of Mollenkopf et al. (2011) had as a primary focus to understand better the long-term stability and change of the perceptions about out of-home mobility. Using data collected for ten years (1995-2005) from 82 people, aged 55 or more years old, living in Mannheim (western Germany) and Chemnitz (eastern Germany), found that there is a strong impact of activities with life satisfaction and emotional well-being. Also, they concluded that out-of-home mobility has a large impact on the QoL of the elderly and, overall, the meaning attributed to mobility has remained stable between 1995 and 2005. The perceived mobility changes in the course of the time, were considered losses of mobility experiences and decreasing satisfaction with mobility opportunities, out-of-home leisure activities and travelling.

The study of Ravulaparthy et al. (2013) focused on investigating the links between elderly transport mobility and well-being. The participants were 395 couples (with both spouses of at least age 50 and at least one spouse age 60 or older) from the Supplement on Disability and Use of Time Survey 2009, a longitudinal survey of U.S. individuals and their families. Computer-assisted telephone interviews were performed to the couples questioned, separately, the same randomly selected weekday or weekend day. Their results show that the elderly who are engaging in out of home activities, socializing and enjoy better mobility, also report higher levels of subjective well-being (defined as satisfaction with life, health, memory, finances and marriage), leading as such to a better QoL.

La Grow et al. (2013) analysed 2,473 data from participants of the second wave of Health, Work and Retirement (HWR) survey. It is a nationally representative longitudinal study, conducted between May and June of 2008, of New Zealanders aged 55 to 70 years old (in 2006), who are in the transition from work to retirement. The purpose of the study is to

define the way mobility is related to QoL. The two estimated models of possible mechanisms provide interesting takeaways. The one tests the direct relation of mobility together with a number of health conditions and satisfaction with functional capacity, life essentials (e.g. transport availability, access to health services, and conditions of living space) and personal relationships. On the other hand, the second model relates mobility with QoL only through the satisfaction with functional capacity. The authors argue that their study provides only preliminary[7] evidence for the close connection of mobility with QoL of older people. The study concludes in favour of the second model as being able to explain better the link between mobility and QoL, which shows that the motorial aspect is a salient alliance of QoL for the aged people. In fact, it is accepted by other scholars (Cao and Zhang, 2016; Rantakokko et al., 2013; Kochera et al., 2005) that increasing the possibility of going where and when one wants, may promote QoL and participation in the community for the older people.

In health sciences, the researchers are mainly concerned about the functional capability of the elderly to remain mobile and its impact on QoL. Thus, mobility is, besides, studied with respect to its impact on the so-called *health-related quality of life (HRQoL)* (Andersson et al., 2014). The term HRQoL is widely used in medicine to define the QoL of an individual which results from its health status, experience of diseases, and process of natural aging (Kawecka-Jaszcz et al., 2013, p.1). Remarkably, the policymakers consider the elderly mobility from a social-equity point of view and only recently have started focusing on the relation of mobility with health and QoL (Somenahalli et al., 2016).

Bentley et al. (2013) based on the Wilson and Cleary (1995) model[8] investigated the mediating role that life-space mobility plays on HRQoL of the older people. They tested this relationship by elaborating data from 677 participants of the University of Alabama at Birmingham (UAB) Study of Aging. It is a longitudinal study about mobility among community-dwelling older adults, randomly sampled from a list of Medicare beneficiaries living in one of five counties (two urban and three rural) in central Alabama. The research question was studied both using longitudinal and cross-sectional autoregressive statistical models. Figure 2.9 represents graphically the conceptualization of the

[7] The limitation of the study (as reported by the authors) is judged to be the measurement tool of mobility, as it has more precisely been assessed by the self-reported response to the question: "*How well are you able to get around?".*

[8] The Wilson and Cleary (1995) model was conceived with the scope to create a conceptual framework for the measurement of HRQoL usable by physicians and clinical researchers, because the existed models did not include the whole range of variables considered for its measurement (Bentley et al., 2013).

investigated research question[9]. Their findings verify that the functional status limitations, as defined by difficulties of ADL, predicted lower levels of life-space mobility. Consequently, the resulting mobility limitations are projected on declined HRQoL. However, the estimates of the mediating role of mobility appeared to be larger (Physical Component Summary-PCS: about 13%; Mental Component Summary-MCS: about 44%) at the longitudinal autoregressive models compared to the cross-sectional models (PCS: about 5%; MCS: about 21%). Noteworthy, Abdullah et al. (2018) interviewed 481 Malaysian older adults (aged 50 years and above living in urban areas) with the scope to specify how mobility disability affects QoL. The authors evaluated five elements as a part of QoL as measured in the quality of life questionnaire (WHOQOL-BREF) (WHO, 1996): general quality of life, physical health, psychological, social relationship and environment. They found that all QoL domains were lower for the elderly suffering from mobility disabilities with descending order as presented here: general QoL, social relationship, environmental, psychological and physical health. The interesting observation is that in this study the physical health had the weakest contribution to the QoL.

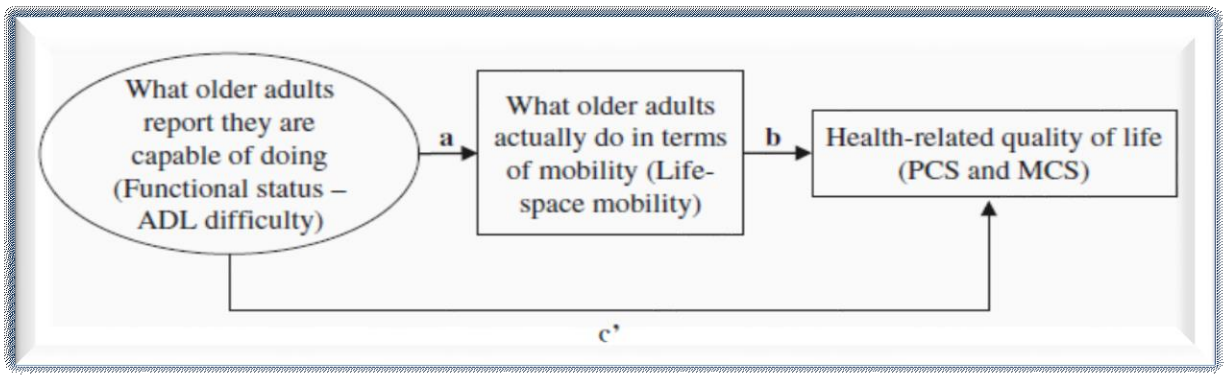


Figure 2.9 *Relationship of mobility with HRQoL (Bentley et al., 2013)*

A more complete evaluation of QoL of the elderly people who suffer from impaired physical mobility (caused either by physiological changes or pre-existing chronic conditions) is presented by the review of De Paula et al. (2013). The authors highlight that mobility limitations affect negatively the QoL of the older people. As the number of functional disabilities increase, the QoL scores moved reversely. More, they note that the included

[9] The total effect on HRQoL (ab+c') is given by the sum of the direct effect (c') and the indirect effect (ab). The mediated proportion is the indirect effect out of the total effect (ab/(ab+c')). HRQoL consists of Mental Component Summary (MCS) and Physical Component Summary (PCS) scores. Life-space mobility was found to be less significant with PCS rather than with MCS. The justification is given by the fact that functional status, life-space mobility, and PCS are conceptually overlapping (Bentley et al., 2013).

studies assessed the QoL with respect to personal satisfaction and functional capability. As regards the first factor, the elderly who reported satisfaction with QoL were involved in the society and experienced worthwhile situations associated with their independence and well-being. Referring to the second factor, i.e. functional capability, when mobility limitations and feelings of pain were present they tended to undermine the QoL, as this was reported by the participants of the study.

Unarguably, the elderly people are highly sceptical of the loss of their independence that restricted mobility may bring (McInnes, 2011). In such a situation, they are vulnerable to depression symptoms and it is less likely to feel high purpose in life or resilience (Musich et al., 2018). Even the moderate physical activity (walking and cycling) can prevent a decline of HRQoL (Choi et al., 2013). Thus, mobility problems seem to be a prime factor for healthcare professionals in the assessment procedure of HRQoL (Andersson et al., 2014), as they could predict potential health-related disturbances, like incontinence, and consequently lead to a low HRQoL (Stenzelius et al., 2004). In line with the results of Bentley et al. (2013), Esmat and Hussein (2012) supports actively that health education programs for the improvement of the QoL of the older adults should include advices for physical mobility maintenance, coping with daily living activities, prevention of joint/muscles diseases and socio-psychological harms.

Table 2.5 *Empirical studies for the relationship of elderly mobility with well-being/QoL*

Study	***Sampling strategy***	***Data collection***	***Statistical/ econometrical analysis***	***Mobility measure***	***QoL/ well-being measure***	***Results***
Abdullah et al. (2018)	481 Malaysian residents randomly selected, aged 50 years old and above, able to comprehend Bahasa Malaysia or English and not bedridden.	Interviews using a structured questionnaire, cross-sectional study	Descriptive statistics	400-meter walk test within 15 minutes	Quality of life questionnaire (WHOQOL-BREF)	The older people with mobility disabilities had lower mean QoL scores across all QoL domains.
Bentley et al. (2013)	677 participants aged 65–97 years old from the University of Alabama at Birmingham (UAB) Study of Aging (population-based, longitudinal study about mobility among community-dwelling older adults, randomly sampled from a list of Medicare beneficiaries living in one of five counties, two urban and three rural, in central Alabama.	Participants were recruited by mail and followed up by telephone. Baseline in-home interviews between November 1999 and February 2001, follow-up interviews were conducted by telephone.	Autoregressive mediation models, Cross-sectional mediation models, Structural equation modelling	Life-Space Assessment (LSA) mobility based on the distance each participant reported moving during the 4 weeks preceding the assessment	Version 1 of the SF-12 was used to assess HRQoL	The longitudinal autoregressive models supported the mediating role of life-space mobility and suggested that this effect is larger for the mental component summary score than the physical component summary score of the SF-12. Mediated effect estimates from longitudinal autoregressive models were generally larger than those from cross-sectional models.
Esmat and Hussein (2012)	199 older adults in Egypt, aged 60 years or above, who were attending the outpatient clinics in Ain Shames Centre for geriatric medicine, diagnosed with mobility impairment and agreed to participate in the study by written consent.	Interviews with a structured questionnaire conducted in two areas: Ain Shames centre for geriatric medicine and client's home.	Descriptive statistics	Mobility impairment is defined as disabilities that affect the ability to move, manipulate objects, and interact with the physical world.	Modified scale of QoL as developed by Kouppi and Hartikainen (2008): included (a) physical aspect, (b) psychological well-being and (c) social concern.	29.2% of older adults with mobility impairment had arthralgia, 66.8% continuous pain, 58.2% lived in houses with poor kitchens and toilets in safety measures, 80.9% were unable to prepare their food, 54.3% had feelings of hopelessness and 61.8% were not able to participate in social activities.
La Grow et al. (2013)	Participants from the second wave of Health, Work and Retirement (HWR) study conducted between May and June of 2008. A nationally representative longitudinal study of New Zealanders aged 55 to 70 (in 2006) in the transition from work to retirement.	As suggested by Health, Work and Retirement (HWR) study	Structural equation modeling	Self-report answers to question "How well are you able to get around?," with responses made on a 5-point Likert-type scale ranging from 1/ Very poor to 5/ Very well	The global QOL item from the WHOQOL-BREF "How would you rate your quality of life?," responses on a 5-point Likert- scale ranging from 1/ Very poor to 5/Very good	Two models were assessed: (a) mobility affects directly QOL along with other variables and (b) mobility influences QOL through satisfaction with functional capacity. both models found that mobility and all three measures of life satisfaction were significantly associated with QOL, goodness of fit indices were higher for the second model.

Mollenkopf et al. (2011)	82 people aged 55 or more years old in 1995, randomly sampled from the population registers maintained by the Municipality Registration Offices of Mannheim (western Germany) and Chemnitz (eastern Germany).	Semi- structured interviews	Statistical testing using t-tests	Satisfaction with mobility options 'How satisfied are you with your out-of-home mobility? '	QoL is considered in the sense of opportunities that mobility offers, e.g. satisfaction with out-of-home mobility, satisfaction with public transport, leisure activities and travel	Overall stability in the meaning attributed to mobility between 1995 and 2005. The perceived mobility changes in the course of time, are considered losses for mobility experiences and decreasing satisfaction with mobility opportunities, out-of-home leisure activities and travelling, Satisfaction with public transport was found to be increased.
Ravulaparthy et al. (2013)	395 couples with both spouses of at least age 50 and at least one spouse age 60 or older from the Supplement on Disability and Use of Time Survey 2009, a longitudinal survey of U.S. individuals and their families.	Computer-assisted telephone interviews were performed to the couples questioned separately about the same randomly selected weekday or weekend day	Analysis of latent class clusters, ordered probit and multinomial logistic regression models	Transport mobility–travel behavior i.e. walking/cycling, using the car	Subjective well-being defined as satisfaction with life, health, memory, finances and marriage	The respondents who engage in activities out of the home, socialize, and enjoy better mobility also report higher levels of subjective well-being leading to a better quality of life. The model findings also show that illness and pain are related to lower well-being and that quality of life in older age is correlated to mobility.

Well-being/QoL and mobility: causal relationships

If we try to explain further the relationship of mobility with well-being/QoL and search for the direction of the causality, the topic becomes even more complex. Despite the fact that one-way interactions between mobility and well-being or health of the elderly have already been described, the ecological model of Ormerod et al. (2015) specifies a two-way relationship: mobility affects and is affected either by the two concepts i.e. well-being/QoL. The authors assume that what actually happens is a two-way causal direction and a clear causality effect needs careful further investigation.

Furthermore, relating mobility with health and well-being is still problematic since precious attention needs to be paid to the intervening components (Musselwhite and Haddad, 2018). As underlined by La Grow et al. (2013) among the principal factors that affect QoL (e.g. age, gender, levels of mobility, mental and physical health, autonomy and independence, economic standards of living, social support, emotional and psychosocial adjustment), mobility is the one that is highly susceptible to interference by public policies. Metz (2000) argues that the psychological, exercise, and community benefits from sufficient mobility would be difficult to measure directly, but instead, some proxy variables could be occupied for the empirical measurement: the time voluntarily spent outside the home, the time walking outdoors (or cycling) and the time of involvement in social interaction outside the home accordingly.

Inevitably, the physiological changes that come with ageing will cause losses of physical mobility and might decrease the QoL of the elderly (De Paula et al., 2013). Further research is required not only for the identification of other interfering factors, such as psychological, social, biological, and physical (La Grow et al., 2013) but also studies about the variation of the levels of QoL with respect to mobility levels (Metz, 2000). Mobility and physical activity contribute to health and successful ageing but how much activity and how intense it needs to be in order to achieve this goal is still unknown (McInnes, 2011). The destination-independent benefits like psychological, exercise and community engagement reaped by the elderly might exhibit a turning point up to which negative feelings of fatigue or boredom might emerge (Metz, 2000). Discovering the ideal level of mobility for the ageing population is a challenge assigned to researchers for future studies. The greatest challenge is to disentangle the reduction in QoL of the elderly attributed to reduced mobility and the one due to the disability per se (Metz, 2000). In this case, it is

more than important to invent compensatory mechanisms in individual, social and environmental level that will permit the elderly retain their well-being levels (Gagliardi et al., 2010). As lack of an established relationship between mobility and QoL renders problematic the evaluation of mobility measures (Metz, 2000), targeted research is necessary in order to guide the policy makers towards effective decision-making and supportive mobility strategies.

Abbreviations

ADL	Activities of Daily Living
CB&M	Community Balance and Mobility scale
DeMMI	de Morton Mobility Index
DGI	Dynamic Gait Index
DTGS	Dual-task Gait Speed test
FSST	Four Square Step
GMV	Gray Matter Volumes
HRQoL	Health-Related Quality of Life
LSA	Life-space Assessment
MCS	Mental Component Summary
PCS	Physical Component Summary
POMA	Performance Oriented Mobility Assessment
QoL	Quality of Life
RCT	Randomized Controlled Trial
SPPB	Short Physical Performance Battery
STS	Sit-To-Stand
SWB	Subjective Well-being
TRG	Timed Rapid Gait
TUG	Timed Up and Go
UGS	Usual Gait Speed
WHO	World Health Organization
WHOQOL-BREF	World Health Organization Quality of Life: Brief Version

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2.2 A systematic review of mobility effects on well-being

Whereas elderly mobility is studied by scientists and researchers from various disciplines, it is not only conceived, defined and measured differently in each discipline, as already discussed in Section 2.1.1, but also they investigate heterogeneous effects of mobility in later life. The scope of the present chapter is to answer two research questions by reviewing systematically the literature of elderly mobility in various disciplines.

RQ.1 What are the effects of mobility on community living elderly people as these have been studied in health, general, economic and social sciences?

RQ. 2 What specific measurement tools of mobility have been used in the literature in order to discover the corresponding effects?

The material of this section has been presented in various scientific organizations listed below. Moreover, extracts of this have led to two publications also presented below.

Publications

1. Pantelaki, E., Maggi, E., Crotti D. (2020). Mobility Impact and Well-Being in Later Life: a Multidisciplinary Systematic Review, Research in Transportation Economics. 100975. DOI: https://doi.org/10.1016/j.retrec.2020.100975
2. Pantelaki, E., Maggi, E., Crotti, D. (2020). Elderly mobility under the microscope: a multidisciplinary systematic review. Pedestrians, Urban spaces and Health. Proceedings of the XXIV International Conference on Living and Walking in Cities (LWC 2019), September 12-13, 2019, Brescia, Italy, Taylor & Francis. DOI: https://doi.org/10.1201/9781003027379

Conference presentations (*denotes presenter)

1. Maggi E., **Pantelaki E.*** & Crotti D. (2019). Elderly mobility under the microscope: a multi-disciplinary systematic review. Talk presented at the *XXIV International Conference, "Living and Walking in Cities", 12-13 September, Brescia (Italy).*

2. Maggi E., **Pantelaki E.*** & Crotti D. (2019). A Multi-disciplinary Systematic Review of the Literature on Elderly Mobility: How Mobility Affects Later Life and What is the Role of Public Transport. Talk presented at the *6th International Workshop on the Socio-economics of Ageing, 25- 26 October, Lisbon, (Portugal).*
3. Maggi E.*, **Pantelaki E.** & Crotti D.* (2019). Investing in mobility: a worthy asset in later age. Talk presented at the *International Conference, "Seniors, foreign caregivers, families, institutions: linguistic and multidisciplinary perspectives", 9-10 April, Varese, (Italy).*
4. Maggi E.*, **Pantelaki E.** & Crotti D. (2019). A Multi-disciplinary Synthesis of the Literature on Elderly Mobility: Where we Stand and What to Expect from Public Transport. Talk presented at the *59th European Regional Science Association Congress "Cities, regions and digital transformations: opportunities, risks and challenges", 27- 30 August, Lyon (France).*
5. Maggi E., **Pantelaki E.*** & Crotti D. (2019). Healthy Ageing: A Multidisciplinary Review of Elderly Mobility and the Contribution of Public Transport. Talk presented at the *XXI Scientific Meeting: "Transport and sustainability", Italian Society of Transport and Logistics Economists (SIET), 9-10 September, Bologna (Italy).*
6. Maggi E.*, **Pantelaki E.** & Crotti D. (2019). A Multidisciplinary Synthesis of the Literature on Elderly Mobility: Well-being Implications and the Role of Public Transport. Talk presented at the *XL Annual Scientific Conference Italian Association of Regional Science, 16-18 September, L'Aquila (Italy).*
7. **Pantelaki E.*,** Maggi E. & Crotti D. (2019). The effects of mobility in later life: a multidisciplinary systematic review. Talk presented at the *47th European Transport Conference 'Planning for Sustainable Land Use and Transport', 9 – 11 October, Dublin, (Ireland).*
8. **Pantelaki E.*** (2019). The Importance of Mobility in Later Life and the Role of Public Transport: a Review of the Literature. Talk presented at the *Internal Ph.D. workshop, 27-28 May, University of Insubria, Varese (Italy).*

Paper Published in Research in Transportation Economics

MOBILITY IMPACT AND WELL-BEING IN LATER LIFE: A MULTIDISCIPLINARY SYSTEMATIC REVIEW

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Abstract

In modern societies, the understanding of how active mobility affects the elderly's psycho-physical well-being is crucial to design ageing-friendly transport measures. From a multidisciplinary perspective, this systematic review points out the mobility impact on three elements of the EU Active Ageing Index: health, independence and social connectedness. By scanning four databases (Scopus, Web of Science, PubMed, and TRID), 3,727 peer-reviewed papers published in the last decade were found, of which 57 met the inclusion criteria. The screening process was conducted following the PRISMA protocol and registered to the database PROSPERO, while the quality assessment was done using the Mixed Methods Appraisal Tool. More than 80% of the papers showed that an active mobility prevents psycho-physical harms, while only few papers study the relation of mobility with independence and social inclusion, to reduce the need for assistance and the related public expenditures. The findings of this review give important information both to transportation researchers and policymakers and companies, underlining the need for further research as well as investments in targeted age-friendly transport systems. The Covid-19 emergency has further underlined the importance of this issue, being the elderly one of the more disadvantaged and frailer social group.

Keywords: Mobility; Elderly; Active ageing; Multidisciplinary; Systematic review

JEL codes: I10, I31, J14, J18, R42

2.2.1 Introduction

Together with decreasing birth rates, advances in medicine and technology have pushed up life expectancy, resulting in ageing populations in both developing and developed countries (Cao and Zhang, 2016). In 2050, 25.1% of the total population in OECD countries will be over 65 years old, from 7.7% in 1950 (OECD, 2015), while life expectancy is overall projected to rise from 69 years in 2005-2010 to 76 years in 2045-2050 and to 82 years in 2095-2100 (UN, 2013). These projections on longevity made scholars and policymakers devote a growing attention on ageing studies for many reasons. From an economic perspective, ageing societies indeed raise concerns about an increasing segment of the population which would need an effective pension system and intense supportive health care (Abdullah et al., 2018). Furthermore, as people age they will have to adapt their homes in a sufficient a way in order to compensate them for their decreasing capabilities or even relocate their place of living, thus, imposing financial pressure to the family expenses (Samuel et al., 2019).

Beyond the issues related to the provision of ageing-oriented products and services (Metz, 2000), this trend has strong implications on policies aimed at helping the elderly to remain healthy, active and socially included (Aguiar and Macário, 2017; Musselwhite, 2017). Developed by the World Health Organization, the Active Ageing approach has emerged as the *process of optimizing opportunities for health, participation and security in order to enhance the quality of life as people age* (WHO, 2002). In 2012 the European Commission, together with the United Nations Economic Commission for Europe (UNECE), developed the Active Ageing Index (AAI) as an objective, supportive tool for policymakers to evaluate the challenges of ageing societies (European Commission, 2013). AAI is measured by considering 22 indicators belonging to four domains: employment (where the related rate is measured for different age ranges, from 55 to 74 years-old), participation in society (including voluntary activities, political participation, etc.), independent, healthy and secure living, and capacity and enabling environment (including mental well-being and social connectedness). In 2015 the concept of 'healthy ageing' replaced the 'active ageing' policy framework, as a way to further emphasize the need for action across sectors by 2030, in order to enable the older people to remain a resource to own families and communities (WHO, 2018). Nowadays, the importance of policies targeted to older adults (together with other vulnerable social groups) is even stressed by the occurrence of the Covid-19

emergency, a pandemic which asks a specific attention to measures to avoid isolation and difficult access to necessary services (EU Commission, 2020).

Although the active-ageing framework refer to measurable factors that may affect well-being in later life (Kalache and Kickbusch, 1997; WHO, 2018), a multidisciplinary synthesis displaying how those intermediate aspects may be enhanced among older adults has not been conducted yet (Johnson et al., 2017). In order to contribute to fill that research gap, the aim of this paper is to focus on the indirect impacts of mobility on well-being: more specifically, to investigate how mobility can favour a healthy, independent and socially-connected living, thus increasing the older adults' well-being.

The present systematic review gives two important contributions to the literature on this issue: first, it summarizes and classifies the main results of the studies belonging to different disciplines; second, it outlines the strengths and weaknesses of research efforts in health and social sciences, stimulating inter-disciplinary discussion and suggesting further research patterns and transport policy implications. Although mobility-related effects were provided within health and social sciences by using specific terminology and tailored tests (Musselwhite and Haddad, 2010; 2018), related findings rarely spilled over (Murray, 2015).

The paper is organized as follows. Section 2.2.2 and 2.2.3 outlines respectively the research background and the applied methodology. Key results are presented in Section 2.2.4, while a general discussion of the findings is provided in Section 2.2.5. Conclusions, future research suggestions and policy implications are finally presented in Section 2.2.6.

2.2.2 Background

The European active-ageing framework highlighted that physical activity and social participation (or health as an underlying cause) make people happy, and vice versa: Figure 2.10 shows that the two-way relationship between Active Ageing Index (AAI) and levels of life satisfaction for over 65 people in EU28 countries is often clear-cut (UNECE/European Commission, 2019). Specifically, social isolation was found to have a substantial impact upon well-being in older adults, accounting for around 70% of depression (Golden et al., 2009). In addition, physical activity (through functional ability) has been shown to improve other dimensions of well-being, such as quality of life (Hyde et al., 2003; Törnvall et al., 2016;

McPhee et al., 2016; Jackson et al., 2019) or Health Related Quality of Life (HRQoL) (Kawecka-Jaszcz et al., 2013; Forte et al., 2015), and reduce depressive symptoms (Conn, 2010; Holmquist et al., 2017). Moreover, the Madrid International Plan of Action on Ageing and its Regional Implementation Strategy (MIPAA/RIS) for the 56 UNECE countries explicitly links AAI domains with recommendations emerging from policies aimed at promoting active ageing. As shown in Table 2.6, quality of life, independent living, health and well-being is connected to two AAI domains, i.e., 'independent, healthy and secure living' and 'capacity and enabling environment' (European Commission, 2019).

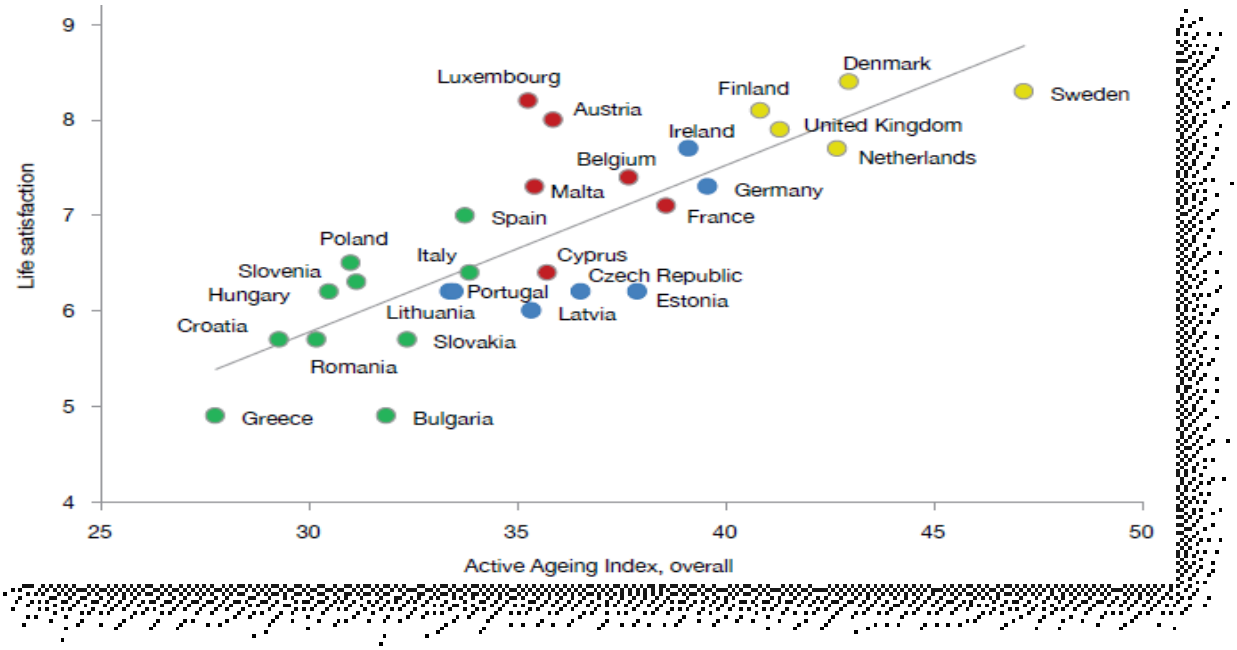


Figure 2.10 *EU28: overall AAI scores and life satisfaction among 65+ in 2018 (colours represent clusters) (European Quality of Life Survey Integrated Data File, 2003-2016, as cited in UNECE / European Commission, 2019)*

However, how mobility, in terms of functional capability, could affect well-being in later life? Overall, the concept of well-being in later life itself has been related to a set of feelings, emotions and habits consisting of three relevant dimensions: (i) "having", i.e., income, housing standards, employment, health and education; (ii) "loving", i.e., relations with family, friends, and other; and (iii) "being", i.e., self-esteem, leisure activities, social reputation and political resources (Allardt, 1975; as cited in Hjorthol, 2013).

Table 2.6 *Correspondence between AAI domains and MIPAA/RIS commitments (European Commission, 2019)*

2017 Madrid International Plan of Action on Ageing and its Regional Implementation Strategy (MIPAA/RIS) areas of commitment	Active Ageing Index domains			
	Employment	**Participation in society**	**Independent, healthy & secure living**	**Capacity and enabling environment**
Full integration and participation of older persons		☑		
Equitable and sustainable economic growth			☑	
Adjusted social protection	☑			
Responsive labour markets	☑			☑
Lifelong learning and education			☑	☑
Quality of life, independent living, health and well-being			☑	☑
Mainstreaming gender	☑	☑	☑	☑
Supporting families providing care and promoting intergenerational		☑		

According to this manifold notion of well-being, even the concept of mobility should be approached from a multidimensional perspective (Gagliardi et al., 2010; Ziegler and Schwanen, 2011; La Grow et al., 2013), especially taking into consideration that 'the ability to get out and about' (Banister and Bowling, 2004) might have an impact on many psycho-social dimensions. In a seminal paper, Metz (2000) provide a notion of mobility of older people integrating five key attributes, i.e., travelling to achieve access to desired people and places, psychological benefits of movement, exercise benefits, involvement in the local community, and the potential to travel. Later, in other than health sciences, mobility in terms of functional capabilities, has been defined as actual or potential embodied movement through physical space (Schwanen et al., 2012) or the ability to move around safely and independently inside or outside the residence home (Ravulaparthy et al., 2013). Yet, following those approaches, various types of 'demand for' mobility by older adults might arise in many daily-life aspects, where mobility itself could have a positive effect on cognition and physical activity (Webber et al., 2010). As a result, mobility in later life should not be just considered as a way to reach desired places by using transport means (Mizokami

et al., 2014; Yeoh et al., 2018), but also as a mediator to improve well-being through physical and mental factors, including independence and social connections (Spinney et al., 2009; Ziegler and Schwanen, 2011; Siren et al., 2015) or, in general, as a way to express freedom and remaining life force (Mollenkopf et al., 2011). Even when specific restraints limit the possibility to move freely (e.g., isolation due to the Covid-19 emergency), an active mobility to reduce frailty in later life (Avgerinou et al., 2019; Frost, 2018; Cadore et al., 2013) is of primary importance, and thus has to be strongly encouraged and supported (Hartmann-Boyce et al., 2020).

2.2.3 Methodology

Search strategy

In order to capture the large strand of published research in health and social sciences, this systematic review has been conducted by screening in the period January 2010 and December 2019 four electronic databases: Scopus, Web of Science, PubMed and Transportation Research International Documentation (TRID). We searched (in titles only) for the keywords: "mobility" AND ("elder*" OR "old*" OR "senior*" OR "late*life" OR "age*" OR "aging"). We used the asterisks in order to retrieve articles that included any desinence of the keywords (e.g., 'ageing' or 'age-related'). Since this research is focused on health and social features as mediators between functional mobility and well-being, no terms related to transport means or travel were used. The effects on ageing well-being of the usage of transport means (e.g., private vehicles, public transit, etc.) and related policies for seniors, e.g., free bus pass, concessionary fares, etc. (see, among others, Rosenbloom, 2009; Shergold and Parkhurst, 2012; Shrestha et al., 2017; Laverty et al., 2018; Reinhard et al., 2018) are out of scope of this review.

Inclusion criteria

The review includes the studies meeting the following prior criteria: (i) published in peer-reviewed journals, (ii) published in (or translated into) English, (iii) studying effects of mobility on the three above cited dimensions of life quality, by using qualitative e.g. interviews' text analysis, and/or quantitative methods e.g. objective or self-reported data

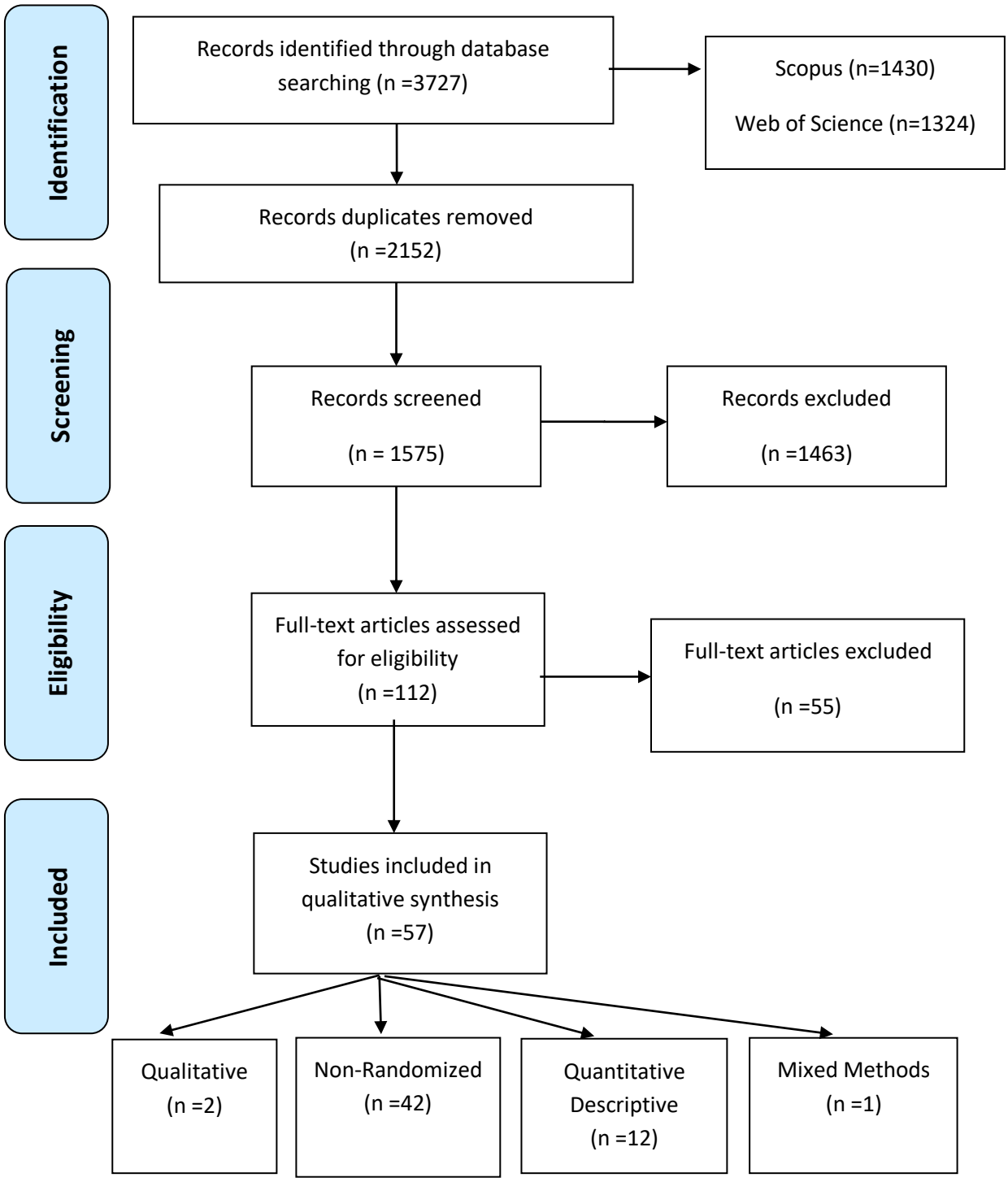
analysis, (iv) published between January 2010 and December 2019, (v) having considered (as a study group) community-dwelling elderly people (i.e., persons over 60 not living in an institution, such as hospitals or nursing homes) living in developed countries according to the United Nations Conference on Trade and Development classification. Commentary articles, grey literature and other reviews of any type were excluded. Since the AAI was developed by the EU Commission in 2012, the publishing time-window used starts from papers published in 2010, allowing us to retrieve research studies recognizing the quantitative evolution of the active ageing framework.

Screening and classification

The screening process used in the review was conducted according to the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Moher et al., 2009; see Appendix C.) and registered to PROSPERO, a database of systematic reviews (record CRD42019142194, October 2019). Our search strategy retrieved first 3727 sources from the scanned electronic libraries (Scopus: 1430; Web of Science: 1324; PubMed: 856; TRID: 117). After removing the duplicates, 1575 studies remained for possible inclusion. As shown in Figure 2.11, the screening phase was initially based on titles and abstracts, keeping only the articles satisfying all the above described criteria. As a result, 112 articles were found as eligible for full text reading. After skimming through the whole text (and again using the inclusion criteria), all the papers investigating the direct impact of mobility on well-being (i.e., without a specific analysis of mediate factors) were excluded. As a result, 57 articles were finally included for data extraction.

To best allocate the studies into a specific domain, we applied the journal classification adopted by Science Metrix (Archambault, 2016), distinguishing three different groups: Health Sciences, Economic & Social Sciences and General Science (where a multidisciplinary approach is explicitly identified). In case of papers that were impossible to associate to specific fields, as an alternative, the Web of Science Journal of Citation Reports and /or Scimago Journal Ranking were consulted.

Figure 2.11 *PRISMA 2009 Flow Diagram*



Assessing the risk of bias

To perform a quality assessment of the included studies, the Mixed Methods Appraisal Tool (MMAT; Hong et al., 2018) was used, because it allows to evaluate studies using different methodologies. MMAT, in fact, identifies five categories of papers according to the method used: (i) qualitative research, (ii) randomized controlled trials, (iii) non-randomized studies, (iv) quantitative descriptive studies, and (v) mixed methods studies. None of the reviewed paper belongs to the second category (see Figure 2.11). The most frequent category of studies found in the literature is the non-randomized (73.7%), followed by the quantitative descriptive papers (21%). The appraisal consists of two initial screening questions, applied to all the studies, about the clearness of the research inquiry and the appropriateness of the data to address it, and then, proceeds to five more specific questions for each category of study (see Appendix A). All the studies that fulfilled the inclusion criteria were considered for quality appraisal (see section Quality appraisal).

2.2.4 Results

Characteristics of the included studies

The attention on effects of mobility on psycho-social status in later life had an increasing trend, except for 2019 (probably because some recent papers are still in process of publication; see Figure 2.12). Included articles belong to few domains: health sciences (clinical medicine, public health & health services; 53 studies, 93%); economic and social sciences (economics & business, social sciences; 3 studies, 5.2%); and general sciences (general science & technology; 1 study, 1.8%). Beyond the conceivable and large dominance of health sciences with respect to other domains, we notice that multidisciplinary contributions are almost absent while in economic and social sciences it seems that the research topic has concerned a bit more.

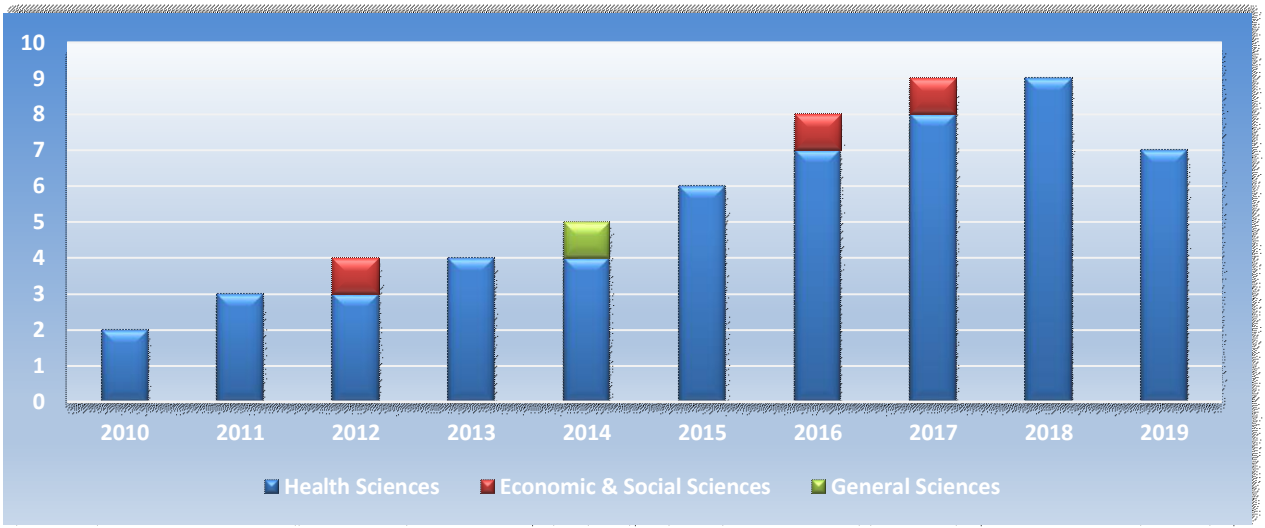


Figure 2.12 *Number of studies (per domain) and year of publication*

Table 2.7 shows the location of included studies at a country-level: 35.1% belongs to European area, while 64.9% are not European. Scandinavian countries dominate the European research in this topic, with Finland (10.5%) and Sweden (7%), displaying a common high commitment to ageing-related social changes. Most of non-European studies indeed were conducted in the United States (47.4%).

Table 2.7 *Study allocation by domain and country of research*

Domain	Field	Studies/Country
Health Sciences	Clinical Medicine 29/57	15 (US), 4 (Finland), 2 (Canada, UK), 1 (Australia, France, Ireland, Japan, Poland, Sweden)
	Public Health & Health Services 24/57	11 (US), 2 (Selected EU, Finland, Italy), 1 (Australia, Belgium, Japan, Norway, Sweden, Canada Spain)
Economic & Social Sciences	Economics & Business 1/57	1 (Sweden)
	Social Sciences 2/57	1 (US, UK)
General Sciences	General Science & Technology 1/57	1 (Sweden)

In terms of sample size, more than half of the studies has considered samples with at most 1,000 participants (Table 2.8). Interestingly, three recent studies in health sciences are based on more than 20,000 observations, as they rely on large longitudinal datasets such as the Survey of Health, Ageing and Retirement in Europe (SHARE) database (Litwin et al., 2018; Litwin and Levinson, 2018)

and the Canadian Longitudinal Study on Aging (Demnitz et al., 2018), containing micro-data on health status of older adults.

Table 2.8 *Sample size by type of study*

Type of study	Sample size participants					
	<200	200-1000	1000- 3000	3000-5000	5000-20000	>20000
Qualitative	2					
Non-Randomized	8	15	12	3	1	3
Quantitative	7	2	2	1		
Mixed Methods	1					
Total	31.6%	29.8%	24.6%	7.0%	1.8%	5.3%

The effects of mobility on health, independence and social inclusion

In this section, relevant findings of the systematic review are summarized to explicitly tackle our research questions by considering three domains (largely inspired by the AAI), such as health status (including physical and psychological conditions), independent living, and social connectedness (Tables 2.9-2.11). All the included studies with their main characteristics are provided in Appendix B. Furthermore, for a more comprehensive description of the mobility tests used in the included literature, refer to Paz and West (2014) and Soubra et al. (2019).

Health status: physical and psychological conditions

Fifty papers found in this review investigate the impact of mobility on various health outcomes, highlighting its crucial role (Katz, 2000; Galloway and Jokl, 2000). Thirty-four papers use objective tests (including GPS metrics to track movements) to assess mobility functions in later life (different movement indicators are described in Kaspar et al., 2015 and Fillekes et al., 2019) while sixteen studies are based on self-reported information (e.g., surveys, qualitative interviews, etc.) and/or mixed research strategies. Below detailed findings about the impact of mobility on health are provided, starting from the top three outcomes, i.e., falls (and risk of falling), mortality, and cognition.

Falls (and risk of falling)

About 20% of the reviewed papers analyse how falls and risk of falling could be reduced through higher levels of mobility. On that matter, scientific contributions which overall confirm that relationship have been detected in clinical medicine (Manty et al., 2010; Dai et al., 2012; Balasubramarian et al., 2015; Jefferis et al., 2015; Lo et al., 2016; Musich et al., 2018; Langeard et al., 2019) and public health (Panzer et al., 2011; Topuz et al., 2014; Mulasso et al., 2016; Litwin et al., 2018).

By using screening questions focused on difficulties with walking or climbing stairs, mobility limitations were investigated in Musich et al. (2018). In that case, analysing a sample of 4,661 U. people over 64 years old, the authors found that moderate or severe mobility constraint simply increasing falls, and (in turn) related higher healthcare expenditures. Similarly, mobility constraints were also considered in Jefferis et al. (2015), for which the association between baseline physical activity features (e.g., step counts, sedentary time, etc.) and mobility limitations in 3,137 UK elderly helped detecting fitness condition as a mediator to reduce falls risk. Controlling for several confounders, the Life-space Assessment Approach (LSA) was successfully used with 940 US residents over 65 in Lo et al. (2016), who found that falls odds increase in the presence of deprived neighbourhood-level characteristics (implying less accessible life spaces) and reduced out-of-home activities. Manty et al. (2010) consider a sample of 428 twin older community-living women in Finland and argue that the mobility decline can likely aggravate the fall history and increase the risk of future falls. Finally, Dai et al. (2012), instead, used a structural equation model to investigate the interactions among functional mobility and falls in 511 US older adults. Beyond finding that the TUG test is a good screening tool for mobility and fall risk, the authors highlight that satisfactory mobility rates can prevent the risk of falling. Interestingly, contrary to the above-mentioned studies where the positive link between mobility in non-disabled older adults and less risk of falling was detected, in case of mobility impairments (implying a movement loss due to functional abnormality), Langeard et al. (2019) did not get conclusive findings. By processing TUG test and other mobility scores (i.e., Gait Composite Score, Balance Composite Score, Physical Capacity Score) drawn from a sample of 26 Canadian older adults, their results suggest that mobility impairment does not significantly distinguish fallers and non-fallers.

From a public health perspective, Litwin et al. (2018) exploited 22,533 observations (19,023 controlling for the country, 20,654 without frailty variable) on over-65 people from the SHARE project in 13 European countries and conclude that mobility limitations act as moderators between fear of falling and falling. Panzer et al. (2011) found that the indicators related to different real-life mobility challenges perform better to identify the falls-related status, offering superior sensitivity in predicting injuries, for instance, with respect to the Performance Oriented Mobility Assessment test (POMA). Clearly, research findings about falls are in fact closely related to the more suitable type of mobility tests to be used in various fields, including the TUG test, the Timed Chair Stand test, the Functional Reach test, and the One-Leg Balance test (Topuz et al., 2014 for a multivariate testing framework). For instance, Mulasso et al. (2016) did not find it significantly associated with falls in a study based on 192 older adults over 65 living in a small area of Italy. The authors support that the multidimensional nature of frailty should be detected with a multidimensional tool like the Tilburg Frailty Indicator. In that sense, Balasubramarian et al. (2015) examine the predictive ability of various tests, i.e. TUG, Dynamic Gait Index (DGI), Short Physical Performance Battery (SPPB), and Community Balance and Mobility scale (CB&M). The authors concluded that the CB&M test detected fallers from non-fallers and more the DGI and CB&M recurrent fallers from those with fewer or no falls.

Mortality

Mortality is the second studied effect in health sciences (17.5% of the studies) and it can be seen as a tricky research target since it occurs naturally as people age, and sometimes the prediction of such an event is not a meaningful issue for this stage of life. Yet, beyond the concerning life expectancy rate also included in the 'capacity and enabling environment' domain of the EU Commission's active-ageing framework, there is a consensus within health sciences that the scores of mobility tests can be a sounding indicator for the risk of mortality anyway. The papers listed in Table 2.9, displayed that, controlling for other pertinent factors, mobility in later life reduces mortality odds by decreasing various co-morbidities.

As for clinical medicine, four studies were retrieved. Using survey data from 1,852 persons between 60 and 85 years old in the US, Frith et al. (2017) reported that older adults with difficulty in walking without special equipment (and with reduced cognition) are more

prone to mortality risks. Comparing the size of the effect with the groups that are either mobility disadvantaged or suffer from cognitive deficiency, the results are not statistically significant.

Applying Walking While Talking test on 631 US over 70 people in the Bronx County (594 completed the survey), Verghese et al. (2012) found it to be a robust predictor of latent mobility abnormalities, in turn increasing mortality rates. This test assigned to the older people to walk on a 15 feet walkway while pronouncing letters of the alphabet (e.g.; a, c, e.) and, in the same time, they should avoid task prioritization but, instead, it was needed to equally perform both tasks. Applying the Life-Space Assessment (LSA; Baker et al., 2003) in the US, Mackey et al. (2014; 2016) found evidence about the positive effect of mobility on health (gait speed) and reduction of mortality risk either among older men (3892 observations) or women (1498 observations). The LSA has been used whenever the scholars wanted to measure life-space mobility. It is assessed by an interview where the mobility of the last four weeks is given a score from 0 (daily restriction to bedroom) to 120 (daily trips outside town without assistance), and then the elderly are categorised on the scale of the Life-Space score: 0–20, 21–40, 41–60, 61–80, 81–120.

Bergland et al. (2017) applied the TUG test in Norway (survey data about 1,005 people over 65, of which 846 complete), showing that TUG scores are important predictors for survival in both men and women. More particularly, with TUG test they evaluated the time (in seconds) it takes to rise from a chair (with armrests), walk three meters quickly but safely, turn and walk back to the chair and sit down. POMA test, indeed, was found to be effective in mortality prediction among 2,069 US older people by Nam et al. (2017). The measurements have been achieved by the ability to walk (several qualitative aspects of the locomotion pattern) and maintain balance (carrying the subject through positions and changes in position, reflecting stability tasks that are related to daily activities). On the contrary, Ensrud et al. (2016) reported that the SPPB test applied on 1,495 US women (interviews) gave strong evidence of mobility as a predictor of mortality risk but the interaction with cognition was not enough to predict mortality rates. The test investigated the summary score of three controls: balance, gait speed, and chair rise tests. Finally, relying on interviews and/or the Usual Gait Speed (UGS) test about time to walk or mobility difficulty, ten studies found positive evidence of mobility capabilities as mediated parts of the association between social activity and mortality. In that sense, Katja et al. (2014) asked 1,181 Finnish older adults

about own ability to walk indoors, outdoors, and climb stairs, while Olaya et al. (2018) got similar results by using 2,074 data from Collaborative Research on Ageing in Europe (COURAGE) survey, a longitudinal household survey of the non-institutionalized adult population in Spain. Lastly, mobility disability was investigated using the UGS test as a mortality predictor in Yu et al. (2019), where 1,262 US people (aged 75 years on average) did not predict a positive relationship of mobility alone but only after the incidence of mild cognitive impairment (even if mobility disability is more often from mild cognitive impairment). In sum, many and different tests have been considered by the scientists when searching for evidence about the role of mobility in predicting mortality. The common element of all these is that they attempt to outline the physical performance of the elderly people by checking e.g. the walking speed, the balance ability etc.

Cognition

Positive (or improvement) effects of mobility on cognition were studied in some research papers (14% of the total), mainly based in the US and UK (Cohen et al., 2016; Tian et al., 2017; Demnitz et al., 2017, 2018; Donoghue et al., 2018; Sunderaraman et al., 2019). A recent exception was Rajtar-Zembaty et al. (2019), where a total of 800 older adults in Poland were recruited (653 with normal cognitive functioning and 147 participants with mild cognitive limitations) to test whether the relationship between the higher level of global cognition and some global cognitive subscales (including memory and fluency scores) were related to the better physical mobility performance. By applying both the TUG test and the 6-minutes' walk test, the obtained results revealed that higher levels of global cognition were related to better physical mobility performances. Gait assessment and the TUG test were also used by Sunderaraman et al. (2019), who gathered information from 124 older adults in the US Overall, their findings suggested that, in healthy individuals, relatively lowered cognitive performance may be linked to increased risk of gait alterations during the performance of these complex motor functions, or that lowered cognition may represent a higher vulnerability to gait disturbances. The relationship between executive functions and specific aspects of mobility has been strikingly highlighted. Analogously, by interviewing 162 persons in the US between 50 and 89 years old, Cohen et al. (2016) showed a dissociation between motor and cognitive functions, where deficits in the former ones are associated with slow TUG performance, while episodic memory deficits were associated with less

upright posture. Interestingly, in Tian et al. (2017), among initially unimpaired 412 older adults in the US, the temporal relationship between UGS and executive function is bidirectional, with each predicting change in the other, while poor fast walking performance predicts future executive function and memory changes but not vice versa. Two studies conducted in Canada and Britain (Demnitz et al., 2017; 2018) used several measures – such as the walking time course, balance time in one-legged stand, and chair stands tests – to show how cognitive measures were significantly associated with mobility measures, thus concluding that objective measures of poor mobility are sensitive to indices of poorer cognitive function. In a similar fashion, Donoghue et al. (2018) studied the relationship between different tests (i.e., TUG test, UGS and Dual-task Gait Speed tests) and cognitive decline in 2,250 Irish older adults, predicting a slight decline in cognition when mobility is limited. Only one study about mobility and cognition was found in the sociology literature, where, applying 11 indicators of mobility limitations to an age-heterogeneous sample drawn from the Health and Retirement Study (1998–2008) in the US, Bishop et al. (2016) outlined that the elderly with fewer mobility limitations perform better in cognition and word recall.

Other physical conditions

The literature review highlights also other negative physical or mental effects that, according to the literature, could be prevented by mobility in ageing societies (see Table 2.9); different measurement tools and tests have been used. Often combined with either UGS test or walking time measures, the TUG test has been mainly used to assess frailty (Kim et al., 2010; Fallah et al., 2011), neuromuscular performance (Berryman et al., 2013), Parkinson disease (Von Coelln et al., 2019) and urinary incontinence (Fritel et al., 2013), and kyphosis (Sugai et al., 2019). Specifically, Fallah et al. (2011) focused on the rapid gait test and, using data on 754 US people over 70 participating at the Yale Precipitating Events Project, they showed how mobility in later life can be significantly associated with changes in frailty status. By contrast, Kim et al. (2010) combined the TUG test with the 5-chair Sit-To-Stand (STS) test, alternate step, Timed Rapid Gait (TRG) test and UGS test to analyse the link between mobility and frailty in Japan (337 persons over 65). They found that, except for the 5-chair STS test, all the other tests detect lower risk of frailty for better performing mobility. Applied to 48 older adults between 60 and 85 in Canada, the TUG test combined with the 10-meters walking time test indicated that faster individuals display higher neuromuscular

performances, as well as better aerobic capacity and executive function (Berryman et al., 2013). Von Coelln et al. (2019) used three mobility tests: 32 ft. walk, modified TUG, standing posture with a sample of 683 (completed the survey) elderly (mean age 80,7 years old) in Chicago (US); they showed how mobility metrics can complement conventional gait tests and have potential to detect the risks of older adults who may develop parkinsonism. Risks of urinary incontinence have been also studied in Fritel et al. (2013), by combining the TUG test with other two mobility tests, i.e., a timed 6-mwalk test, and a test measuring the time taken to get up from a chair and sit down again five times without using the arms. By surveying 1,942 elderly women in some French cities (i.e., Paris, Boulogne-Billancourt, Lille, Reims, Montpellier, and Amiens), the authors showed a significant relationship between mobility-based limitations and urinary incontinence, thus offering new perspectives for the prevention and treatment of specific ageing-related diseases. Finally, a very recent study by Sugai et al. (2019) focused on the progression of kyphosis in older adults. Even though the causality of kyphosis progression has not been fully elucidated (i.e., the elderly may have a vicious cycle of the progression of kyphosis and generalized weakness, and the other way around), both low handgrip strength and low mobility were significantly associated with that physical trend.

In the last years, other tests contributed to find a positive correlation, between good mobility-related performances and physical activity (Tsai et al., 2015), executive functionality (Tian et al., 2015; Poranen-Clark et al., 2018), depressive symptoms (Polku et al. 2015), muscles strength (Reid et al., 2012; 2014; Curcio et al., 2016), hospitalization (Ensrud et al., 2017), and activities of daily living (ADL) disability (Heiland et al., 2016). For instance, the SPPB test was used in two studies in the US (Reid et al., 2014, 2012), showing that muscle power deteriorates significantly for mobility-limited older groups compared to non-limited (Reid et al., 2012). Later, Reid et al. (2014) elaborated longitudinal data and concluded that both groups presented similar muscle power performance, stressing that different underlining mechanisms are implied. From a general perspective about healthcare, the same test applied on 633 women in Portland (US) allowed Ensrud et al. (2017) to confirm that reduced mobility and poorer cognition should be important in clinical decision-making and healthcare policy planning for ageing societies, considering their independent association with hospitalization days but no evidence for combined effects is detected. Effects of mobility on muscles strength were also studied by using the POMA test in Curcio et

al. (2016), where scores about 337 older adults in Italy were found to be related to muscle mass and strength, independently of several factors including age. Focusing on ADL disability, Heiland et al. (2016) applied the one-leg balance stand test and assessed the walking speed in 2,4 and 6 m walk of 1,971 elderly living in the urban area of Stockholm (Sweden), finding that poor-performing mobility tests indicate hierarchical risk of disability in older adults, especially higher risk of developing disability in ADL.

Regarding the LSA test (Baker et al., 2003), its design has been useful to assess how life-space mobility can enhance physical activity and, therefore, help maintaining healthy people. By interviewing 174 Finnish people aged 75-90, Tsai et al. (2015) showed that a more intense life-space mobility is associated with objectively measured and positive indicators of physical activity (e.g., step count, activity and sedentary time). As for the effects of life-space mobility on executive functionality, both Poranen-Clark et al. (2018), using the LSA test with 169 Finnish people aged between 76 and 91), and Tian et al. (2015), applying a timed 400-m walking test to 347 over 60 persons interviewed in the US, detected significant positive effects. Instead, in a Finnish study involving 848 persons aged 75-90, Polku et al. (2015) studied the different dimensions of depression and their relations with life-space mobility, confirming their association (albeit not stating clearly the direction of the causality due to the cross sectional nature of the data used).

Finally, regarding the effects of mobility on health conditions, we found that sixteen studies in health sciences used self-reported information (e.g., subjective questions) about own mobility status (Knaggs et al., 2011; Kozakai et al., 2013; Choi and DiNitto, 2016; Asp et al. 2017). When using Swedish survey data (2,409 respondents aged 65-99, 2,261 full data) with questions on the difficulty to walk-up stairs or take short walks, Asp et al. (2017) found a significant association between physical activity and obesity only among elderly with physical mobility. Among elderly with impaired mobility, indeed, the obesity was high and similar irrespectively of physical activity. Choi and DiNitto (2016) used a survey conducted in the US (more than 5,000 observations) related to over 65 adults to investigate how mobility could reduce depressive symptoms. Their findings show that non-driving elderly who used to walk as a transport option tend to report lower depressive symptoms than older adults who did not walk. Dealing with mobility limitations, Kozakai et al. (2013) analysed 846 interviews among Finnish adults between 66 and 98, where respondents self-reported perceived difficulty in 2-km walking and climbing one flight of stairs without

resting. Since mobility limitations were found to strongly increase the need for inpatient care in the last year of life among men, the authors argued that a reduced mobility might accelerate the health decline, thus prolonging the inpatient care period in the late phase of life (with related higher healthcare spending). Metabolic costs of daily activities were studied by Knaggs et al. (2011), who using a sample of 42 elderly in the US (aged 70-90), reported on own difficulty when walking ¼ mile, getting up from a chair, climbing a flight of stairs, or performing light housework. As a result, mobility impairments were indeed found to increase metabolic costs of daily living.

As for research on mobility capabilities in the social sciences literature, three studies have assessed mobility without explicitly referring to the quality of transport means (Chiatti et al., 2017; Fristedt et al., 2014). In a study focused on physical and psychological health associated to mobility, Chiatti et al. (2017) showed that, among about 2,400 elderly Swedish, walking at least ½ km daily and being socially engaged have implications on mental self-reported health. Regarding to gender-related outcomes, the authors found that either male or female older adults report better ratings of subjective health associated with mobility. Yet, in another Swedish study, community mobility is associated with better subjective health for both genders (Fristedt et al., 2014). Interestingly, in this study, the 119 elderly men were more involved in sport activities, while the 147 women reported more out-of-home activities of daily living.

Table 2.9 *Summary of the role of mobility on health issues*

Outcome variables	***Discipline***	***Mobility measure(s)***	***Author(s)***
Falls N=19.3% (11/57)	Clinical Medicine	LSA test (Baker et al. 2003)	(-) Lo et al. (2016)
		Self-reported information – Perceived difficulty and task modification in advanced mobility regarding the 2-km walk	(-) Manty et al. (2012)
		Self- reported information - Questions on difficulties with walking or climbing stairs	(-) Musich et al. (2018)
		Self-reported information – Reported grade of difficulty (no difficulty vs some difficulty, moderate difficulty, severe difficulty) getting about outdoors	(-) Jefferis et al. (2015)
		TUG test and Mobility Scores (Gait Composite Score, Balance Composite Score, Physical Capacity Score)	(n) Langeard et al. (2019)
		TUG test	(-) Dai et al. (2012)
	Public Health & Health Services	TUG test, DGI (8 gait tasks assessing ability to adapt to gait challenges), SPPB and CB&M (13 tasks assessing higher-level balance and mobility)	(-) Balasubramanian et al. (2015)
		TUG test	(n) Mulasso et al.
		Composite scores of individual mobility variables such as quiet standing, maximal lean, sit-to-stand, gait, turn, step-in-tub and downstairs	(-) Panzer et al. (2011)
		TUG test, Timed Chair Stand test, Functional Reach test, One-Leg Balance test, and lower limb muscle strength	(-) Topuz et al. (2014)
		Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	(-) Litwin et al. (2018)
	Clinical	LSA test (Baker et al., 2003): Four weeks assessed of mobility by interview, scored from 0 (daily restriction to bedroom) to 120 (daily trips outside town without assistance), and categorising the elderly (0–20, 21–40, 41–60, 61–80, 81–120)	(-) Mackey et al. (2014) (-) Mackey et al. (2016)

Mortality N=17.5% (10/57)	Medicine	Self-reported information – Difficulty walking without special equipment use, walking 0.25 miles (to convert to kilometre, multiply by 1.6), walking 10 steps without stopping; stooping, crouching, or kneeling, walking from one room to another on the same level, standing up from an armless straight chair; or standing or being on their feet for 2 hours	(-) Frith et al. (2017)
		WWT test: Walking on a 15 feet walkway while pronouncing letters of the alphabet (e.g.; a, c, e.) trying to avoid task prioritization , Speed (cm/s) during normal pace walking, SPPB: Summary score of balance, gait speed, and chair rise tests	(-) Verghese et al. (2012)
	Public Health & Health Services	UGS test: time to walk 8 feet (2.4 m)	(-) Yu et al. (2019)
		Self-reported information – Difficulties in the previous 30 days in 15 different mobility-related situations	(-) Olaya et al. (2018)
		POMA: Ability to walk (several qualitative aspects of the locomotion pattern are examined) and maintain balance (carrying the subject through positions and changes in position, reflecting stability tasks that are related to daily activities) and self-reported information – If help is needed from another person or special equipment or a device for a walking across a small room	(-) Nam et al. (2017)
		Self-reported information – Questions on ability to walk indoors, outdoors, and climb stairs	(-) Katja et al. (2014)
		SPPB	(-) Ensrud et al. (2016)
		TUG test: The time (in seconds) it takes to rise from a chair (with armrests), walk three meters quickly but safely, turn and walk back to the chair and sit down	(-) Bergland et al. (2017)
Muscles N=5.3% (3/57)	Clinical Medicine	SPPB	(n) Reid et al. (2014) (-) Reid et al. (2012)
	Public Health&Health Services	POMA	(-) Curcio et al. (2016)
Frailty N=3.5%	Clinical	TUG test, 5-chair STS test, alternate step, TRG test, UGS test	(-) Kim et al. (2010)

(2/57)	Medicine	Rapid gait test: back-and-forth walk over the 20-ft course as quickly as possible	(-) Fallah et al. (2011)
Kyphosis N=1.8% (1/57)	Public Health & Health Services	TUG test	(-) Sugai et al. (2019)
ADL disability N=1.8% (1/57)	Clinical Medicine	One-leg balance stand and assessment of walking speed (m/s) of 2.4 or 6 m walk	(-) Heiland et al. (2016)
Metabolic costs of daily activities N=1.8% (1/57)	Clinical Medicine	Self-reported information – Difficulty in walking ¼ mile, getting up from a chair, climbing a flight of stairs, or performing light housework	(+) Knaggs et al. (2011)
Neuromuscular performances, aerobic capacity and cognitive flexibility N=1.8% (1/57)	Public Health & Health Services	TUG test and 10m walking test	(+) Berryman et al. (2013)
Obesity N=1.8% (1/57)	Public Health & Health Services	Self-reported information – Ability to walk upstairs without difficulty (for example getting on a bus or a train) and take a short walk (about five min) at a reasonably fast pace	(?) Asp et al. (2017)
Parkinson N=1.8% (1/57)	Clinical Medicine	Modified TUG test, 32 ft. walk, Standing Posture	(-) von Coelln et al. (2019)
Urinary incontinence N=1.8% (1/57)	Clinical Medicine	TUG test, Timed 6-m walk test and a test measuring the time taken to get up from a chair and sit down again five times without using the arms	(-) Fritel et al. (2013)
Physical activity N=1.8% (1/57)	Clinical Medicine	LSA test (Baker et al., 2003)	(+) Tsai et al. (2015)
		TUG test and Gait assessment	(+) Sunderaraman et al. (2019)

Cognition N=14% (8/57)	Clinical Medicine	TUG test and the 6 Minute Walk Test	(+) Rajtar-Zembaty
		TUG test, UGS test, and DTGS test (walks under dual-task conditions i.e., reciting alternate letters of the alphabet)	(?) Donoghue et al. (2018)
		TUG test	(+) Cohen et al.
		400-m walk test and usual gait speed for a 6-meter course	(?) Tian et al. (2017)
		Walking time (2.44 m) course, balance time in one-legged stand (cut-off 30s) and chair stands tests	(+) Demnitz et al. (2017)
		Walking time 4 m course, balance time in one-legged stand (cut-off 60s) and chair stands tests	(+) Demnitz et al. (2018)
	Social Sciences	Self-reported information - Difficulty in stooping or crouching, climbing one flight of stairs without resting, climbing several flight of stairs without resting, moving large objects, sitting in a chair for two hours, getting up from a chair after sitting for long periods, lifting weights more than 10 pounds, raising arms above shoulder level, walking one block, walking several blocks, and picking up a dime	(+) Bishop et al. (2016)
Depression N=3.5% (2/57)	Clinical	LSA test (Baker et al., 2003)	(?) Polku et al.
	Public Health & Health Services	Self-reported information - How people (other than driving) got to places that are outside their home during the preceding month	(-) Choi and DiNitto (2016)
Executive function N=3.5% (2/57)	Public Health & Health Services	LSA test (Baker et al., 2003)	(o) Poranen-Clark et al. (2018)
		400-m walk test and usual gait speed for a 6-meter course	(+) Tian et al. (2015)
Hospitalization and inpatient care N=3.5% (2/57)	Clinical Medicine	Self-reported information-Difficulty in walking 2 km and climbing one flight of stairs without resting	(-) Kozakai et al. (2013)
	Public Health & Health Services	SPPB	(-) Ensrud et al. (2017)

Subjective health N=1.8% (1/57)	General Science & Technology	Self-reported information – Ability to transport yourself to places beyond walking distance'', i.e., community mobility by private or public transport, and including walking to and from the vehicle at origin and destination	(+) Fristedt et al. (2014)
Physical and mental health N=1.8% (1/57)	Economics & Business	Self-reported information – Frequency of walking 500 m or more, access and use of private car, bus stop distance from home and use of public transport	(+) Chiatti et al.(2017)

Notes: (-) the elderly with higher mobility levels decrease the probability of developing this outcome variable or show lower levels of it; (+) the elderly with higher mobility levels increase the probability of developing this outcome variable or show higher levels of it; (n) the level of mobility has no effect on the outcome variable; (?) it is not clear the causal relationship between mobility and the outcome variable; (o) the outcome variable is a determinant of mobility

Independent living

Beyond living a healthy and secure life, in order to enhance their well-being, the elderly have been expected by the Active Ageing Index to maintain their ability to be independent, that is, avoiding help in primary daily-life activities, or lifts in general. However, in that case, our review reported a scarce literature dealing with the role of mobility in such a key relationship. This research gap is mostly witnessed by very few studies (only three papers) drawn from either public health or social sciences literature.

From a more conceptual point of view, Schwanen et al. (2012) explored independence in later life and its relations with mobility (or embodied movements through physical space), using in-depth interviews with about 40 community-dwelling adults aged 70 and living mainly in the UK. In that study, independence is described as a qualitative 'complex and fuzzy notion' to be related to technologies, infrastructures, and social networks, but also to the idea that it allows getting rid of lifts by closer people, e.g., kin, friends, or nursing assistants. Of utmost importance when assessing public supportive policies for the elderly, the idea of mobility that comes out from this study is therefore primarily related to psychological and physical conditions which could help maintaining independence, instead of factors linked to technology or infrastructures.

Along this path, the maintenance of independence (defined as living in the community and being able to perform most basic ADLs without assistance) has been recently studied in Diem et al. (2018), where both mobility and cognition in 1,010 community-dwelling older women (mean age 88 years) in Minneapolis, Portland and Pittsburgh (US) were considered. A timed 6-m walking speed test was used to show that mobility and cognition (which could be enhanced by mobility itself) in older women are strong predictors of the maintenance of independence. Even though 41.9% of respondents were found to be independent at follow-up, those with slow walk speed, compared to women with good mobility, were less likely to be independent, after controlling for cognition and other risk factors. Despite some other early studies have focused on specific diseases and behaviours and their contribution to the risk of dependence in later life (notable examples are Gregg et al., 2002; Sauvaget et al., 2002; Dodge et al., 2005; Drewes et al., 2011), still less is known about the combined effects of mobility and cognitive function on survival free of major assistance or lifts.

Adorno et al. (2018) conducted semi-structured interviews to 60 older people (15 of them ill) aged over 55 in Arlington (Texas, US). Their aim was to examine the experiences of the elderly regarding transportation mobility from a social justice and equity perspective. In that study, even if specific attributes of public/private means are not considered, older residents tend to describe the usage of public transit as vital to maintaining independence, however at the same time they perceive their own needs as not valued by local community structures. Although this outcome clearly depends on the study location, ageing-related mobility limitations are here described as health conditions that must be complemented with infrastructures and/or policies to help the elderly being independent in daily activities.

Table 2.10 *Summary of the role of mobility on independent living*

Outcome variable	***Discipline***	***Mobility measure(s)***	***Author(s)***
Independent living N=5.3% (3/57)	Public Health & Health Services	Means of transport broadly	(+) Adorno et al. (2018)
		Walking speed (m/s) at 6 m	(+) Diem et al. (2018)
	Social Sciences	Actual and potential embodied movement through physical space	(+) Schwanen et al. (2012)

Notes: (-) the elderly with higher mobility levels decrease the probability of developing this outcome variable or show lower levels of it; (+) the elderly with higher mobility levels increase the probability of developing this outcome variable or show higher levels of it; (n) the level of mobility has no effect on the outcome variable; (?) it is not clear the causal relationship between mobility and the outcome variable; (o) the outcome variable is a determinant of mobility

Social connectedness

A little more evidence has been detected for the effects of mobility on another key pillar of active ageing: social connectedness. Among 4 papers (about 7% of total articles) included in the review, two of them confirm that mobility in later life facilitate social and community integration from a public health perspective (Rosso et al., 2013; Zeitler and Buys, 2015).

Rosso et al. (2013) investigated cross-sectional associations between life-space mobility with or without disability and social engagement in a sample of 676 adults over 65 based in Philadelphia (US). The authors considered social engagement as the number of times the elderly reported to have participated in social activities, i.e. participation to social organizations, knowing the existence of programs for the elderly people organised by senior centres, frequency of telephone calls with family and friends, frequency and reasons for using the Internet. Using the LSA test, evidence has been found about the relationship between

lower mobility and lower social engagement even in the absence of disability. In that case, the effect of mobility on community engagement is generalized and thus strengthens the idea for which mobile elderly are also more socially included. Lastly, also in suburban environments in Brisbane (Australia), Zeitler and Buys (2015) found that transportation choices influence social participation and the daily life of older citizens (aged 57-87 years). The tracking of movements with GPS devices supported the measurement of social participation simply by the collection of data about the time spent for social activities such as socialising, assisting, volunteering, worship, education and leisure. From a methodological perspective, this research used qualitative design methods integrating a range of data collection strategies (i.e., travel diaries, in-depth interviews) to explore the elderly's perceptions of community liveability and active ageing. Notably, key findings from this study suggest that establishing age-friendly suburban communities is critical not only because of the complexity of built environments to establish in peripheral neighbourhoods, but also due to the fact that within suburbs the lack of mobility displayed by the elderly translates into loneliness and health harms at a faster pace.

Social networks (Litwin and Levinson, 2018) and the use of community services (Lester et al., 2019) are other two issues about social inclusion that have been correlated with mobility. Based on the SHARE survey (with 23,295 respondents) Litwin and Levinson (2018) emphasized how social networks constitute a dominant factor in keeping the elderly connected to the society, thus contributing to successful ageing. After controlling for other confounders, the authors investigated how social networks are linked to activity participation independently of mobility level, or alternatively, if mobility moderates the relationship between networks and activity. Mobility limitations were measured by timed walking-km tests, climbing one flight of stairs without resting and lifting or carrying weights over ten pounds/five kilograms, and a two-fold outcome emerged. First, social networks are especially important in the promotion of activity participation among older adults with mobility limitations. Second, a higher risk of social exclusion is faced by mobility-restricted elderly who are not embedded in resourceful social networks and, therefore, have high priority in efforts to increase active ageing.

Table 2.11 *Summary of the role of mobility on social inclusion*

Outcome variables	***Discipline***	***Mobility measure(s)***	***author(s)***
Community engagement N=1.8%	Public Health& Health Services	GPS tracking and daily travel diaries	(+) Zeitler and Buys (2015)
Social engagement N=1.8%		LSA (Baker et al., 2013) modified	(+) Rosso et al. (2013)
Social networks N=1.8% (1/57)		Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	(+) Litwin and Levinson (2018)
Use of community services N=1.8% (1/57)		SPPB, FSST (measures dynamic balance), gait speed and DeMMI (includes bed mobility, transfers and balance)	(+) Lester et al. (2019)

Notes: (-) the elderly with higher mobility levels decrease the probability of developing this outcome variable or show lower levels of it; (+) the elderly with higher mobility levels increase the probability of developing this outcome variable or show higher levels of it; (n) the level of mobility has no effect on the outcome variable; (?) it is not clear the causal relationship between mobility and the outcome variable; (o) the outcome variable is a determinant of mobility

Lester et al. (2019) considered 70 elderly over 80 years old in New South Wales (Australia), investigating the relationship between the objectively measured mobility status of rural community-dwelling older people and their use of formal and informal services, with variables such as SPPB, Four Square Step Test (FSST), gait speed, UGS test and the de Morton Mobility Index. In rural settings, older people may be indeed disadvantaged, compared to their peers in urban areas, by the geographic distribution of housing, family support and community assets and services. Using measurement tools such as the UGS test and the De Morton Mobility Index (DeMMI; de Morton et al., 2008) - which includes bed mobility, transfers and balance - this study provides strong evidence that the worse an older person's objectively measured mobility scores, the greater their need for community and publicly funded services to support living in their rural community. This finding confirms the increasing perception of risk to the older rural-dwelling person living at home and can influence decisions regarding the provision of community services. As mobility status is a key determinant for access to public-funded supports, related services are indeed typically provided to enable the elderly with mobility limitations to live in their home, thus having also an economic impact in terms of public finance and healthcare needs.

2.2.5 Discussion

The indirect relationship between mobility and well-being

The indirect relationship between mobility and well-being in later life has been investigated in this review by considering how the former might affect health conditions, independence, and social connectedness, which are identified within the EU Active Ageing Index as key drivers of the elderly's life satisfaction. Selected studies were considered in health sciences (clinical medicine, public health) and social sciences (economy, sociology and transportation) to analyse the topic from a multidisciplinary perspective.

As for the reviewed 50 studies on health conditions, mixed evidence arises about physical and cognitive effects of mobility, ranging from mortality to depressive symptoms. For what concerns physical aspects, various tests (the most widely used are the TUG test, the LSA test and the UGS test) display that, even controlling for other confounding factors, mobility for elderly people is particularly important in order to lower mortality and falls risks (together with frailty and in-patient hospitalization) and to improve neuromuscular performance or muscles strength. The effects of limited physical activity and reduced life-space mobility (measured either by quantitative tests or survey-based data processing) have been mostly studied in clinical medicine, but a few papers focused on the economic impact in terms of public health. Mobility limitations, in fact, increase the need of elderly people for early healthcare services (including long-term hospitalization), causing a growth of public expenditures. To fill this gap, future studies should investigate which specific physical harms evolving in chronic diseases could be effectively diminished by well-performing mobility, to tackle the increasing burden for public finance. The Parkinson disease is one notable example because it was detected as a potential outcome of deficient performances in mobility metrics (Von Coelln et al., 2019).

Although not focused on older adults with long-term handicaps, interestingly this review shows that mobility limitations might negatively affect other ADL activities, also increasing related metabolic costs. Hence, when dealing with public policies aimed at preserving health for ageing people, one insight is that more research should be done in order to clearly identify what daily activities are strikingly constrained by impairments which are mainly caused by poor mobility. Similarly, starting from the reported evidence of higher fear of falling in daily-life activities for older adults with lower mobility, even from a psychological perspective the

lack of movement in later life may result in a reduced cognitive functionality, including the fact that the likelihood of depressive symptoms was found to be correlated with bad executive functionality in own life-space (Vallée et al., 2011).

As concerns the second indirect impact, albeit it has been studied in only three of the reviewed papers (based in the UK and the US), the relationship between mobility and *independence* in later life, is a topic that merits further research. The findings of these studies encourage the research to continue in this direction. The scarcity of the literature could be attributed to the abstract nature of independence as a notion and, as a result, the researchers are still trying to identify its characteristic elements. Furthermore, the pathway between mobility and independence is not unique, thus, making the work of researchers even harder. In fact, independence has been recognized as a concept entangling physical and psychological dimensions (Schwanen et al., 2012). For instance, Delbosc and Vella-Brodrick (2015) have introduced and measured the transport independence (see for details Section 3.1.2). From a public-health perspective, the ability of older adults to feel comfortable and self-confident in daily activities without any assistance is first identified in the literature as linked to executive functionality (including cognitive performance). Although such a limited evidence cannot provide robust conclusions, high-level performances in mobility tests (e.g., in walking speed tests) are clearly correlated to feelings of independence, thus increasing the importance of maintaining active-ageing habits. Clearly, the reviewed literature (although scarce) pointed out also that independence goals deal with community-based conditions and built environment, such as especially the infrastructures which could help the elderly to be free to move and getting out on their own (Adorno et al., 2018). A number of related studies focused on external factors would complement the reviewed papers, eventually controlling ageing mobility, and, as a result independent living (Busari et al., 2019). As such, the subjective valuation of out-of-home features has proved to be a crucial factor to allow people benefit from own mobility capabilities (Luoma-Halkola et al., 2020; Tilley et al., 2017). Another example regards structural elements, including ageing-friendly built environments and adequate transport infrastructures, detected by scholars as strongly linked to mobility performance and limitations, thus implying their localized improvement (Winters et al., 2015; Chudyk et al. 2015; Clarke, 2014). Beyond studies explicitly assessing the quality evaluation of public transit or private means of transport, hence significantly further research should be carried out to explore in-depth how transport systems (including vehicles and supportive

devices) could strengthen the beneficial effects of mobility on the elderly's perception of independence.

Referring to the third indirect impact, the social connectedness, from a public health point of view, four papers have analysed the connection between mobility capabilities and social inclusion in later life, that is, the capability to participate in public activities interacting with other people and to maintain a social network. By using methods borrowed from clinical medicine, also in that case the reviewed literature displays a scarce (although growing) interest in exploring how mobility could help the elderly to keep on being part of society and, more interestingly, to have frequent interactions non only with other older people (Ormerod et al., 2015). Similarly to what has been noted for the case of independence for the lack of studies, it can be supported for the concept of social connectedness. All the reviewed studies (based in the US, Asia and Europe) highlight that preventing mobility limitations does emerge as a primary objective to maintain social connectedness. However, a wider (and more detailed) variety of out-of-home spaces should be studied to provide more evidence of what places the elderly consider as welfare-enhancing. Interesting evidence was also found on the fact that mobility impairments (e.g., limitations in ADL activities) should be first prevented to guarantee social life with kin and friends. Work activities are included as social dimensions to be safeguarded for the 'younger' elderly, while social networks (recognized as crucial sources of inclusion) must be sustained by reducing mobility constraints and by improving functionality features. Moreover, from an economic perspective, the local provision of community services was found to be affected by mobility conditions. Those services (including psychological assistance) are often made available to people unable to reach centres of social interactions, thus increasing the need for public funding even in case of potentially avoidable harms.

Quality appraisal

The results of the appraisal are presented in more details in Appendix A and presented in this section briefly. According to the MMAT criteria, the quality of the qualitative studies and of the mixed methods papers included in this review is very high (Table A.1 and A.4). Regarding the non-randomized studies, the lower scores, either because the criterion was not satisfied or not enough information was provided by the authors, regard the representativeness of the samples, the collection of complete outcome data and the inclusion of the crucial confounders

in the design of the analysis (Table A.2). The areas that the quantitative descriptive studies scored lower were the use of representative samples and the non-response bias (Table A.3). Additionally, it should be mentioned that the use of cross-sectional data rather than longitudinal, in most of the included studies, raises issues for the identification of the causality inferences between mobility and its effects. In general, however, the papers' quality was high, as it was expected from peer-reviewed works, which have passed the selection and review process of scientific journals.

The reviewed literature displays some relevant strengths. Firstly, all the considered active-ageing dimensions were covered (although at different extents) in the investigated scientific domains, with the only limitations already underlined. Secondly, most studies used heterogeneous datasets, combining primary data from interviews with information drawn from national surveys, but coming often to similar findings, reinforcing them. Since primary data are often lacking, the number of studies where questionnaires and measurable tests have been setup for a specific goal is high. Lastly, the variety of tests used is rather comparable in a quantitative and objective manner. As functional tests dealing with either the capability and the extension of movement in later life are detected in several papers (e.g., TUG, UGS, POMA, LSA, SPPB and different walking speed tests, etc.), related findings can be indeed generalized, especially in case of large samples, allowing comparison between different groups (e.g., over vs. under 65 people, seniors with or without mobility impairments, etc.). Moreover, in case of different geographical contexts, the usage of standard tests turns out to be helpful, especially when they are combined with subjective methods based on interview.

2.2.6 Conclusions and implications for future research

Findings from this systematic review give evidence that well-preserved mobility could improve ageing life satisfaction through three key dimensions of the EU Active Ageing Index: health conditions (including increasing life expectancy), independence and social connectedness. Whereas living a healthy and socially included life was already associated in the literature to higher levels of life satisfaction, this paper has the merit to be the first multidisciplinary review that systematically resume and compare the different findings of several studies, stressing the indirect effect of mobility on well-being. Moreover, the paper displays the different methodologies that could be used to measure how mobility capabilities can be related to physical and psychological status. The findings highlight that independence and social connectedness need more research efforts, in terms of both absolute number of studies (and thus robustness of results) and variety of countries of application.

This systematic review has some limitations related to the chosen inclusion criteria, that further research on the studied issue could eventually overcome. First, it focused on research studies published only in peer-reviewed journals, not considering non-academic literature (e.g. research reports commissioned by institutions). Second, by extending the scanning phase to other databases than the four considered or to a longer time period (before 2010) or by considering other keywords of selection, the number of studies could be increased. Referring to the period, we have decided to concentrate the attention on mainly the post-effects of the Active Ageing framework that was developed in 2012, but the inclusion of also the papers published in the two years before permits to partially show how research had anticipated the European Commission tool. As regards the keywords' selection, including words such as 'movement' or 'motility' could allow to consider also some clinical aspects related to the ability of older adults to get around, but were here out of the paper scope. Analogously, our research has analysed the impacts of 'mobility', while considering the topic from the point of view of 'immobility' (by searching for appropriate keywords) as a substantial element for impeding an independent and healthy life might sure deserve further investigation. Similarly, since our attention has been devoted to psycho-physical attributes (and performances) having the opportunity to either prevent ageing issues and easing the accessibility to transport systems, the analysis of the quality attributes of transportation means demanded by the elderly is out of the aim of this review and so they have been not included in the keywords' selection.

As regards the policy implications, the findings of this review give useful insights to policymakers and transport operators. Since the scientific studies highlight that impaired mobility in older adults has a negative impact on quality of life and a range of health and well-being outcomes, and also, as people age their activity space is getting restricted, further attention is required to the design and implementation of ageing-friendly transport measures for active mobility. The transport system can help the elderly people maintain a certain level of mobility and, as a result, the undesired impacts that we found in this study (see Table 2.9-2.11) and might be caused due to the decreased/increased mobility, can be prevented through e.g. regular public transport use (as Sections 3.1-3.2 demonstrate). Also, in Section 3.3 there are described some examples of public transport policies for the elderly. Indicatively, we mention here the low-floor buses or the maintenance of the pavements as cases of removal of the physical barriers of movements.

Relevant transport policies should consider especially the elderly who were car-dependent when they were younger (Ahern and Hine, 2012) or the elderly women who are usually more transport disadvantaged, as they are highly dependent to men for lifts (Li et al., 2012). The burst of the pandemic Covid-19 recently opened a big challenge for the policy makers to handle active ageing within the framework of social distancing and plan for mobility actions under this perspective. When the limits to movement imposed by the sanitary emergency will be removed, the transport system should be ready to supply services tailored on elderly's every-day life needs. The over-65 people, who constitute a significant and increasing share of the total population, are one of the more disadvantaged and frailer social group. More investment and resources on travel demand management and transport policies for elderly should be strongly encouraged and supported to prevent phycho-physical diseases and avoid isolation, thus saving public health expenditures in the long term.

Abbreviations

AAI	Active Ageing Index
ADL	Activities of Daily Living
CB&M	Community Balance and Mobility scale
DeMMI	de Morton Mobility Index
DGI	Dynamic Gait Index
DTGS	Dual-task Gait Speed
FSST	Four Square Step Test
LSA	Life-space Assessment
MIPAA/RIS	Madrid International Plan of Action on Ageing and its Regional Implementation Strategy
POMA	Performance Oriented Mobility Assessment
SHARE	Survey of Health, Ageing and Retirement in Europe
SPPB	Short Physical Performance Battery
STS	Sit-To-Stand test
TRG	Timed Rapid Gait Test
TUG test	Timed Up and Go test
UGS	Usual Gait Speed
UNECE	United Nations Economic Commission for Europe
WWT	Walking While Talking test

CRediT author statement

Evangelia Pantelaki: Conceptualization; Methodology; Formal analysis; Resources; Visualization; Validation; Writing – Original Draft; Writing – Review & Editing

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Appendix A.

Results of Mixed Methods Appraisal Tool application

Table A.1

Criteria for Qualitative Studies N=2	**YES**	**NO**	**CAN'T TELL**
Q 1.1 Is the qualitative approach appropriate to answer the research	100%	0%	0%
Q 1.2 Are the qualitative data collection methods adequate to address the	100%	0%	0%
Q 1.3 Are the findings adequately derived from the data?	100%	0%	0%
Q 1.4 Is the interpretation of results sufficiently substantiated by data?	100%	0%	0%
Q 1.5 Is there coherence between qualitative data sources, collection, analysis	100%	0%	0%

Table A.2

Criteria for Non-Randomized Studies N=42	**YES**	**NO**	**CAN'T TELL**
Q 3.1. Are the participants representative of the target population?	64%	22%	14%
Q3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?	81%	0%	19%
Q 3.3. Are there complete outcome data? (complete data threshold 80% (Thomas et al., 2004), 30% withdrawal rate for studies with a follow up period of more than one year (Viswanathan and Berkman, 2012))	64%	34%	2%
Q 3.4. Are the confounders accounted for in the design and analysis?	69%	21%	10%
Q 3.5. During the study period, is the intervention administered (or exposure occurred) as intended?	80%	10%	10%

Table A.3

Criteria for Quantitative Descriptive Studies N=12	**YES**	**NO**	**CAN'T TELL**
Q 4.1. Is the sampling strategy relevant to address the research question?	100%	0%	0%
Q 4.2. Is the sample representative of the target population?	17%	17%	66%
Q 4.3. Are the measurements appropriate?	83%	0%	17%
Q 4.4. Is the risk of non-response bias low? (threshold 60%, Pluye et al., 2011)	75%	25%	0%
Q 4.5. Is the statistical analysis appropriate to answer the research question?	100%	0%	0%

Table A.4

Criteria for Mixed Methods Studies N=1	**YES**	**NO**	**CAN'T TELL**
Q 5.1. Is there an adequate rationale for using a mixed methods design to address the research question?	100%	0%	0%
Q 5.2. Are the different components of the study effectively integrated to answer the research question?	100%	0%	0%
Q 5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?	100%	0%	0%
Q 5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?	100%	0%	0%
Q 5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?	0%	0%	100%

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Appendix B.

Main characteristics of the studies included in the review

Author(s), Year	***Study Type***	***Country***	***Mobility Measure***	***Findings***
Asp et al. (2017)	NR	Sweden	Self-reported information – Ability to walk upstairs without difficulty (for example getting on a bus or a train) and take a short walk (about five min) at a reasonably fast pace	Association between physical activity and obesity was found only among the physically mobile elderly and not among those with impaired mobility suggesting the existence of complexity between physical activity, physical mobility, and obesity.
Adorno et al. (2018)	QL	USA	Means of transport broadly	Transportation mobility facilitates independent living, accessibility to health care, goods, services, family involvement and social networks.
Balasubramanian et. al (2015)	NR	USA	TUG test, DGI, SPPB	Predicting falls for ambulatory community-dwelling older adults requires assessments both of mobility and balance and targeting cutoff scores. CB&M scale identified both fallers and recurrent fallers on the basis of their fall history while (CB&M, ABC, DGI, and BBS) discriminated recurrent fallers from those with fewer or no falls.
Bergland et al. (2017)	NR	Norway	TUG test	TUG test is a valid measure of mortality for both genders.
Berryman et al. (2013)	QN	Canada	TUG test and 10m walking test	Faster individuals in the mobility tests used demonstrate higher neuromuscular performances as well as higher aerobic capacity and better cognitive flexibility.

Bishop et al. (2016)	NR	USA	Self-reported information - Difficulty in stooping or crouching, climbing one flight of stairs without resting, climbing several flight of stairs without resting, moving large objects, sitting in a chair for two hours, getting up from a chair after sitting for long periods, lifting weights more than 10 pounds, raising arms above shoulder level, walking one block, walking several blocks, and	Better cognitive health was related to fewer mobility limitations, and faster decline in word recall was associated with more rapid increase in mobility limitations over the 10 years of aging observed.
Chiatti et al. (2017)	QN	Sweden	Self-reported information – Frequency of walking 500 m or more, access and use of private car, bus stop distance from home and use of public transport	Higher physical and mental self-reported health is associated with walking more than 500 m on a daily basis, use of a private car and frequent engagement in social activities. Access to the car is only associated with physical health. Mental health scores are significantly lower among those living far from the closest bus stop and never using public transport.
Choi and DiNitto (2016)	NR	USA	Self-reported information - How people (other than driving) got to places outside their home during the preceding month	Non-drivers who walked for transport had lower depressive symptoms than those who did not walk at either T1 or T2, and perception of transportation barriers to visiting friends/family was associated with higher depressive symptoms at T1 only.
Cohen et al. (2016)	QN	USA	TUG test	Deficits in visuomotor performance were associated with slow TUG performance, whereas verbal episodic memory deficits were associated with less upright posture.
Curcio et al. (2016)	QN	Italy	POMA	Tinetti Mobility Test score, together with muscle strength and evaluation, can preventively detect sarcopenic elderly subject at risk of falls.

Dai et al. (2012)	NR	USA	TUG test	Balance and mobility testing should be a priority in fall screening and the TUG is a good functional screening tool for mobility and fall risk.
Demnitz et al. (2017)	NR	UK	Walking time (2.44 m) course, balance time in one-legged stand (cut-off 30s) and chair stands tests	The objective measures of mobility used related poor mobility to poorer cognitive function, e.g. processing speed, markers of decreased GMV and white matter microstructure.
Demnitz et al. (2018)	NR	Canada	Walking time 4 m course, balance time in one-legged stand (cut-off 60s) and chair	Cognitive measures were significantly associated with mobility measures.
Diem et al. (2018)	NR	USA	Walking speed (m/s) at 6 m	Mobility and cognition in community dwelling older women are each strong independent predictors of the maintenance of independence i.e. living in the community and performing most basic ADLs without assistance.
Donoghue et al. (2018)	NR	Ireland	TUG test, UGS test, and DTGS test	Cognition did not variate much within the follow up period of 5.9 years, thus not permitting the association with mobility. Further research for longer periods is needed.
Ensrud et al. (2016)	NR	USA	SPPB	There was not strong evidence of an interaction between mobility and cognition for prediction of mortality risk. Mortality risks were increased among women with intermediate and poor after considering cognition and other mortality risk factors.
Ensrud et al. (2017)	NR	USA	SPPB	Reduced mobility and poorer cognition were each associated with higher inpatient health care utilization.
Fallah et al. (2011)	NR	USA	Rapid gait test: back-and-forth walk over the 20-ft course as quickly as possible	Mobility was significantly associated with frailty status, but not with mortality.

Fristedt et al. (2014)	NR	Sweden	Self-reported information – Ability to transport yourself to places beyond walking distance'', i.e., community mobility by private or public transport, and including walking to and from the vehicle at origin and destination	Community mobility among men was associated with higher ratings of subjective health for both genders. Men, on the one hand, reported more involvement in sport activities while women, more instrumental activities of daily living outside the home.
Fritel et al. (2013)	QN	France	TUG test, a timed 6-m walk test and a test measuring the time taken to get up from a chair and sit down again five times without using the arms	The study shows a strong proportional relationship between motor functional problems and urinary incontinence (urge urinary incontinence but not stress urinary incontinence) for the elderly women.
Frith et al. (2017)	NR	USA	Self-reported information – Difficulty walking without special equipment use; walking 0.25 miles (to convert to kilometer, multiply by 1.6); walking 10 steps without stopping; stooping, crouching, or kneeling; walking from one room to another on the same level; standing up from an armless straight chair; or standing or being on their feet for 2 hours	Individuals suffering both from reduced cognition and mobility were at the highest risk of all causes of mortality. These presenting either cognition or mobility deficit are also at risk of mortality. Comparing the groups (either cognitive or mobility deficits with the co-existence of pathologies group) no statistically significant results arise.
Heiland et al. (2016)	NR	Sweden	One-leg balance stand and assessment of walking speed (m/s) of 2.4 or 6 m walk	Mobility tests can indicate hierarchical risk of disability in older adults.
Jefferis et al. (2015)	NR	UK	Self-reported information – Reported grade of difficulty (no difficulty vs some difficulty, moderate difficulty, severe difficulty) getting about outdoors	Associations between baseline physical activity levels (step counts, sedentary time, light PA, and MVPA) and number of falls differed y presence of mobility limitations.
Katja et al. (2014)	NR	Finland	Self-reported information – Questions on ability to walk indoors, outdoors, and climb	Mobility mediated part of the association between social activity and mortality.

Kim et al. (2010)	NR	Japan	TUG test, 5-chair STS test, alternate step, TRG test, UGS test	The four mobility performance tests, except the 5-chair STS, proved to have the potential of discriminating the older women at high and low risk of frailty. The TRG test, at the cut point of 6 s, had the highest sensitivity and specificity in identifying high risk of frailty.
Knaggs et al. (2011)	QN	USA	Self-reported information – Difficulty in walking ¼ mile, getting up from a chair, climbing a flight of stairs, or performing light housework	Compared to normative values, metabolic costs of daily activities are substantially different in older adults and having mobility impairments increases this metabolic cost.
Kozakai et al. (2013)	NR	Finland	Self-reported information-Difficulty in walking 2 km and climbing one flight of stairs without resting	Mobility limitation (vs. intact mobility) at 5.8 years prior to death markedly increases the need of inpatient care in the last year of life among men.
Langeard et al. (2019)	QN	Canada	TUG test and Mobility Scores (Gait Composite Score, Balance Composite Score, Physical Capacity Score)	In older adults with fear of falling cognitive impairment significantly distinguishes fallers and non-fallers, whereas mobility impairment does not.
Lester et al. (2019)	QN	Australia	SPPB, FSST, gait speed and DeMMI	The worse an older person's objectively measured mobility scores, the greater their use of community services to remain living in their rural community.
Litwin and Levinson (2018)	NR	Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Italy, Netherlands, Slovenia, Spain, Sweden and Switzerland	Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	Social networks are especially important in the promotion of activity participation among older adults with mobility limitations. The co-presence of mobility limitation and social isolation brings this group in a more disadvantaged position compared to only mobility limited elderly.

Litwin et al. (2018)	NR	Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Italy, Netherlands, Slovenia, Spain, Sweden, and Switzerland	Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	Fear of falling predicts falling only for the elderly who present low to moderate mobility limitations while for highly limited elderly it is not the case.
Lo et al. (2016)	NR	USA	LSA test (Baker et al., 2003)	Associations were found between neighborhood disadvantage and falls and between life-space and after controlling for relevant covariates.
Mackey et al. (2014)	NR	USA	LSA test (Baker et al., 2003)	Life-space mobility can be a predictor of the risk of mortality in addition to that provided by gait speed, which is widely recognized as the strongest physical performance predictor of mortality in older adults.
Mackey et al. (2016)	NR	USA	LSA test (Baker et al., 2003)	Life-space scores of 60 or less were associated with mortality in older women independent of other strong risk factors.
Manty et al. (2012)	NR	Finland	Self-reported information – Perceived difficulty and task modification in advanced mobility regarding the 2-km walk	Indications of mobility decline together with history of falls increased the risk of future falls.
Mulasso et al. (2016)	NR	Italy	TUG test	The Tilburg Frailty Indicator was significantly associated with falls whereas the TUG test not.
Musich et al. (2018)	QN	USA	Self- reported information - Questions on difficulties with walking or climbing stairs	Moderate and severe limitations demonstrated significantly increased falls, decreased preventive service compliance and increased healthcare utilization and expenditures as mobility limitation

Nam et al. (2017)	NR	USA	POMA and self-reported information – If help is needed from another person or special equipment or a device for a walking across a small room	The assessment of mobility using POMA and ADL tests is an effective predictor of mortality.
Olaya et al. (2018)	NR	Spain	Self-reported information – Difficulties in the previous 30 days in 15 different mobility-related situations	High physical activity and mobility levels are both significant predictors of survival among older adults, and their effects are independent of physical, cognitive, and mental health functioning.
Panzer et al. (2011)	NR	USA	Composite scores of individual mobility variables such as quiet standing, maximal lean, sit-to-stand, gait, turn, step-in-tub and downstairs	Mobility measurement variable sets distinguished falls-status and showed the same results POMA and Computerized Dynamic Posturography Sensory Organization Test.
Polku et al. (2015)	QN	Finland	LSA test (Baker et al., 2003)	The associations between life-space mobility and different dimensions of depression were partially mediated through different factor. Differences appear between men and women in these associations. Cross sectional data are used thus not permitting to conclude on the temporal dimension.
Poranen-Clark et al. (2018)	NR	Finland	LSA test (Baker et al., 2003)	Since better EF at baseline predicted higher life space mobility at follow but baseline life-space mobility did not predict EF at follow-up the authors concluded that executive function was a determinant of life-space mobility.
Rajtar-Zembaty et al. (2019)	NR	Poland	TUG test and the 6 Minute Walk Test	The results reveal that higher levels of global cognition were related to the better physical mobility performance after controlling for age, sex, body mass index, medication use, depressive symptoms, and health characteristics.
Reid et al. (2012)	NR	USA	SPPB	The contractile properties of surviving muscle

				fibers are maintained in older adults with overt mobility impairments in an attempt to preserve overall muscle function.
Reid et al. (2014)	NR	USA	SPPB	The major finding of this investigation is that lower extremity muscle power deteriorates at the same amount but with different physiological mechanisms over a 3-year interval in healthy and mobility-limited older groups.
Rosso et al. (2013)	NR	USA	LSA (Baker et al., 2013) modified	Low mobility is associated with low social engagement even in the absence of disability; associations with disability differed by type of social engagement.
Schwanen et al. (2012)	QL	UK	Actual and potential embodied movement through physical space	Independent mobility is a fuzzy concept and in this study it is conceived by the participants as avoiding lifts provided by next of kin, friends or others for getting around.
Sugai et al. (2019)	NR	Japan	TUG test	The causes of kyphosis progression are not fully understood. However, this paper finds that the elderly who performed low at the TUG test, their incidence of kyphosis progression was 34.5%, whereas it was 11.4% among those with normal mobility.

Sunderaraman et al. (2019)	QN	USA	TUG test and Gait assessment	Among healthy individuals, relatively lowered cognitive performance may be linked to increased risk of gait alterations during the performance of these complex motor functions, or that lowered cognition may represent a higher vulnerability to gait disturbances. The study does not support the cause-effect relationship due to cross sectional nature of the data.
Tian et al. (2015)	NR	USA	400-m walk test and usual gait speed for a 6-meter course	Higher lap time variation may be an early indicator of executive function decline independent of mean lap time.
Tian et al. (2017)	NR	USA	400-m walk test and, usual gait speed to the nearest 0.1 second was measured or on a 6-meter course. The average speed in m/s over two trials was used for analyses	Among initially unimpaired older adults, the temporal relationship between usual gait speed and executive function is bidirectional, with each predicting change in the other, while poor fast walking performance predicts future executive function and memory changes but not vice versa.
Topuz et al. (2014)	QN	Belgium	TUG test, Timed Chair Stand test, Functional Reach test, One-Leg Balance test, and lower limb muscle strength	The mobility and activity levels of the elderly living in a retirement village and in community were found to be significantly different, in terms of falling and fear of falling, there were no remarkable differences. Therefore, the life status should be considered in order to reach safe conclusions.
Tsai et al. (2015)	NR	Finland	LSA test (Baker et al., 2003)	Participants with a restricted life space were less physically active and about 70% of them had exceptionally low values in daily step and moderate activity time.

Verghese et al. (2012)	NR	USA	WWT test, Speed (cm/s) during normal pace walking, SPPB	The WWT test is a robust predictor of risk of frailty, disability, and mortality in high-functioning older adults. Comparing WWT with SPPB, the first may better predict frailty whereas the second may better predict disability.
von Coelln et al. (2019)	NR	USA	modified TUG, 32 ft. walk, Standing Posture	The mobility measures have potential to enhance risk stratification of older adults who may develop Parkinson.
Yu et al. (2019)	NR	USA	UGS test: time to walk 8 feet (2.4 m)	Mild cognitive impairment predicted mortality. Developing first mild cognitive impairment and then mobility disability doubled the risk of death. The reverse order did not affect the risk.
Zeitler and Buys (2015)	MM	Australia	GPS tracking and daily travel diaries	Age-friendly means of transportation enhance older people's activity engagement in community. The findings also suggest the need for further research into this relationship between transportation and participation within the community environment.

Notes: *Classification according to Mixed Methods Appraisal Tool. QL/qualitative study, QN/quantitative study, MM/mixed methods study, NR/non- randomized study*

Appendix C.

PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	78
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	78
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	79-83
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	80
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	84
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	83-84
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	84
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	83
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	84

Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	84
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	86-87
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	86
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	N/A

Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	108-109
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	85
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Appendix B.
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Appendix A.
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	88-105
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	108-109
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			

Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	106-108
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	109
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	110-111
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	112-113

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For more information, visit: **www.prisma-statement.org**.

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2.3 Conclusion

In this chapter, it has been presented the mobility of the aged people as one of the basic ingredients of healthy and active ageing. Starting from the clarification of the principal terminology, followed by the presentation of existing theoretical mobility models and empirical testing of them, we synthesised critically the state-of-the-art mobility theory. The Chapter concluded with our published paper referring to the intermediate determinants of the relationship between mobility with well-being.

The main purpose of the Chapter was to study deeply the elderly mobility, mainly from a theoretical point of view, elaborating the published scientific literature on the topic and uncovering research gaps. We believe that we accomplished to frame the topic of elderly mobility by touching core thematic topics such as the terminology and the theoretical papers (and empirical testing of them) as well as the intermediate impact of mobility on well-being. Another important contribution, relates to the fact that we selected to study the topic under a multidisciplinary optique. However, some boundaries have to be acknowledged. Particularly, only the second part of the Chapter (Section 2.2) is an exhaustive analysis of the scientific evidence while the remaining is highlighting some important literature. Nevertheless, we admit that some papers on the topics might be missing and, thus, we suggest that the researchers proceed in the future with systematic approaches.

CHAPTER 3

PUBLIC TRANSPORT

3. Introduction

In the following sections included in Chapter 3, we analyse the role of the public transport in later life. As people age, their capabilities decrease and sooner or later they will have to face driving cessation, especially those who were car drivers in their younger life stages. Also, for those who were not driving it is equally important to support their mobility needs. Specifically, the chapter starts with the critical synthesis of the literature responding to the research question: "*How is the public transport system positioned in the daily life of the elderly people, as regards the aspects of well-being/QoL (Section 3.1.1), independence (Section 3.1.2) and social inclusion (Section 3.1.3)?".* In Section 3.2, we investigate, more particularly, the association of the public transport use with the physical, mental and self-perceived health of the Italian older people. After having framed the position of the public transport in the life of the aged individuals (Section 3.1) the Chapter concludes with Section 3.3 presenting some examples of good practices of public transport policies that exist to support the transport needs in later life.

3.1 Placing public transport in later life

3.1.1 Well-being and QoL

A complete evaluation analysis of the transport policies should include societal, economic and environmental goals. As regards the social policy goals in transport, they need to target the enhancement of mobility but with the ultimate goal to improve people's well-being (Stanley and Stanley, 2007). We suggest that the reader refers to Section 2.1.5 for a complete presentation of the meanings of well-being and QoL, as well as their differences. In general, a rather scarce attention has been devoted on how transport is involved in people's well-being (Delbosc, 2012). This could be justified by the indirect relation of transport mobility and SWB and, more, the mechanisms that link mobility with well-being are culturally, materially and politically formed (Vella-Brodrick and Stanley, 2013) (see Section 2.1.3 about the links of mobility with well-being). For instance, Delbosc (2012) introduced a theoretical model according to which transportation affects subjective well-being through three possible channels: (a) access to important activities, (b) increasing physical mobility levels, and (c) the externalities caused by the physical transport infrastructures.

More specifically, the physical transport infrastructures affect directly and indirectly the well-being through common externalities, such as creating noise, producing pollutant emissions and causing accident injuries that might impact individual health levels.

With respect to the links of transport with *well-being,* Stanley et al. (2011) undertook surveys in Metropolitan Melbourne (N = 535) and the Latrobe Valley (a regional area in the State of Victoria-N = 148) with participants aged 15+ years old (including the elderly people). Transport mobility was measured as the actual daily trips made. They applied the three stage least squares (3SLS) methodology, using as dependent variable the risk of social exclusion and afterwards personal well-being. The findings show that mobility indeed is linked indirectly with well-being through the influence on the risk of social exclusion. Although they verified the link between mobility, social interactions and well-being they didn't clarify the direction of the causality. Specifically, this refers to whether mobility creates human contacts, or whether a large social network feeds mobility.

Rather than well-being, *QoL* (see Section 2.1.5 for more details about the definition of QoL) is more often used in transportation research (Delbosc, 2012). Although travel is one important element included in the QoL, connecting QoL to transport systems is a quite complex issue (Aguiar and Macário, 2017; Banister and Bowling, 2004). For instance, Spinney et al. (2009) analysed data of 1558 Canadian adults over 65 years old, retrieved from Statistics Canada's GSS Cycle 12 Time-Use survey, and investigated the transport mobility role to the QoL. Transport mobility was measured through the revealed mobility, i.e. the benefits derived from travel activities: psychological, exercise, community helping and community socializing. In the same time, QoL was evaluated with self-reported questions (see Table 3.1). Their findings indicate a significant association between all four transport mobility benefits and QoL, but the benefits vary by life situation situations (e.g. age, gender, living arrangement, and the presence of disabilities) and QoL. In reality, as soon as the concept of QoL is not universally defined, the linking mechanisms with transport will remain too vague.

When talking specifically about the elderly people, on the one side, and the contribution of *public transport on their well-being/QoL*, on the other side, the general takeaways are not very different from what is assumed for the role of the transport system on QoL, more broadly speaking, Specifically, the existing literature affirms superficially that access to public

transport will allow the elderly not only access easier various goods, services, employment and activities but also maintain their independence social connections, participation in the society, and finally improvement of their QoL (Brown et al., 2018; Wong et al., 2018; Hounsell et al., 2016; Green et al., 2014; Fiedler, 2007). However, from an empirical point of view, there are only a few studies on the topic. Basically, what the researchers are usually trying to do is to verify several hypothetical pathways that relate public transport use with elderly's well-being/QoL.

In this sense, Jackson et al. (2019) investigated the influence of the free bus policy (as a mean to increase bus use) on the *well-being* of the elderly people in the UK. They analysed data of 5861 adults aged ≥50 years from the English Longitudinal Study of Ageing (Wave 6: 2012/13). Firstly, it has been analysed the direct relationship of bus use on well-being (measured through quality of life, life satisfaction, and depressive symptoms), and subsequently, were considered the intermediate factors of social isolation and physical activity in the relationship of bus use – well-being. In fact, the results confirmed what was expected: ownership and use of a concessionary bus pass was significantly associated with better quality of life, higher life satisfaction, and fewer depressive symptoms. Furthermore, the intermediate factors, social isolation and physical activity, were indeed significant and explained 7.7–20.1% and 9.0–17.4% of the well-being levels respectively.

Very recently, Kim et al. (2020) analysed data of the bus trips (number of bus trips per person and average travel time per trip) performed in the whole network of Shizuoka city (Japan) in January 2015. The scope of the research was to measure travel satisfaction and, also, to study the effect of *travelling on QoL*. The data analysis revealed that the non-elderly and the younger-old (65-74 years old), have similar bus usage patterns and, also, traveling was of high importance for both of them. For the older-old, above 80 years of age, the overall public transport plays a less important role determining their life quality. Additionally, the youngest elderly people who perform either short regular trips or longer sporadic use of public transport the QoL was found to be high. On the contrary for the oldest elderly the authors did not find a difference at their QoL caused by the public transport use.

Other scholars investigated the role of public transport on facilitating *activity participation.* From them, Banister and Bowling (2004) used data for 999 people over 65

years old from the national British survey "Quality of Life Survey". The focus of the research was to study the ingredients of perceived QoL in later age. The participants of the survey self-rated the overall quality of their lives on a 7-point Likert scale and, also, more specifically some socio-economic indicators of QoL (mobility, locality and social networks). The results showed that as regards the relations of public transport use (local transport) with QoL these are mixed. They found some indications that those participants who had participated in more activities increased the rating of the local transport. Interestingly, even nearly 40% of the respondents rated the local public transport as good, and they did not use the public transport to reach social activities. These findings are not giving a clear picture about the role of public transport on activity participation and as a result higher QoL. Additionally, the authors support that a more inclusive analysis of how transport affects the QoL of the elderly needs to include the neighbourhood characteristics and the degree of community integration of the older people.

A more detailed analysis about the typology of *activity participation* (formal, informal with family, informal with friends and solitary)[10] that the mobility capital (i.e. car, public transport, walking and cycling) facilitates was conducted by Shergold (2019). The author elaborated survey data (N = 920) collected by the 'Grey and Pleasant Land?' study of UK rural citizens aged 60 and above and applied the activity theory. The focus of the survey was to explore the activity participation for groups of elderly with and without car access. Using binary logistic regressions for the four types of activity participation as dependent variables and various covariates (e.g. health status, age, gender, car accessibility etc.) the results showed that the elderly people who have access to a car, are frequently involved in formal activities. On the other hand, the older people without car accessibility tend to prefer the informal one. Lastly, all the types of activities took place within a small distance range. Similar findings were extracted by Burlando and Cusano (2018). The authors found that the Italian elderly of their sample made on average 2.7 trips daily and within a distance range between 1 and 5 km. This remark is in line with the view of the "15 minutes cities", an approach that targets to disconnect from high urban mobility levels and keep the welfare space within the borders of the neighbourhood.

[10] As formal activity it is meant the involvement in community groups, informal activity means the interactions with family and friends and solitary are activities that are performed by the individuals themselves alone (Shergold, 2019).

A key observation from the literature analysed above is that elderly mobility or travelling, meets well-being and QoL merely through intermediate channels As Gagliardi et al. (2010) very pertinently point, the knowledge of the main variables that influence well-being of the older people is essential to understand better their needs and goals, and finally what interventions need to be made to determinant domains from the perspective of policy making. As we have underlined in this section, there is only sparse empirical evidence for the role of public transport on well-being/QoL and further exploration of the links is essential to give us a deeper insights. Additionally, the existing literature has studied, mainly, QoL rather than well-being as it has already being noted.

Table 3.1 *Empirical quantitative studies about the relationship of transport/public transport use by the elderly people with QoL/ Well-being*

Study	***Sampling strategy***	***Data collection***	***Statistical/ econometrical analysis***	***Transport/public transport measure***	***QoL/well-being measure***	***Results***
Banister and Bowling (2004)	999 people over 65 years old from the national survey "Quality of Life Survey" in Britain	Respondents aged 65 and over, who were interviewed for the Omnibus Survey (April, September, November, 2000; January 2001 surveys) were asked at the end of that interview if they would be willing to be re-interviewed for QoL questions.	Pearson chi-square tests.	Access to a car/van and ability to walk 400 yards.	***QoL questions:*** • Thinking about your life as a whole, what is it that makes your life good—that is, the things that give your life quality? You may mention as many things as you like. • What is it that makes your life bad—that is the things that reduce the quality in your life? You may mention as many things as you like. • Thinking about all these good and bad things you have just mentioned, which one is the most important to you? • What single thing would most improve the quality of your life? • What single thing, in your opinion, would improve the overall QoL for people of your age?	A more accurate study of QoL needs to include the travel, the place of living and the social connectivity of the elderly people.

Jackson et al. (2019)	5861 adults aged ≥50 years from the English Longitudinal Study of Ageing (Wave 6: 2012/13)	Random stratified sample of households who participated in the Health Survey for England.	• Continuous variables: one-way independent analysis of variance • Categorical variables: chi-square tests • Linear regressions	Holding bus pass: Do you have a concessionary travel bus pass issued by your local authority? Using bus pass: In the last month, how many times have you used your concessionary travel bus pass when boarding a bus?	Psychological well-being: quality of life, life satisfaction, and depressive symptoms.	Ownership and use of the free bus pass was significantly associated with better QoL, higher life satisfaction and fewer depressive symptoms. Also, significant indirect associations were found for social isolation and physical activity on well-being.
Kim et al. (2020)	Bus trip records in Shizuoka city (Japan) of the whole network for January 2015.	Matching data from smart card called "LuLuCa" and a subset people from a survey regarding their perceived travel satisfaction and QoL.	Ordinal regression models.	Bus trips per person and average travel time per trip.	***QoL questions:*** • Are you satisfied with your current life? • Are you satisfied with your current life compared to last year? • Do you think your everyday life is complete? • Do you feel insecurity and trouble in your everyday life? • Do you think that you are happy? • Do you think that you are healthy?	The non-elderly and the younger-old have similar bus usage patterns.Also, traveling is of high importance for both of them. For the older-old, above 80 years of age, the overall public transport plays a less important role on QoL.

Shergold (2019)	849 UK rural citizens aged 60 and above collected by the 'Grey and Pleasant Land'survey.	Stratified random sampling, corresponding to the national age-structure for the over-60s in the study areas, slightly biased towards women. Face-to-face 30 minutes home interviews.	Binary logistic regressions.	***Questions about mobility (***divided to people with and without car accessibility): • Vehicle mileage • No of modes of transport used in last month (mean) • Lack of transport is a barrier to involvement in community activity • Concerns about poor public transport in community • No of facilities and services difficult to access	***Subjective well-being questions:*** • I experience a general sense of loneliness (Agree / Disagree / Don't know) • During the last four weeks, how much have you been bothered by emotional problems (such as feeling anxious, depressed or irritable)? (Very much / Quite a lot / Moderately / Slightly / Not at all)	Those with car access are up to three times more likely to participate in formal activities, while those without car access is more likely to participate in informal activities. In both cases, the activities were performed within a local distance range.
Spinney et al. (2009)	1558 retired elderly Canadians over 65 years old, data taken from Statistics Canada's GSS Cycle 12 Time-Use survey.	Single-day time-diary survey with a five- minute temporal resolution covering all 12 months of 1998.	Analysis of variance (ANOVA).	Transport mobility is perceived through the benefits derived from travel activities i.e. psychological exercise, community helping and community socializing.	***QoL questions:*** • Presently, would you describe yourself as very happy … very unhappy? • How satisfied do you feel about your life as a whole right now? • Please rate your feelings of satisfaction about your job or main activity. • Compared to other people your age, how would you describe your state of health? • How would you describe your sense of belonging to your local community? Would you like to spend more time alone?	All benefits of transport mobility were found to be sensitive to several dimensions of life situations (e.g. age, gender, living arrangement, and the presence of disabilities) and across selected domains of quality of life, as measured by the questions of QoL.

Stanley et al. (2011)	Surveys were undertaken in Metropolitan Melbourne (N = 535) and the Latrobe Valley (a regional area in the State of Victoria - N = 148). The participants aged 15+ years old (including the elderly people).	Self-completed (April 2007 – June 2008) questionnaires about travel.	Three stage least squares (3SLS).	Actual daily trips.	Subjective well-being: assessment of respondent's level of satisfaction with seven theoretically derived QoL domains: standard of living, health, achieving in life, relationships, safety, community-connectedness and future security.	Transport mobility is linked indirectly with well-being through the influence on the risk of social exclusion.

3.1.2 Independence

The fact that access to transportation options might assist people in feeling independent (Kochera et al., 2005; OECD, 2005) or psychologically autonomous (Delbosc and Vella-Brodrick, 2015) is widely accepted in the literature and considered almost self-evident but, generally speaking, it is a poorly studied topic and even more for the elderly people. For details about the definition of independence see Section 2.2.4. On the other hand, Delbosc and Vella-Brodrick (2015) introduced the term 'transport independence' as the extent of freedom to access desired locations and activities without worrying about transport. Together with the term the authors built on a measurement tool, the Transport Independence Scale (TIS). It is a subjective evaluation of the level of independence provided by transport, assessed on a seven-point scale (1 strongly disagree – 7 strongly agree) responses to a list of self-reported questions (Table 3.2) about the relationships of transport and the relative flexibility that it offers in getting involved in daily activities.

Table 3.2 *Transport Independence Scale (TIS) (**Delbosc and Vella-Brodrick, 2015**)*

	Questions
1	I feel like I can get to all the activities I would like to do.
2	If I want, I can generally get to work or school on time.
3	If a friend invites me somewhere, I know I can get there when I want to.
4	I have to rely on others to get around. (reverse-scored).
5	I have to limit where and when I travel because of transport issues. (reverse-scored).
6	I have a range of transport options available to me.
7	Planning my travel is complicated. (reverse-scored).
8	I don't generally worry about how I'll travel to activities.
9	I feel like I am missing out on things I would like to do because of transport issues. (reverse-scored).
10	I have to rely on friends visiting me more often than I can visit them. (reverse-scored).

The older people understand independence as the avoidance of lifts by the people around them (Schwanen et al., 2012). Very often, they do not feel comfortable to ask or accept lifts from family and friends, hence, it is crucial to compensate them and especially after the period of the driving cessation (Su and Bell, 2009; Davey, 2007). It is fundamental to recommend new and different kinds of public transport options that are viable, affordable, accessible, safe and co-ordinated and, also, to motivate the elderly to use them

more frequently (Fiedler, 2007; Whelan et al., 2006). The elderly might not be eager to use forms of transportation if they do not contribute to their independence (Brown et al., 2018). Instead, the public transport use in later age seems to allow self-reliance and, thus, it might be preferred to asking for lifts (Coughlin, 2001).

Notable, to the best of author's knowledge, empirical quantitative studies about independence and transport use in later life do not exist in the literature. Since independence is a fuzzy term and it is better understood through the interactions with the environment, empirical qualitative studies will more accurately uncover this feeling. In this sense, some studies explored qualitatively the meaning of the bus pass for the elderly holders (see Table 3.3). For instance, in his report Butcher (2015) supports that the elderly people, holders of the bus pass, appreciate that it provides them with independence in the sense of freedom of movements. Independence is measured by the self-declaration of the feelings of the older people. Furthermore, Green et al. (2014) interviewed 47 adults aged over 60 living in London and being users of the free bus pass. After critical analysis of the documented interviews it emerged that the older people declared that the public bus (contrary to transport dedicated for those with disabilities) can make them feel more independent. Similarly, Andrews (2012) conducted a survey of 487 concessionary pass-holders in south-west England. Interestingly, the elderly reported about independence *'I couldn't do without the car: it's a mixture of the two I think. I'm glad I've got my bus pass as I won't lose my independence altogether, but having no car will go a long way to losing my independence.'* Generally, the elderly declared a sense of independence, freedom and their perception that they are valued by the society. These results are in line with the second level of mobility needs' satisfaction of Musselwhite and Haddad (2010) model, which has already been presented in Section 2.1.2.

Table 3.3 *Empirical qualitative studies about the relationship of public transport use by the elderly people with independence*

Study	***Sampling strategy***	***Data collection***	***Statistical/ econometrical analysis***	***Public transport measure***	***Independence measure***	***Results***
Andrews (2012)	487 concessionary pass-holders on a major operator's route in south-west England over a two-week period in winter 2009.	On-board bus survey and a series of 10 qualitative focus groups.	A mixture of manual coding and NVivo software use.	Holding the free bus pass.	Self-reported affirmations about feelings of independence.	The bus pass was considered from most of the participants beyond a mean to access places. It is offering less obvious gains: trip flexibility, removal of financial barriers, isolation, transferring financial funds absorbed by travel costs to other sectors of the economy, volunteering work, smooth driving cessation, social integration and feelings of independence.
Green et al. (2014)	47 adults aged over 60 living in London, reached through community organisations (such as lunch clubs and senior citizens' events), contacts in public spaces (e.g. park benches) and personal networks.	Interviews individually (N=14), dyadically (N=12) or in small groups (N=21).	Documentation and critical analysis of extracts from the interviews.	Free bus pass users.	Self-reported affirmations about feelings of independence and freedom with daily movements.	The Freedom Pass facilitated access to health-related goods and services, social interactions, feelings of independence, sense of belonging and visibility in the society.

Widely speaking, the transport policies are structured mainly around economic incentives (i.e. travel time savings) but such focus could raise the risk of underestimating the psychological benefits for disadvantaged groups of the population (Delbosc, 2012). When planning for the public transport systems, it is thus crucial to take into consideration the needs of older people to maintain also their independence and support their autonomy (Windle and Burholt, 2003). It should be noted that the lack of studies on the topic, keeps our knowledge rather limited. Further studies are required not only to investigate the relation but also its extent. Chiatti et al. (2017) underline that searching for evidence on the fact that this aspect of public transport outweighs the burden[12] for the society, it will more easily justify any public transport investments.

3.1.3 Social inclusion

The urban land use and transport strategies are often built on the triple bottom line (TBL) goals: improving economic productivity, reducing social exclusion and lowering the environmental impacts (Lowe et al., 2018). Out of these three goals, the reduction of social exclusion is the less considered in transport policy and planning although it has the potential to facilitate both personal well-being and enhance the capacity of people to fulfil their productive potentials (Lowe et al., 2018; Stanley and Lucas, 2008).

Although more than ten years have passed since Stanley and Lucas (2008) underlined the need for theoretical and empirical contributions, and the operational integration of social policy in transport planning, the validity of the argument remains still relevant. Small progress has been made in research, that could summarized briefly in three points (Lucas, 2012): (a) social inclusion is now a more familiar term within the transport research and policy community, (b) the researchers are further building on the methodology and measurement tools and (c) the transport-related social exclusion has almost become a universally used term.

The lack of social connectedness is tougher in later age than younger stages of life (Grenade and Boldy, 2008). In general, it is a two-sided coin that should be better separated from each

[12] Here it is implied the reduction of home care services provided and medical care (Chiatti et al., 2017).

other: (a) being socially isolated (objective approach) and (b) feeling loneliness (subjective approach) (De Koning et al., 2017). *Loneliness* is subjectively constructed by the individuals after evaluating the human relationships (Scharf and de Jong Gierveld, 2008). However, the subjective nature of loneliness means that someone with social interactions might feel alone at the same time (Grenade and Boldy, 2008). The levels of loneliness among the elderly may vary a lot between the studies, starting from 7-19% and reaching even 40% (see Dickens et al., 2011). The variation is caused by the reluctance of many older people to report the real situation and the diversity of the measures used by the researchers (Grenade and Boldy, 2008). In any case, though, the researchers draw our attention about the serious health consequences that could be caused because of loneliness, or even mortality, especially in men when coexists with depression (Holwerda et al., 2016).

When talking about social exclusion and inclusion (social exclusion is more widely used) in later life, the systematic literature review of Van Regenmortel et al. (2016) detects the early articles referring to it in the beginning of the millennium and most of the literature exists from 2010. Indeed, the report of the UK Social Exclusion Unit (2003) was the first document to link social exclusion with transport and stressed that the understanding of how people access important activities through transport is salient

Social exclusion regards mostly the lack of income as central to all types of exclusion, although it includes other dimensions, such as health, education, access to services, housing, debt, QoL, dignity and autonomy (MacKinnon, 2008). Among these aspects, the mobility-related exclusion is defined as the process by which "*people are prevented from participating in the economic, political and social life of the community because of reduced accessibility to opportunities, services and social networks, due in whole or in part to insufficient mobility in a society and environment built around the assumption of high mobility*" (Kenyon et al., 2002). The definition by Kenyon et al. (2002) condemns the insufficient mobility for social exclusion that is particularly relevant for the elderly people, since mobility capability decreases with ageing.

The knowledge about loneliness and social exclusion remains rather limited both as regards the causal pathways but also with respect to what is a dimension or a determinant factor of them (Van Regenmortel et al., 2016; Burholt and Scharf, 2014). Since loneliness and social isolation may not be always derived by the similar factors, building on independent predictors

will help health practitioners to identify the individuals at risk and carry out targeted interventions. Roughly speaking, our understanding says that the factors that affect loneliness and social exclusion in later age range from individual (psychological state and health) to social and environmental. For instance, physical activity and network relationships increase opportunities for social contact and, thus, decrease both social isolation and loneliness (De Koning et al., 2017; Wenger et al., 1999). In general, the people who are engaged in social life are happier and healthier (Kochera et al., 2005). The access to transport and services is considered in the literature both as a dimension and a determinant of social exclusion (Van Regenmortel et al., 2016). In his review, Lutz (2014) reports that in communities where transportation solutions are limited, the people are at risk of social exclusion and poorer health outcomes. In that sense, Shergold and Parkhurst (2012) studied transport-related social exclusion in a sample of 920 adults over 60 years old, living in six rural areas of the UK. The sense of community integration has been evaluated with various questions. Specifically for social exclusion, the participants were asked to respond 'yes' or 'no' to the following affirmation 'I often feel excluded within my own community'. Among the barriers for community participation, it has been assessed the 'lack of access to transport'. Notably, while having a car was not important factor for social inclusion, instead not having access seems to be an obstacle in reaching destinations, implying that enhanced accessibility and mobility are considered to mitigate social exclusion.

Overall, it is accepted by the scholars that transportation services give access to activities and assist the elderly, in reaching the three C's with respect to the community, i.e. choice, connectivity, and contribution (Kerschner and Silverstein, 2017). The elderly who do not have their family and relatives near them, and especially in rural areas (Shergold and Parkhurst, 2012), having accessibility to transport allows them maintain social interactions (Grenade and Boldy, 2008; Windle and Burholt, 2003). As a consequence, transportation policies are crucially linked both with the participation in family and community life (WHO, 2002), thus, supporting the satisfaction of the elderly needs and offsetting social exclusion (Bajada et al., 2016; Somenahalli et al., 2016).

However, as regards the literature about the social role of public transport in later age, there are only a few empirical studies that provide some more specific evidence. As such, Van den Berg et al. (2016) performed 430 in person surveys at the respondents' home address, between January and March 2014, to inhabitants living in Noord-Limburg (the southwest

region of Netherlands). 344 complete questionnaires returned data about loneliness, personal mobility and built environment characteristics. Through ordered logistic regressions, they aimed to study the role of mobility characteristics, neighbourhood and personal characteristics in subjective feelings of loneliness. As regards the transport use it was assessed by whether or not the respondents use a car, a bicycle and public transport, loneliness from the response to the statement: "I experience social isolation/loneliness" and the social contacts by the number of face-to-face social interactions in 2 days. The researchers reached their conclusions supporting, that the use of different transport modes, among which is included the public transport, significantly reduces loneliness in later age. Additionally, it is underlined that the public transport accessibility not only facilitates the social interactions, but also, it is in itself a fertile ground for social connectivity.

Additionally, there exist a few empirical studies that have investigated the relation of public transport with social inclusion through the evaluation of the UK transport policy for the elderly, i.e. the free bus pass (see more details on that in Section 3.3.1.2). Specifically, the study of Green et al. (2014) studying qualitatively the effects of the concessionary fares for the elderly in London, apart from feelings of independence (Section 3.1.2) uncovered that the elderly users confess mitigation of the feelings of loneliness through everyday social interactions (although the incentive of the transport policy was not explicitly that). The authors illustrated that the bus pass includes less visible advantages for the elderly and argued that the bus itself is a place for socialization for the elderly, or as it is named in Andrews (2012) a '*mobile social space*' which provides access to informal support networks, social engagement and contact with the outside world. In this last study, additionally to feelings of independence (Section 3.1.2), the results demonstrated that holding the free bus pass improved the QoL of the beneficiaries, drawing special attention to the reduction of loneliness and isolation. More, he found that as the older people are involved actively in the volunteering activities in the UK, the bus pass facilitates the participation in society without having to worry about the travel costs. In a similar empirical study, Reinhard et al. (2018) analysed data from seven waves of ELSA (Wave 1: 2002 - Wave 7: 2014). They noticed that the public transport use not only reduced loneliness and increased social engagement (in the form of volunteering and contacts with children and friends) but also reduced depressive symptoms among the elderly who took advantage of the free bus pass in the UK. For the

measurements of social connectedness and public transport use we suggest the reader to have a look at Table 3.4.

As it has already been stressed for the case of well-being/QoL in Section 3.1.1, it is equally important here to consider intermediate factors when assessing the social implications of the public transport, e.g. the interpersonal interactions[13] (Stanley and Vella-Brodrick, 2009). Stanley et al. (2010) considered exactly this element. The authors interviewed 535 people in Australia aged over 15 years old divided in distinct age groups considering the role of social capital[14] as a mediating factor between travel patterns and social exclusion. Social exclusion was evaluated in the sense of household income, employment status, political activity, social support and activity participation while travelling as the frequency of difficulties met in accessing activities because of the lack of public or private transport and evaluation of the importance of related characteristics of these transport means. They concluded that social capital and social inclusion were strongly correlated. The people that did fewer trips have been found to be socially excluded. However, they didn't condemn the public transport for the scarse personal interactions but, instead, the lack of an extensive social network. Interestingly, among the age categories considered, the people over 65 years old were at a higher risk of social exclusion. As far as the public transport use is concerned, although the related age-group was not explicitly stated in the study, the people who were socially included used, indeed, the public transport services.

Concluding this session, quantifying the overall impacts of the public transport is not always possible and this comes fairly clear form the above studies, included for the sake of simplicity in Table 3.4. Two challenges have been identified in the literature with respect to the research on transport and social exclusion (Lowe et al., 2018): (a) the personal responsibility towards deprivation, which means that trying less in everyday life increases the probability to reach lower levels of achievements, and (b) the assumption that people search to satisfy needs rather than how transport and social exclusion relate to needs' satisfaction. Even if the social policy in transport and more specifically its relation with the social contribution of the public transport use by the elderly people is still in its infancy, collaborations with researchers from health, social policy, development studies and housing planning is highly recommended

[13] The so-called social capital (Stanley and Vella-Brodrick, 2009) which is defined as networks, trust and reciprocity (Stanley et al., 2010).
[14] See Currie and Stanley (2008).

because the topic remains very relevant also for them (Lucas, 2012). Hence, an interdisciplinary approach is highly advised for a broader understanding of the value and role of transport services other than the environmental and economic (Vella-Brodrick and Stanley, 2013). More specifically, the association of public transport use with physical activity and health status of the elderly is analysed in the next Section (3.2).

Table 3.4 *Empirical quantitative-qualitative studies for the relationship of transport/public transport use by the elderly people with social inclusion*

Study	***Sampling strategy***	***Data collection***	***Statistical/ econometrical analysis***	***Transport/public transport measure***	***Social inclusion measure***	***Results***
Andrews (2012)	487 concessionary pass-holders on a major operator's route in south-west England over a two-week period in winter 2009.	On-board bus survey and a series of 10 qualitative focus groups.	A mixture of manual coding and NVivo software use.	Holding the free bus pass.	Self-reported affirmations about reduction of social isolation.	The bus pass was considered from most of the participants beyond a mean to access places. It is offering less obvious gains: trip flexibility, removal of financial barriers, isolation, transferring financial funds absorbed by travel costs to other sectors of the economy, volunteering work, smooth driving cessation, social integration, feelings of independence.
Green et al. (2014)	47 adults aged over 60 living in London, reached through community organisations (such as lunch clubs and senior citizens' events), contacts in public spaces (e.g. park benches) and personal networks.	Interviewed individually (N=14), dyadically (N=12) or in small groups (N=21).	Documentation and critical analysis of extracts from the interviews.	Free bus pass users.	Self-reported affirmations about psycho-social benefits arising from access to interactions with other people and keeping themselves 'active'.	The Freedom Pass facilitated access to health-related goods and services, social interactions, feelings of independence, sense of belonging and visibility in the society.
Jackson et al. (2019)	5861 adults aged over 50 years from the English Longitudinal Study of Ageing (Wave 6: 2012/13).	Random stratified sample of households who participated in the Health Survey for England.	• Continuous variables: one-way independent analysis of variance • Categorical variables: chi- square tests • Linear regressions	Holding bus pass: Do you have a concessionary travel bus pass issued by your local authority? Using bus pass: In the last month, how many times have you used your concessionary travel bus pass when boarding a bus?	Social isolation was assessed with an index that takes into account living status, frequency of contact with friends and relatives, and membership of social organisations.	Ownership and use of the free bus pass was significantly associated with better QoL, higher life satisfaction and fewer depressive symptoms. Also, significant indirect associations were found for social isolation and physical activity on well-being.

Reinhard et al. (2018)	18 453 residents of England aged ≥50 of the English Longitudinal Study of Ageing (ELSA) (Wave 1-Wave 7 (2002 - 2014).	Random stratified sample of households who participated in the Health Survey for England.	Instrumental variable (IV) Approach.	***Questions:*** • Do you use public transport … a lot, quite often, sometimes, rarely, or never?' In 2006, this question changed to: 'How often do you use public transport … every day or nearly every day, 2 or 3 times a week, once a week, 2 or 3 times a month, once a month or less, or never.'	Social isolation: score ranging from 0/not socially isolated)to 5/very socially isolated, created by the responses: (1) not married or cohabitating, (2) less than monthly contact (including face-to-face, telephone or written/email contact) with children, (3) less than monthly contact with other immediate family, (4) less than monthly contact with friends, (5) does not participate in any organisations, religious groups or committees. Social engagement: Binary variables about whether respondents volunteered at least monthly, were a member of any group/club/organisation and whether they had a least monthly face-to-face contact with children, other immediate family members and friends.	Free bus travel reduces depressive symptoms, feelings of loneliness, increases volunteering at least monthly, having regular contact with children and friends and social engagement.
Shergold and Parkhurst (2012)	920 adults over 60 years old, living in six rural areas of the UK.	920 completed a quantitative survey and 38 semi-structured interviews lasting about an hour.	Descriptive statistics and ordinal regressions for variables age, car access, and rurality.	Car accessibility and lack of access to transport.	Response to the statement 'I often feel excluded within my community' (Agree/Disagree).	Car availability is not a strong indicator of overall inclusion but non-availability was important in limiting access to particular types of location. More, the short travel distances required to access community activities was a key factor in high community participation.

Stanley et al. (2010)	535 people from Metropolitan Melbourne, Australia.	Self-completed questionnaires (April 2007 - June 2008) and an additional optional interview in home, lasting just over an hour on average.	Descriptive statistics and pearson's bivariate correlations.	Frequency of difficulty accessing activities because of lack of public or private transport and importance of transport-related characteristics.	Social exclusion: household income employment status, political activity, social support, activity participation.	The people at risk of social exclusion travelled less often, less distance, owned fewer cars and used public transport less but they attributed the risk to the small social capital rather than the transport disadvantage.
Van den Berg et al. (2016)	344 complete data from inhabitants (including adults over 65 years old) of Noord-Limburg, located in the southeast of the Netherlands.	In person surveys at the respondents' home address, between January and March 2014.	Ordered logistic regressions.	Questions about whether or not the respondents use a car, a bicycle and public transport.	Loneliness: Response to the statement : "I experience social isolation/loneliness" (1/Fully agree - 5 Fully disagree) Social contacts: The number of face-to-face social interactions in 2 days.	When only age was included in the ordered logistic regression (loneliness was the dependent) showed that older people are likely to feel lonelier but it was explained only a small portion of variance in loneliness. Instead, as regards the mobility characteristics on loneliness they found that the use of different transport modes (bicycle, car and public transport) significantly reduces loneliness. The transport accessibility facilitates the social interactions, but also, specifically the public transport is a fertile ground for connectivity.

Abbreviations

SWB	Subjective Well-being
TIS	Transport Independence Scale
WHO	World Health Organization

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3.2 Public transport and health status

The design of a transport system that connects individuals to goods, services, and social opportunities of the community contributes to successful aging, remaining active in the society and it is an integrable part of the age-friendly city (Kochera et al., 2005; Windle and Burholt, 2003; WHO, 2002). This chapter describes the association of public transport means (compared to car use) with the health status of the Italian elderly people. Specifically, the research question is:

RQ. What is the association of public transport use with the physical, mental and self-perceived health of the Italian older people?

The material of this section has been presented in various scientific organizations listed below. Moreover, extracts of this have led to one publication also presented below.

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Publications

Crotti D., Maggi, E., Pantelaki, E., Rossi F. (2020). Public transport use and health status in later life: which relationship? Research in Transportation Business & Management. 100591. DOI: https://doi.org/10.1016/j.rtbm.2020.100591

Conference presentations (*denotes presenter)

1. Crotti D., Maggi, E., **Pantelaki, E. *,** Rossi F. (2020). *Public transport use and health status in later life: which relationship?* Talk presented at the *61st Annual Conference 2020 of the Italian Economic Association, October 20-23, Online.*
2. Crotti D., Maggi, E., **Pantelaki, E. *,** Rossi F. (2020). *Public transport use and health status in later life: which relationship?* Talk presented at the XXII Conference of the Italian Association of Transport Economics and Logistics "*Transport in a changing world", September 17-18, Online.*
3. Crotti D., Maggi, E., **Pantelaki, E. *,** Rossi F. (2020). *Public transport use and health status in later life: which relationship? Talk* presented at the *60th European Regional Science Association Web Congress "Spatial challenges for the New World", 25- 27 August, Online.*

Paper Published in Research in Transportation Business & Management

PUBLIC TRANSPORT USE AND HEALTH STATUS IN LATER LIFE: WHICH RELATIONSHIP?

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Abstract

In many developed countries, ageing trends have called for mobility policies oriented to active travels for older adults, preventing some diseases. As a result, in the transport and health literature, the elderly's psycho-physical health is growingly recognized as linked to the accessibility to local public transport (LPT) and its usage frequency. Using data drawn from a survey by the National Institute of Statistics (ISTAT) on the Italian citizens' daily life, this paper investigates the relationship between health dimensions of the subsample of people aged over 60 years in Italy and their use of LPT, considered as a more active and sustainable means with respect to car. By applying a recursive mixed-process approach and controlling for LPT service availability and parking issues, the findings highlight that (i) taking public transport services or driving cars more frequently is associated with higher levels of psychological and self-perceived health; (ii) especially for people over 65 years old, the use of LPT at least once a week is linked to better physical conditions. From a policy perspective, the insights of this study are two-fold. First, improving the accessibility to welfare and activity spaces by using LPT is likely to increase ageing people's mental health and their social inclusion. Second, stimulating the LPT usage might be a primary way to effectively promote physical health, to prevent ageing-related diseases, and to help reducing healthcare expenditures connected to the lack of active mobility in later life.

Keywords: Aging; Local public transport; Car; Seniors health; Transport policies; Mixed-process models

3.2.1 Introduction

The increase of the ageing population has raised some concerns in modern societies for the excess burden that the governments will face to their healthcare and pension systems (Abdullah et al., 2018). Among the list of aside outcomes that will inevitably come up two are of key importance: the provision of specific ageing-oriented products or/and services, and society transformations, i.e. the changes of the daily life of the people surrounding the elderly (Metz, 2000). Notably, in 2019 Italy was the second country in the world (after Japan) in terms of old-age dependency ratio (United Nations et al., 2020). As confirmed by recent estimations of the Italian National Institute of Statistics (ISTAT) (http://dati-anziani.istat.it), the segment of the population aged over 65 years old was 22.8% and the average age of the total population 45.4 years old. The same estimations for the next twenty years project an increasing trend both for the percentage of the over 65s (32.2%) and the average age (50.2 years old) of the total population.

As described in section 3.2.2, it has been stressed by various scholars that ageing mobility affects various health-related issues and influences the health-related quality of life that the elderly enjoy (among the others, Sugai et al., 2019; Musich et al., 2018; Sunderaraman et al. 2019; Yu et al., 2019). Even if there is no consensus between international experts about the suggested levels of physical activity in order to maintain sufficient health condition, it is proposed at least half an hour of moderate intensity exercise most days of the week (WHO, 2006). To obtain this aim, among the key priorities of the World Health Organization (WHO, 2018) in living actively and achieving healthy ageing is the provision of appropriate transport services that respond indeed to the mobility needs of the older people, enhancing not only the physical health but also the psychological one. The transport system therefore become a necessary condition to facilitate the accessibility to the destinations of the "welfare-space" (Johnson et al., 2017), such as accessibility to goods, services, employment and other activities (Hounsell et al., 2016). Furthermore, it can assist in maintaining social connectedness and community participation (Wong et al., 2018; Brown et al., 2018; Green et al., 2014). Through the satisfaction of utilitarian, affective and aesthetic needs, it has the potential to promote the levels of quality of life of the older people (Kim et al., 2020; Musselwhite and Haddad, 2010; Banister and Bowling, 2004).

Considering the Italian demographic changes and the crucial role of mobility for satisfactory health performance and quality of life, it is needed sufficient preparation of the scientists and policymakers in order to overcome the great challenges that will appear in the near future.

Considering these reflections, enhancing transport aspects in later life, i.e. prolonged driving capability, car availability and accessibility of destinations through well-served public transport systems, need to be considered seriously by the policy makers when seeking ways of improving health in later life (Nordbakke and Schwanen, 2015). Designing age-friendly transport systems and facilities will require efficient allocation of the public funds and sufficient research could best justify this decision. However, despite the role of transport mobility in later age, the mobility of the elderly people in Italy is in general an ignored topic in the scientific literature (Mariotti et al., 2018). Within this framework, the objective of the current analysis is to stress a topic that has been neglected by the literature (see section 3.2.2): the relationship between health dimensions of ageing people and their public transport use compared to car. In terms of policy implications, the findings would give indications to policymakers about how to increase the use of local public transport (including bus, tram, subway and local trains), that should be promoted as it implies an *active* way to travel and satisfy own mobility demand in a sustainable way. In other words, our intention is to give an answer to the following research question:

What is the link between the health status of the Italian elderly (as measured by mental, physical and self-perceived health indicators) and the frequency of the local public transport (LPT) use with respect to private car?

The paper is organized as follows. Next section presents the literature review on the transport habits of the elderly population and the links of public transport usage with health dimensions. Section 3.2.3 describes the dataset and the methodology and section 3.2.4 presents the estimation results. Section 3.2.5 includes the discussion of the results and some key policy implications, and lastly, section 3.2.6 draws the conclusions, the limitations of the study and future research directions.

3.2.2 Literature review

Nowadays, the elderly people live more active and mobile compared to their peers in the previous decades (Klein-Hitpaß and Lenz, 2011). The human needs for mobility and social interactions do not decrease when people get older (Shrestha, 2017), but what actually change are the mobility patterns, e.g. health issues could cause a decreased percentage of people moving outside of their homes on an average day, fewer trips and kilometres travelled per person (Ryan et al., 2015; Sikder and Pinjari, 2012). The mechanisms of transport mode selection are not a simple task to be analysed by the researchers. From a trans-disciplinary perspective, it reflects habits, personal norms, perceived mobility necessity, occupation, social norms, life stage, structural environment, income, symbolic and affective meanings (Nakanishi and Black, 2015). Several studies indicate that even within the group of the elderly people there are observed heterogeneous transport behaviours. For instance, the younger seniors are more likely to travel compared to the older elderly (Yang 2018) and the male elderly travel usually longer distances than females on a daily basis (Shrestha, 2017; Siren and Haustein, 2013).

The selection of the transport mode for the satisfaction of the transport needs in later age can be determined by various parameters. First, the age is an obvious one. A study conducted in Sweden (Levin and Berg, 2009) found that between 65-84 years old 60% of travels are made by car, while after the age of 84 years old the public transport services become more popular. In another study conducted in the city of Milan (ISFORT, 2016, as cited in Mariotti et al., 2018), it has been found that the willingness to decrease car use or increase LPT use is higher for the people aged 60-69 years old than the over 70's. Second, the gender plays its own role. Older men more frequently use the private car than women, nevertheless, as women are getting involved in driving the gap with males will gradually shorten (Klein-Hitpaß and Lenz, 2011). Potential reasons for gender heterogeneities are proposed by some researchers (Legendre et al., 2014; Klein-Hitpaß and Lenz, 2011): (a) the absence of mobility alternatives, (b) the personal characteristics and constraints e.g. income, time budget, individual abilities, (c) the car availability and (d) the possession of a driving license.

In the literature, there is a general consensus that the private car is considered by the elderly people the synonym of independence (Ziegler and Schwanen, 2011). When the elderly face driving cessation, they have to reorganize their daily routine. Beyond feelings of discomfort in

asking for informal support from others (Murray and Musselwhite, 2019), additional undesirable effects of driving cessation are described by the researchers, for example depressive symptoms (Marottoli et al., 1997), limitations to out-of-home and social activity participation (Spinney et al., 2020) and social isolation (Dabelko-Schoeny et al., 2020), an issue aggravated in the rural areas of residence (Hansen et al., 2020). Evidently, providing alternative means of transport such as tailor-based transport services or well-organized public transport systems can support the elderly mobility and, thus, their life satisfaction (Lee and Choi, 2019). Beimborn et al. (2003) outline that the elderly might be "trapped" in using public transport because of disabilities, economic hardship or family reasons. Indeed, according to Shrestha (2017) the public transport is one of the transport choices during the period of driving cessation. Under a more holistic point of view, as sustainability has become an urgent challenge in the transport research the public transit has the advantage to be more environmentally friendly than the private car (Rojas-Rueda et al., 2012).

While extensive literature has analysed the modal choice determinants, including age and other socio-economic characteristics, for many years, transport and public health scholars were ignoring the links between health and public transit. According to Mulley et al. (2016), this could be justified, by the dominating perceptions in transport research that (a) intermodal interchanges of public transport were considered as a negative aspect rather than as an opportunity for additional daily walking (as a type of light physical exercise), and (b) the lack of inclusive datasets with data both of transport and health related variables. However, in public health science there is a growing interest to suggest ways of delaying the appearance of comorbidities that come with ageing as they can aggravate substantially the quality of life (Xuan et al., 1999). In that sense, nowadays the links between public transport and health are attracting more attention by transport and health scholars who are searching for stronger evidence (Mulley et al., 2016). The connection of public transport use with health status can be seen through the lens of different perspectives. The frequent public transport usage has some positive impacts both on community and individual level: lower number of traffic accidents and pollution levels (air and noise), increased physical activity (walking), improvement of mental health (through social participation and reduction of loneliness), facilitation of transport affordability (in economic terms) and promotion of basic mobility, e.g., access to healthcare services and healthy food (Litman, 2010). In the last few years, active travel (as a type of light physical exercise) has been studied by some scholars for its impact on

health dimensions, such as cardiovascular diseases and increased physical activity (e.g., see Norwood, 2014; Laverty et al., 2013). Moreover, it has been demonstrated that higher level of mobility in an ageing stage positively affect several diseases (Pantelaki et al., 2020), improve cognition (Sunderaraman et al. 2019), reduce falls (Musich et al., 2018) and even mortality (Yu et al., 2019) and other health-related issues (among others, Sugai et al., 2019; Curcio et al., 2016).

A few studies have been published for the relationship of public transport use with various physical and mental health dimensions in later life, mainly coming from targeted European countries and the majority regarding UK (see Table 3.5). Any study has been performed in Italy. As regards the contribution to physical health, the use of public transport requires more effort of walking to reach the transport infrastructures (Coronini-Cronberg et al., 2012). Indeed, Rissel et al., 2012 reviewed 27 studies revealing that 8–33 additional minutes of walking are attributed to the public transport use. This additional physical activity might keep lower the levels of *obesity* (Webb et al., 2012) and *adiposity* (Laverty et al., 2018b; Webb et al., 2016); moreover, it is demonstrated that the elderly users could perform better than non-users to *gait* (Webb et al., 2016) and *walking speed tests* (Rouxel et al., 2017). Apart from the physical health implications, some scholars have uncovered mental health associations with public transport use. The public transport facilitates the accessibility to places for socialization with family, friends, and the participation to volunteering activities (Reinhard et al., 2018), thus the elderly will not feel alone (Van den Berg et al., 2016) and their overall cognitive ability (Reinhard et al., 2019) could be maintained for a longer period. Being surrounded by loved people improves life satisfaction and reduces depressive symptoms (Jackson et al., 2019). As such, some scholars have pointed that the proximity to public transport services might be beneficial to mental health (e.g., Chiatti et al., 2017). From a transdisciplinary perspective, other activities different than the physical exercise (such as the use of the transportation means) could play a dual role in the elderly's life, offering the main benefits of physical activity together with their inherent function (Sallis et al., 2006).

Table 3.5 *Summary of studies on public transport use and health outcomes in later life*

Study	***Data source***	***Age***	***Country***	***Findings***
Coronini-Cronberg et al. (2012)	National Travel Survey Longitudinal (2005-2008)	≥60	UK	The possession of a free bus pass significantly increases physical activity.
Webb et al. (2012)	ELSA Longitudinal (wave 1: 2002, wave 2: 2004, wave 3: 2006, wave 4: 2008)	≥50	UK	The eligible for bus pass elderly were more likely to use the public transport and less likely to be or become obese than non-users.
Van den Berg et al. (2016)	Cross sectional 2014	>35-75	Netherlands	Using different transport modes (bicycle, car and public transport) significantly reduces loneliness.
Webb et al. (2016)	ELSA Cross-sectional wave 6 (2012)	≥62	UK	Female bus pass holders had faster gait speed, lower body mass index and waist circumference than women without a pass.
Chiatti et al. (2017)	SEBEM study Cross sectional	75-90	Sweden	Mental health scores are significantly lower among those living far from the closest bus stop and never using public transport.
Rouxel et al. (2017)	ELSA Longitudinal (wave 2: 2004, wave 3: 2006, wave 4: 2008, wave 5: 2010, wave 6: 2012)	≥60	UK	Older adults who did not use public transport had slower walking speeds compared to frequent public transport users.
Laverty et al. (2018b)	ELSA Longitudinal (wave 4: 2008, wave 6: 2012)	≥50	UK	Both starting using and increasing public transport use increases physical activity and may be associated with lower levels of adiposity for elderly women.
Reinhard et al. (2018)	ELSA Longitudinal (wave 2: 2004, wave 3: 2006, wave 4: 2008, wave 5: 2010, wave 6: 2012, wave 7: 2014)	≥50	UK	Using public transport reduces feelings of loneliness, increases volunteering at least monthly, and increases regular contact with and friends.
Jackson et al. (2019)	ELSA Cross-sectional wave 6 (2012-2013)	≥62	UK	Public transport use improves well-being, and this is in part explained by increased physical activity and social interactions.
Reinhard et al. (2019)	ELSA Longitudinal (wave 2: 2004, wave 3: 2006, wave 4: 2008, wave 5: 2010, wave 6: 2012, wave 7: 2014)	≥50	UK	Free bus pass holders used more the public transport and the elderly bus users performed higher to cognitive tests.

3.2.3 Methodology

Variables and descriptive statistics

The data used for the present analysis were drawn from the ISTAT "Aspects of Daily Life" 2017 survey, a yearly cross-sectional and multipurpose national survey on several aspects of everyday life of a representative sample of households and individuals: public services usage, perceived health, social and family relationships, leisure activities, eating habits, lifestyle, etc. (ISTAT, 2019). The 2017 edition gathered information on 48,855 individuals, who answered to 683 questions. For the focus of our analysis, we restricted the sample to participants aged over 60 years. After error-checking and cleaning the data, 15,097 responses have been used for this study.

Outcomes: Mental, physical and self-perceived health

In this study we focus on three outcomes related to the older adults' health. By retrieving and partially adjusting information taken from the survey, we first derived an indicator of the mental health conditions by adding up the Likert-scale values of the following five questions: *1."In the last four weeks, how long do you feel calm and/or peaceful?*" (From 1/never to 6/always); *2. "In the last four weeks, how long do you feel discouraged and sad?*" (From 1/always to 6/never); *3. "In the last four weeks, how long do you feel very agitated?*" (From 1/always to 6/never); *4.* "*In the last four weeks, how long do you feel down in the dumps?*" (From 1/always to 6/never); *5. "In the last four weeks, how long do you feel happy?*" (From 1/never to 6/always).

On average, the interviewed elders show a quite good mental status. More specifically, as regards the considered negative feelings (question 2, 3 and 4),, only very few of the elderly (less than 2.5%) feel always sad or agitated or down in the dumps (see Figure 3.1). However, when considering the positive feelings (question 1 and 5) included in the mental health indicator, 60% (i.e. the sum of 1, 2 and 3 levels of the Likert-scale in the second column of Figure 3.2) stated not often feeling happy.

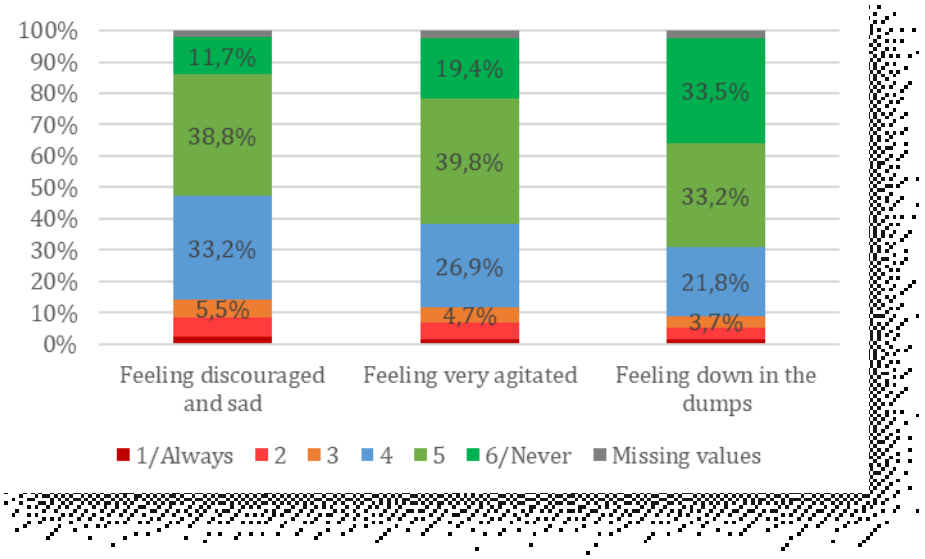

Figure 3.1 *Mental health indicator - Negative feelings: frequency among older adults interviewed (%) (Authors' elaboration on ISTAT "Aspects of Daily Life" 2017 survey)*

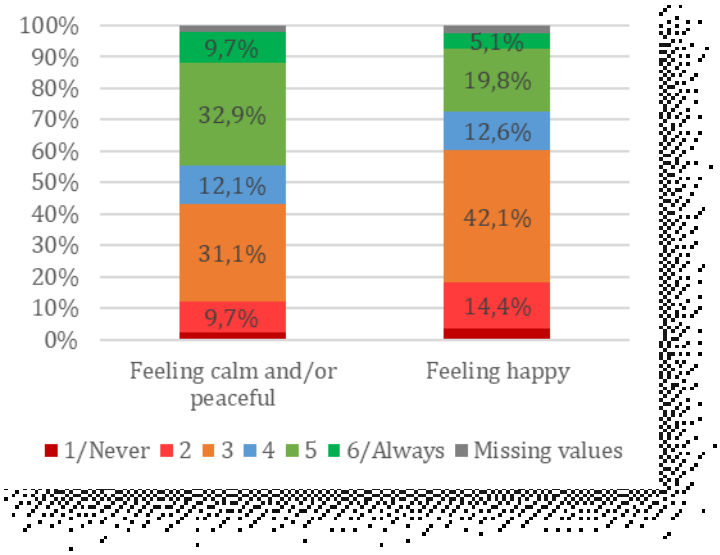

Figure 3.2 *Mental health indicator - Positive feelings: frequency among older adults interviewed (%) (Authors' elaboration on ISTAT "Aspects of Daily Life" 2017 survey)*

The mental health variable used in the econometric analysis is thus built by summing up the values of the positive and negative feelings, obtaining an aggregated indicator ranging from 5 to 30 (and handled as a continuous dependent variable): the higher the value, the better the older adults' mental health.

In order to develop a study-specific measure of physical conditions, according to the literature linking ageing and health, we selected five key diseases which were found to be more affected by active mobility: diabetes, arterial hypertension, angina pectoris or other heart diseases, arthrosis and/or arthritis and osteoporosis (Wilby, 2019; Poduri, 2017; Nascimento et al., 2015; Norwood, 2014; Zhang et al., 2008; WHO, 2006). As shown in Figure 3.3, angina pectoris or other heart diseases (82.1%) and diabetes (76.2%) are the most frequent diseases among the older adults interviewed. Summing up the values of the binary answers (Yes/0, No/1) for each question about these pathologies (e.g. *"Do you suffer from diabetes?", "Do you suffer from arterial hypertension?" etc.*), the score ranges from 0 to 5 (treated as a continuous dependent variable within the econometric model), where higher values indicate a better physical health.

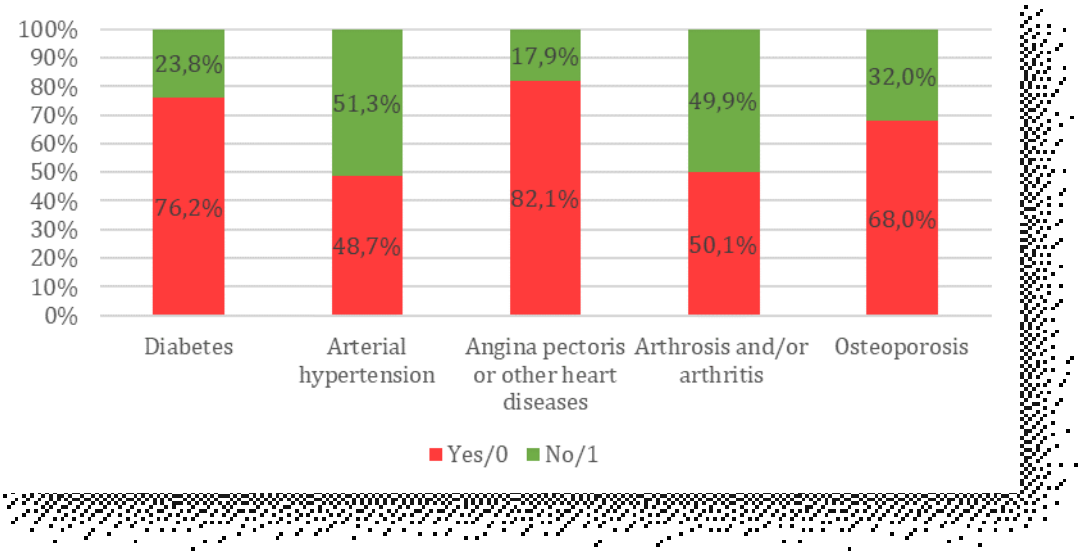

Figure 3.3 *Physical health indicator: frequency of diseases among older adults interviewed (%) (Authors' elaboration on ISTAT "Aspects of Daily Life" 2017 survey)*

Lastly, we used the outcomes (Likert scale; from 1/very bad to 5/very good) of a general question about subjective health: "*How is your overall health in general?*" which is handled as an ordinal dependent variable in the econometric model. Figure 3.4 shows the distribution of these self-assessed health responses: only 4% of the interviewed elderly perceive their health as very good, 35.3% perceive to be in good health conditions, while the majority (46%) chose the value in the middle of the scale (nor bad, nor good).

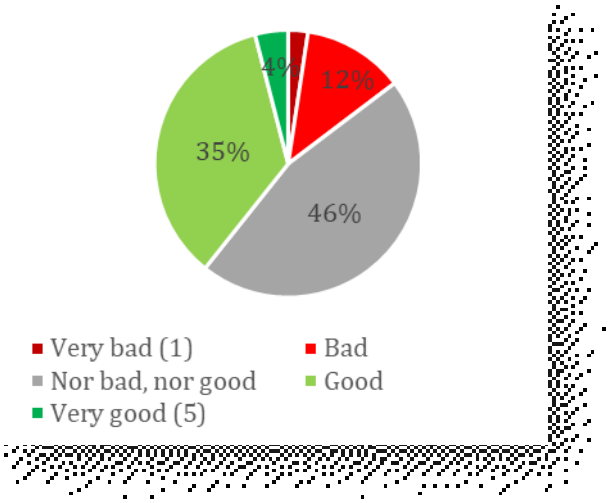

Figure 3.4 *Frequency of self-perceived health responses (%) (Authors' elaboration on ISTAT "Aspects of Daily Life" 2017 survey)*

Exposures: usage of LPT and private cars

Since the main aim of the study is to investigate the linkages between the older people's mobility in Italy and different dimensions of their health, we assessed the usage frequency of LPT and private cars by retrieving the following survey questions, both measured on a Likert scale (from 1/never to 5/every day): "*How often do you use local public transports (bus, trolley bus and light rail)*?" and "*How often do you drive a private car*?". Table 3.6 shows the frequency of the responses to the above two variables: only 1.8% of the respondents use LPT every day, while 62.56% never use them. By contrast, 35.99% of the interviewed elderly drives every day a private car, 16.59% uses it sometimes during the week, and 42.03% never drives. Reported missing values (18.68%) related to the usage of LPT are due to the lack of respective services in the neighbourhood/area where older adults reside. For these elderly people, other means of transport (included cars) are an unavoidable choice.

Table 3.6 *Elderly's mobility habits: LPT and private cars usage – Summary statistics*

Categories (Likert scale)	**LPT** (use frequency)	**Private car as a driver** (use frequency)
1 (*Never*)	9444 (62.56%)	6346 (42.03%)
2 (*Few times a year*)	1048 (6.94%)	257 (1.70%)
3 (*Few times a month*)	744 (4.93%)	435 (2.88%)
4 (*Few times a week*)	770 (5.10%)	2490 (16.59%)
5 (*Every day*)	271 (1.80%)	5433 (35.99%)
Missing values	2820 (18.68%)	136 (0.90%)

Comparing the answers of the elderly with those of younger age cohorts of the survey, it emerges that in general the Italians do not use frequently the LPT (Figure 3.5). On average, 61.5% of people aged 60-64 years old, 60.9% of elders with 65-74 years old and 64.8% of the over 75's has never used the public transport services and the tendency is rooted to the earlier years of life course. Notably, 64% of people aged 35-59 years old declared that have never used the LPT. On the other hand, 11.6% of the 14-34 years old use LPTs every day, while the other age cohorts remain below the national average (5.5%). Accordingly, data from ISFORT (2019; p. 4) show that in the last twenty years the mobility rate of the Italian elderly people is consistently lower compared to the mobility of the younger generations and seems to be a bit lower (69.9%) compared to the last decade rate of their peers (71.9%).

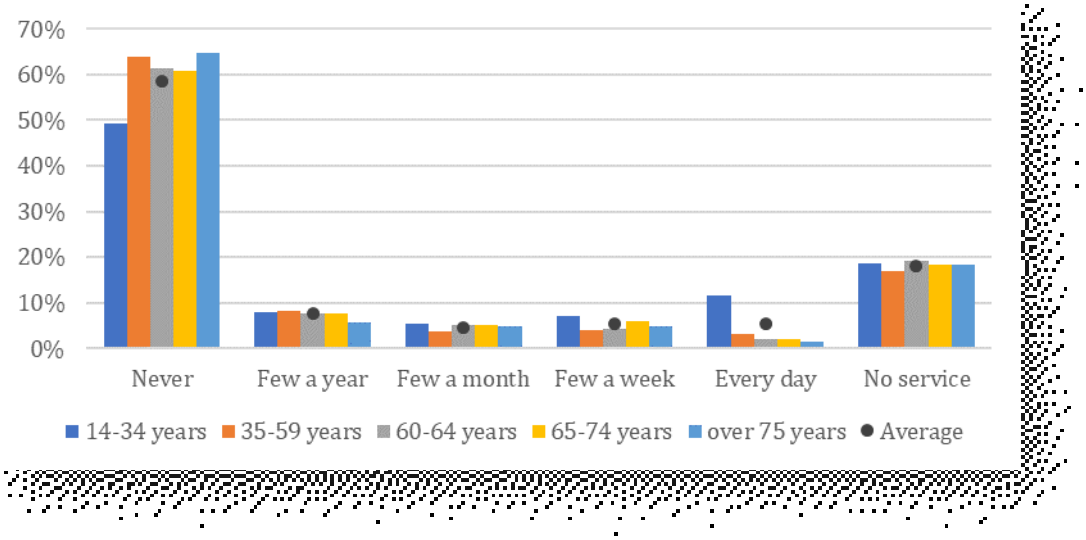

Figure 3.5 *Frequency of LPT usage among age cohorts (%) (Authors' elaboration on ISTAT "Aspects of Daily Life" 2017 survey)*

Looking at the data of private car driving, Figure 3.6 shows that car is the favourite transport mode for the everyday travels among the ages of 35-59 years old (65.9% - quite above the national average of 47%). Similar numbers are observed for the car usage few times a week and few times a month among all the age cohorts, with averages of 16.2% and 3.3% respectively. Instead, the percentage use by the elders is lower than younger and the percentage of the interviewed elderly who never drive a private car increases with age progression (20.9% for people aged 60-64 years old, 32.1% for the 65-74 years old, 63.5% for the 75+), probably because they no longer hold a driving license.

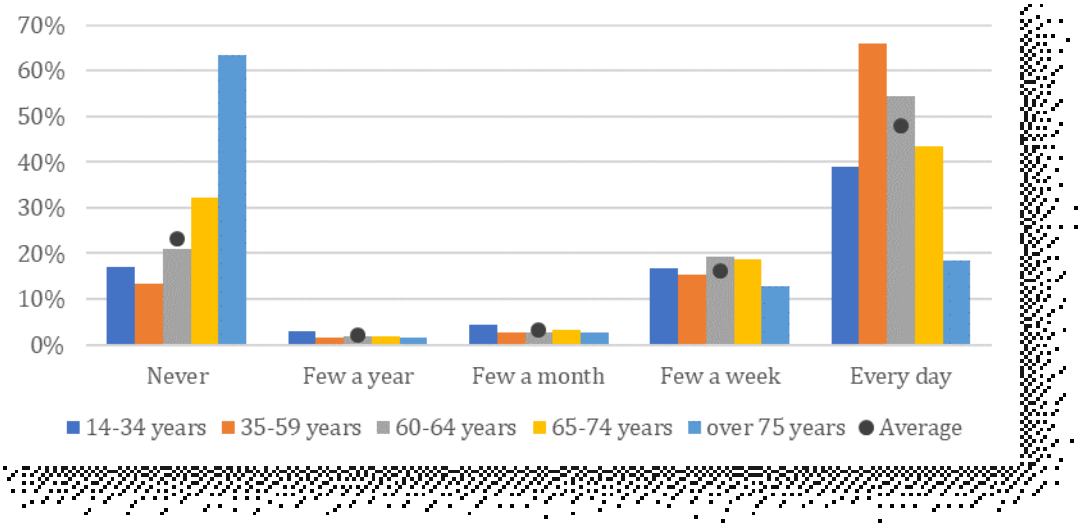

Figure 3.6 *Frequency of driving a private car among age cohorts (%) (Authors' elaboration on ISTAT "Aspects of Daily Life" 2017 survey)*

The observation that the private car is the favourite transport mean in Italy is confirmed also in the report of ISFORT (2019). According to that, almost six out of ten trips in 2018 have been made by car, five out of which as drivers. Moreover, considering the overall trips of the Italian population, the share of trips undertaken by the elderly (over 65 years old) is 24.1% for cycling, 20.6% for walking, 16.5% by car, 14.5% by LPT and 10.9% by motorcycle. Remarkably, nowadays as regards the elderly people, the LPT usage is lower than ten years ago (16.6% in 2008), while the car usage is higher (11.1% in 2008).

Covariates

In the econometric models, we control for various socio-demographic characteristics that are commonly used in the scientific literature to assess the impact of transport on the health of the elderly people, as previously described (see section 3.2.2): age, gender, civil status, family members, source of income, level of education, geographical location across Italian macro-areas and social relations/contacts. Table 3.7 reports some descriptive statistics.

Table 3.7 *Socio-demographics covariates used – Descriptive statistics*

Variable	N	%	Mental health Mean (SD)	Physical health Mean (SD)	Self-perceived health Mean (SD)
Age (classes)					
60-64	3283	21.75%	21.66 (4.55)	4.15 (0.96)	3.57 (0.78)
65-74	5864	38.84%	21.60 (4.73)	3.73 (1.12)	3.32 (0.76)
75+	5950	39.41%	20.71 (4.90)	3.30 (1.23)	3.03 (0.82)
Gender					
Female	8284	54.87%	20.69 (4.87)	3.45 (1.24)	3.18 (0.81)
Male	6813	45.13%	21.97 (4.57)	3.89 (1.05)	3.36 (0.81)
Civil status					
Not married	1034	6.85%	21.67 (4.82)	3.81 (1.13)	3.32 (0.85)
Married	9359	61.99%	21.66 (4.58)	3.79 (1.10)	3.33 (0.79)
Divorced	1035	6.86%	20.91 (4.91)	3.86 (1.13)	3.35 (0.84)
Widowed	3669	24.30%	20.22 (5.06)	3.20 (1.27)	3.04 (0.82)
Family members					
Alone	3781	25.04%	20.65 (5.08)	3.41 (1.26)	3.14 (0.84)
Two	7285	48.25%	21.29 (4.55)	3.82 (1.13)	3.36 (0.79)
More than two	4031	26.70%	21.56 (4.71)	3.69 (1.14)	3.27 (0.80)
Income					
Family aids	1718	11.38%	20.76 (4.79)	3.67 (1.16)	3.28 (0.76)
Self-sufficiency	13379	88.62%	21.33 (4.77)	3.65 (1.18)	3.26 (0.82)
Education					
Primary school	6773	44.86%	20.66 (4.96)	3.38 (1.23)	3.07 (0.81)
Middle school	3771	24.98%	21.45 (4.73)	3.79 (1.12)	3.33 (0.80)
High school	3296	21.83%	21.98 (4.47)	3.91 (1.05)	3.46 (0.77)
University degree	1257	8.33%	22.05 (4.29)	4.01 (1.00)	3.56 (0.76)
Residence area					
North	6379	42.25%	21.76 (4.73)	3.78 (1.11)	3.36 (0.79)
Centre	3001	19.88%	20.95 (4.91)	3.67 (1.16)	3.26 (0.81)
South and Islands	5717	37.87%	20.88 (4.72)	3.50 (1.23)	3.15 (0.83)
Social contacts					
No contacts	3274	20.69%	20.38 (5.16)	3.53 (1.22)	3.11 (0.88)
One group	2468	16.35%	21.01 (5.01)	3.64 (1.19)	3.24 (0.82)
Two groups	9356	61.97%	21.64 (4.53)	3.70 (1.15)	3.32 (0.78)

Concerning the socio-demographic characteristics of our sample, people aged over 75 years are overrepresented (39.41%), also reporting, as intuition suggests, the lowest average scores in all the considered health dimensions. Female elderly (54.87%) are those associated to worse general health conditions, while people married (62%) seem to have better

psychological conditions compared to divorced and widowed (probably due to less loneliness), as well as financially self-sufficient people (88.6%) compared to those supported by other family members. Alone older people (25%) report the lowest average scores in all the considered health dimensions. Most of the older adults in the sample hold a primary or middle school license (about 70%), associated to relatively lower scores in all the outcomes. From a geographical perspective, the largest group of interviewed elderly lives in the Northern part of Italy (42.25%), followed by the Southern part and Islands (37.87%). The Northern Italian over 60 citizens seem to be healthier than those living in the remaining part of Italy. Finally, the variable labelled as "Social contacts" captures the elderly social relations using the following three categories: No contacts (i.e., the interviewed stated that they do not have parents, nor friends, nor neighbours: 20.69%); One group (i.e., the interviewed declared to have contacts with one group among friends, family and neighbours: 16.35%); Two groups (i.e., the interviewed stated to have contacts with at least two groups among friends, family and neighbours: 61.97%). The social connectedness seems to be positively related to all the three health variables, confirming the findings of the literature (e.g., see Brown et al., 2018; Green et al., 2014).

Econometric modelling

In order to study how the usage of LPT (compared to that of private cars) might be related to health measures in later life, we started our analysis by considering potential sources of endogeneity problems (i.e., unobservable factors having an impact on both transport usage and health status). From a methodological perspective, we used two instrumental variables (Ivs) to deal with the problem of *self-selection bias*, considering that the respondents' choice to use transport means does potentially lack of exogenous predictors with respect to health conditions (Clougherty et al., 2015). Among the available data, we identified the difficulty of LPT accessibility (e.g., distance from bus stops, low ride frequency, etc.) and residential parking issues (e.g., lacking parking slots), respectively, as Ivs that are reasonably correlated with the use of LPT and private cars but not, in principle, with the outcomes described in section Outcomes: mental, physical and self-perceived health, i.e., mental, physical and self-perceived health (Jackson et al., 2019). In the survey, those features are explicitly captured by the two following questions (measured with a Likert scale, from 1/*Not at all* to 4/*Very high*): "*In the neighbourhood where you live, are there any problems of connection by public transports?*" and *"In the neighbourhood where you live, are there any parking difficulties?"*

(Table 3.8). Interestingly, about 61% of sampled Italian respondents indeed reported LPT accessibility issues, while residential parking deficits are advised by 58% of them. In order to check the suitability of the selected instruments and to be in line with related studies (among others, for LPT see Wong et al., 2017; and for the usage of private cars, see Guo, 2013), the linkage between the use frequency of transports and their limitations has also been analysed by the Spearman correlation test, whose results confirmed that the chosen Ivs can be considered as appropriate (ρ: -0.0924, $p < 0.001$ for LPT; ρ: -0.0889, $p < 0.001$ for cars).[15] Similar results were derived running Kendall's rank correlation tests (Gibbons and Chakraborti, 2011).

Table 3.8 *Instrumental variables for LPT and private cars use – Summary statistics*

Reported issues (Likert scale)	***LPT accessibility issues* (IV for *LPT use*)**	***Residential parking issues* (IV for *Private car use*)**
1 (*Not at all*)	4803 (31.81%)	5832 (38.63%)
2	4423 (29.30%)	3858 (25.55%)
3	3082 (20.41%)	2968 (19.66%)
4 (*Very high*)	1731 (11.47%)	2013 (13.33%)
Missing values	1058 (7.01%)	426 (2.82%)
Spearman rank correlation test (ρ)	-0.0924 ($p < 0.001$)	-0.0889 ($p < 0.001$)

Therefore, we specified two functions where the use of LPT and private cars are dependent variables of as many ordered probit models (Kwon et al., 2020; Duncan et al., 1998).

As for the use of public transit, the mechanism follows the process:

$$LPT_i = l \text{ only if } k_{l-1} \leq LPT_i^* = \theta_{i,LPT} + \varepsilon_{i,LPT} < k_l \qquad [1]$$

where $\theta_{i,LPT} = \delta_0 \times Z_{i,LPT} + \boldsymbol{\delta' X_i}$, $k_0 = -\infty$ and $k_5 = \infty$, and LPT_i^* measures unobserved frequencies of LPT use (with l ranging from $1/Never$ to $5/Every\ day$) of the i-th respondent;

[15] In order to rule out not suitable exclusion restrictions related to such IVs, we checked that LPT accessibility issues and residential parking problems have not a cross-impact on the usage of studied transport means among the elderly. In particular, Spearman rank correlation tests were applied, where the ρ between LPT issues and the use of private cars is -0.0139 (p-value = 0.836) and that between parking issues and the use of LPT is 0.0850 (p-value = 0.114). Of course, since we have considered the use of cars as a driver only, probably LPT accessibility issues may have a significant effect on the resort to cars as a passenger, or to carpooling. However, those data were not available in the analysed survey.

$\varepsilon_{i,LPT}$ is a normally-distributed error; $\boldsymbol{X_i}$ indicates the vector of individual-specific covariates described in section Covariates; and $Z_{i,LPT}$ measures the IV related to the use of public transit, i.e., the level of LPT accessibility issues.

Analogously, for what concerns the use of private cars (as a driver), we consider the following mechanism:

$$Cars_i = h \text{ only if } k_{h-1} \leq Cars_i^* = \theta_{i,Cars} + \varepsilon_{i,Cars} < k_h \qquad [2]$$

where $\theta_{i,Cars} = \tau_0 \times Z_{i,Cars} + \boldsymbol{\tau' X_i}$, $k_0 = -\infty$ and $k_5 = \infty$, and the value h of the latent variable $Cars_i^*$ ranges from $1/Never$ to $5/Every\ day$ for the i-th respondent; $\varepsilon_{i,Cars}$ is a normally-distributed random term; while $Z_{i,Cars}$ captures the IV related to the use of private cars, i.e., the level of residential parking issues. For both the ordered probit models, observed variables are in a censored form, with thresholds k_g and k_h (for $g, h = 1, .., 5$) defining the intervals into which $LPT_i^*$and $Cars_i^*$ might fall (Wooldridge, 2010).

Since they have been used to control for endogeneity between health and transports usage, the above two functions were natural ingredients of three recursive systems of equations (as described in the Appendix), where endogenous variables appear on the right-hand side of them (Greene, 2012). Therefore, as far as the effects of the use of LPT and private cars on health in later life are concerned, we developed one system of equations for each outcome, where function [1] and [2] are in common. Specifically, while the self-perceived health (S) is measured by an ordered variable, instead mental (M) and physical (P) conditions are captured by continuous indicators. As for those two latter outcomes, we have:

$$M_i = \theta_{i,M} + \varepsilon_{i,M} \qquad [3]$$

where $\theta_{i,M} = \alpha_0 + \alpha_1 \times LPT_i + \alpha_2 \times Cars_i + \boldsymbol{\alpha' X_i}$, and

$$P_i = \theta_{i,P} + \varepsilon_{i,P} \qquad [4]$$

where $\theta_{i,P} = \beta_0 + \beta_1 \times LPT_i + \beta_2 \times Cars_i + \boldsymbol{\beta' X_i}$.

For each i-th respondent, the impact of the use of LPT and private cars and other established covariates $\boldsymbol{X_i}$ are estimated. As for the self-perceived health (S), its linkage with transports is explored by using an ordered probit model, as follows:

$$S_i = s \text{ only if } k_{s-1} \leq S_i^* = \theta_{i,S} + \varepsilon_{i,S} < k_s \qquad [5]$$

where $\theta_{i,S} = \gamma_1 \times LPT_i + \gamma_2 \times Cars_i + \boldsymbol{\gamma}'\boldsymbol{X_i}$, $k_0 = -\infty$ and $k_5 = \infty$, and S_i^* represents the unobserved (latent) self-perceived health of the elderly.

In order to estimate the three systems of equations where health conditions and transports usage are investigated, we follow a recursive mixed-process: different types of models (linear and non-linear) are combined and all the parameters – i.e., $\delta_0, \tau_0, \boldsymbol{\delta}, \boldsymbol{\tau}$ for function [1] and [2], and $\alpha_0, \alpha_1, \alpha_2, \boldsymbol{\alpha}, \beta_0, \beta_1, \beta_2, \boldsymbol{\beta}, \gamma_1, \gamma_2, \boldsymbol{\gamma}$ for function [3], [4] and [5], respectively – are simultaneously estimated for each system by maximum likelihood (Roodman, 2011). Details of the recursive ML procedures are provided in the Appendix.

In the next section, estimations are presented, starting from the determinants of transports usage (i.e., functions [1] and [2] that the systems have in common) and then moving to the relationship between the use of transports and health outcomes, as expressed in [3], [4] and [5]. The goodness of fit of the ML estimations (that are performed by using Stata 16; Gould, 2010) is computed for each system of equations and evaluated by the likelihood-ratio (LR) test, whose scores are reported in the related tables.[16]

3.2.4 Estimation results

Determinants of LPT and private cars use

For each system of equations, the estimation of functions [1] and [2] first helps retrieving the choice to use or not more frequently the public transport and/or private cars in later life, by controlling for the most relevant socio-economics variables (also used as covariates in the estimation of functions [3], [4] and [5]). As expected, the findings about the determinants of the use of LPT and cars are very similar across the three systems (as displayed in Tables 3.9 - 3.11). Firstly, the coefficients show that LPT accessibility and residential parking issue (described in section Econometric modelling) are negatively correlated with the probability to use LPT (range from -0.087 to -0.084, $p < 0.001$) and/or cars more frequently (from -0.115 to -0.101, $p < 0.001$).

[16] The LR test considers the (double) difference between the log-likelihood of unrestricted models (including all the covariates) and that of (restricted) intercept-only models. In case of ordered probit models, intercepts are interpreted as the first cut point with reverse sign, since it reflects the predictive cumulative probabilities at zero-valued covariates (Greene and Hensher, 2010). The related LR test statistics (distributed χ_2 with degrees of freedom equal to the number of removed parameters in the restricted models) is associated with a *p-value* indicating whether the null hypothesis of indifference between the models can be rejected (see Tables 3.9 -3.11).

Dealing with individual characteristics affecting transport use, as recognized in the recent ageing literature (Shrestha et al., 2017; Aguiar and Macário, 2017; Somenahalli et al., 2016; Klein-Hitpaß and Lenz, 2011), we found a striking heterogeneity of the elderly as a population group. Ageing is significantly related to an increasing use of LPT across the estimated systems (especially as age increases from 60-64 to 65-74 years, the coefficients range from +0.121 to +0.127, $p < 0.001$). By contrast, it is detected a lower probability of driving cars when entering the 65-74 age interval (coefficients ranging from -0.280 to -0.277, $p < 0.001$) and even more for over 75 (estimates around -0.958, $p < 0.001$). With respect to women, men reported to be less prone to use LPT many times a week (coefficients between -0.224 and -0.218, $p < 0.001$), but instead to be more willing to drive cars (range from +1.074 and +1.076, $p < 0.001$). As expected, living in larger families may imply the need for a higher trip flexibility (e.g., errands to run), therefore the LPT usage turns out to be reduced when being married (coefficients between -0.167 and -0.161, $p < 0.001$) and/or living with more than two persons (range from -0.194 to -0.184, $p < 0.001$), while driving a private car is more likely when being in a couple (about +0.382 in the three systems, $p < 0.001$). For increasing levels of education, better economic conditions (here proxied by income self-sufficiency) and intense social contacts, a more frequent use of cars (as a driver) is reported, suggesting a substitution effect between public and private means among old citizens, when the former are conceivably more affordable in case of family-aided elderly, and vice-versa (the coefficients related to the LPT use in case of self-sufficiency range from -0.120 to -0.109, $p < 0.001$). Lastly, with respect to the northern regions in Italy, older adults living in central or southern regions display lower transit-related mobility rates, probably because of lacking or inadequate services.

Relationship between use frequency of transports and psycho-physical health

By inspecting Tables 3.9 – 3.11, respectively, the reported estimates of functions [3], [4] and [5] provide indications about how the use frequency of LPT and cars could be related to the three considered outcomes, i.e., mental, physical and self-perceived health in later life.

For what concerns the first outcome (mental health), other things being equal, we have found that, compared to people never using the LPT, older adults taking buses, trams and/or subway trains are more likely to feel joy and/or less depressive, with their everyday usage being particularly effective (+2.563, $p < 0.001$). In a similar way, compared to never driving a car, doing this more times a week lets older people overcome psychological harms, such as anxiety and melancholy (few times a week: +1.276, $p < 0.001$; every day: +1.691, $p = 0.002$).

Among other covariates, we found that ageing, household composition, education and income type are not significantly related to the mental health condition, while its score is positively associated to: being male (+0.460, $p = 0.026$), not being divorced (-1.129, $p < 0.001$) or widowed (-0.746, $p < 0.001$), living in the North of Italy (Centre: -0.456, $p < 0.001$; South: -0.304, $p = 0.009$) and having strong ties with relatives and friends (two groups: +0.836, $p < 0.001$).

As far as the correlation between transports usage and physical conditions is concerned, interestingly the relative impacts are quite different for LPT and private cars. On the one hand, taking public transit is associated to overall better health conditions (captured in our data by the lack of key ageing-related diseases), especially when the usage frequency is few times a week (+0.324, $p = 0.002$) or every day (+0.459, $p = 0.002$), meaning that LPT policies should stimulate a more intense usage of active travels among the elderly. On the other hand, instead the ability to drive a car at increasing frequency rates was found not to be significantly related to physical conditions, except for a positive effect when considering older adults driving a car few times a month (+0.194, $p = 0.015$). Since car driving is clearly not an active transport mode, yet that occasional use of private cars might probably improve elderly's physical conditions only because healthcare services (including hospitals) are relatively easier to be reached. As for the other controls, ageing is a strong determinant of physical conditions, whose scores decline for people aged between 65 and 74 years (-0.370, $p < 0.001$) and over 75 years (-0.652, $p < 0.001$). Being male is associated to a better physical health status (+0.324, $p < 0.001$), while positive effects are detected also for married people (widowed: -0.214, $p < 0.001$), with higher education (middle school: +0.091, $p = 0.002$; high school: +0.163, $p < 0.001$; university degree: +0.241, $p < 0.001$) and living in the North of Italy (South and Islands: -0.228, $p < 0.001$). In our sample, other covariates are not statistically significant.

Table 3.9 *Mental health system of equations (function [1], [2], [3]) – Estimation results*

Explanatory variables		**Dependent variables**								
		Determinants of LPT and private cars use						**Relationship between the use of transports and mental health [3]**		
		LPT use [1]			**Private car use [2]**					
		Coef.t		*S.E.*	*Coef.t*		*S.E.*	*Coefficient*		*S.E.*
LPT use (ref: *Never*)										
Few times a year								1.114	***	0.287
Few times a month								1.409	***	0.355
Few times a week								2.171	***	0.427
Every day								2.563	***	0.615
Private car use (ref: *Never*)										
Few times a year								0.353		0.389
Few times a month								0.936	**	0.331
Few times a week								1.276	***	0.303
Every day								1.691	**	0.541
Instrumental variables	LPT accessibility	-0.089	***	0.013						
	Residential parking				-0.103	***	0.010			
Age (ref.: *60-64*)										
65-74		0.127	***	0.034	-0.280	***	0.028	0.138		0.130
75+		0.082	*	0.038	-0.958	***	0.032	0.018		0.207
Gender (ref.: *Female*)										
Male		-0.223	***	0.028	1.075	***	0.023	0.460	*	0.206
Civil status (ref.: *Not married*)										
Married		-0.163	**	0.056	0.382	***	0.048	-0.120		0.212
Divorced		0.042		0.062	0.342	***	0.055	-1.129	***	0.240
Widowed		-0.118	*	0.054	-0.027		0.047	-0.746	***	0.195
Family members (ref.: *Alone)*										
Two		-0.057		0.043	-0.013		0.039	0.087		0.153
More than two		-0.184	***	0.047	-0.086	*	0.041	-0.181		0.164
Income type (ref.: *Family aid)*										
Self-sufficiency		-0.109	*	0.045	0.374	***	0.037	0.082		0.172
Education (ref.: *Primary school*)										
Middle school		0.262	***	0.033	0.337	***	0.027	-0.079		0.128
High school		0.444	***	0.034	0.585	***	0.029	0.157		0.156
University degree		0.574	***	0.045	0.656	***	0.040	0.177		0.203
Residence area (ref.: *North*)										
Centre		-0.226	***	0.032	0.034		0.028	-0.456	***	0.117
South and Islands		-0.439	***	0.030	-0.186	***	0.024	-0.304	**	0.116
Social contacts (ref.: *No*										
One group		0.037		0.041	0.099	**	0.034	0.313	*	0.142
Two groups		0.035		0.032	0.227	***	0.027	0.836	***	0.116
Constant								19.613	***	0.305
Log-likelihood								-57942.09		
Likelihood-ratio test (Prob > χ^2)								8106.38 (0.0000)		

Notes: observations: 14,753; ***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively. Ordered probit models cut-points: [1] – k_1: 0.29, k_2: 0.64, k_3: 0.98, k_4: 1.67; [2] – k_1: 0.44, k_2: 0.51, k_3: 0.62, k_4: 1.22. The correlations between error terms (off the 1-valued diagonal) of the Σ_M matrix are: $\varepsilon_{LPT}\varepsilon_{Cars} = -.276$; $\varepsilon_{LPT}\varepsilon_M = -.198$; and $\varepsilon_{Cars}\varepsilon_M = -.032$.

Table 3.10 *Physical health system of equations (function [1], [2], [4]) – Estimation results*

Explanatory variables		Dependent variables								
		Determinants of LPT and private cars use						Relationship between the use of transports and physical health [4]		
		LPT use [1]			Private car use [2]					
		Coef.		*S.E.*	*Coef.*		*S.E.*	*Coef.*		*S.E.*
LPT use (ref: *Never*)										
	Few times a year							0.134		0.069
	Few times a month							0.186	*	0.085
	Few times a week							0.324	**	0.103
	Every day							0.459	**	0.148
Private car use (ref: *Never*)										
	Few times a year							-0.179		0.093
	Few times a month							0.194	**	0.080
	Few times a week							0.132		0.076
	Every day							0.042		0.138
Instrumental variables	LPT accessibility	-0.084	**	0.013						
	Residential parking				-0.101	***	0.010			
Age (ref.: *60-64*)										
	65-74	0.121	**	0.034	-0.279	***	0.02	-0.370	***	0.030
	75+	0.075	*	0.038	-0.959	***	0.03	-0.652	***	0.051
Gender (ref.: *Female*)										
	Male	-0.224	**	0.028	1.076	***	0.02	0.324	***	0.051
Civil status (ref.: *Not married*)										
	Married	-0.161	**	0.056	0.381	***	0.04	0.015		0.050
	Divorced	0.046		0.062	0.341	***	0.05	-0.052		0.056
	Widowed	-0.115	*	0.054	-0.028		0.04	-0.214	***	0.045
Family members (ref.: *Alone)*										
	Two	-0.062		0.043	-0.013		0.03	-0.008		0.035
	More than two	-0.193	**	0.047	-0.087	*	0.04	0.036		0.038
Income type (ref.: *Family aid)*										
	Self-sufficiency	-0.112	*	0.045	0.372	***	0.03	-0.014		0.040
Education (ref.: *Primary*										
	Middle school	0.262	**	0.033	0.337	***	0.02	0.091	**	0.030
	High school	0.443	**	0.034	0.586	***	0.02	0.163	***	0.378
	University degree	0.578	**	0.045	0.655	***	0.04	0.241	***	0.049
Residence area (ref.: *North*)										
	Centre	-0.228	**	0.032	0.033		0.02	-0.052		0.027
	South and Islands	-0.443	**	0.030	-0.186	***	0.02	-0.228	***	0.028
Social contacts (ref.: *No*										
	One group	0.032		0.041	0.101	**	0.03	0.026		0.033
	Two groups	0.026		0.032	0.230	***	0.02	0.040		0.027
Constant								3.845	***	0.079
Log-likelihood								-41401.59		
Likelihood-ratio test (Prob > χ^2)								8817.68 (0.0000)		

Notes: observations: 14,760; ***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively. Ordered probit models cut-points: [1] – k_1: 0.28, k_2: 0.63, k_3: 0.97, k_4: 1.66; [2] – k_1: 0.44, k_2: 0.51, k_3: 0.62, k_4: 1.22. The correlations between error terms (off the 1-valued diagonal) of the Σ_P matrix are: $\varepsilon_{LPT}\varepsilon_{Cars} = -.275$; $\varepsilon_{LPT}\varepsilon_P = -.178$; and $\varepsilon_{Cars}\varepsilon_P = -.094$.

Interestingly, as regards the self-perceived health conditions in later life, we lastly found that the usage of LPT is associated to increasing odds of better overall health only when the elderly take transit every day (with respect to never: +0.315, $p < 0.001$), meaning that the subjective health status is likely improved when daily activities and trips are regularly supported by public transports. By contrast, as happened in the case of mental conditions, accessing and/or driving a private car is a strong precondition for reporting a good self-perceived health even for a more sporadic usage (few times a month: +0.311, $p < 0.001$; few times a week: +0.397, $p < 0.001$; everyday: +0.496, $p < 0.001$). As far as other covariates are concerned, the subjective perception of health is worsened by age (65-74: -0.283, $p < 0.001$; 75+: -0.473, $p < 0.001$), being divorced (-0.132, $p = 0.014$) or widowed (-0.094, $p = 0.037$), having a lower education (middle school: +0.067, $p = 0.013$; high school: 0.188, $p < 0.001$; university degree: 0.312, $p < 0.001$), living in central or southern regions of Italy (Centre: -0.097, $p < 0.001$; South and Islands: -0.208, $p < 0.001$) and maintaining a contact with family and/or friends (one group: +0.095, $p = 0.003$; two groups: +0.142, $p < 0.001$). Considering other factors (included the financial self-sufficiency), they are not statistically related to own self-perceived health.

Table 3.11 *Self-perceived health system of equations (function [1], [2], [5]) – Estimation results*

Explanatory variables		**Dependent variables**								
		Determinants of LPT and private cars use						**Relationship between the use of transports and self-perceived health [5]**		
		LPT use [1]			**Private car use [2]**					
		Coefficient		*S.E.*	*Coefficient*		*S.E.*	*Coefficient*		*S.E.*
LPT use (ref: *Never*)										
Few times a year								0.028		0.041
Few times a month								0.055		0.048
Few times a week								0.113	*	0.052
Every day								0.315	***	0.081
Private car use (ref: *Never*)										
Few times a year								0.102		0.078
Few times a month								0.311	***	0.061
Few times a week								0.397	***	0.037
Every day								0.496	***	0.047
Instrumental variables	LPT accessibility	-0.084	***	0.013						
	Residential parking				-0.115	***	0.010			
Age (ref.: *60-64*)										
65-74		0.126	***	0.034	-0.277	***	0.028	-0.283	***	0.028
75+		0.070		0.038	-0.958	***	0.032	-0.473	***	0.034
Gender (ref.: *Female*)										
Male		-0.218	***	0.028	1.074	***	0.023	0.016		0.027
Civil status (ref.: *Not married*)										
Married		-0.167	**	0.056	0.383	***	0.048	-0.017		0.047
Divorced		0.040		0.063	0.340	***	0.055	-0.132	*	0.054
Widowed		-0.123	*	0.054	-0.029		0.047	-0.094	*	0.045
Family members (ref.: *Alone)*										
Two		-0.059		0.043	-0.014		0.039	-0.049		0.035
More than two		-0.194	***	0.047	-0.091	*	0.041	0.008		0.037
Income type (ref.: *Family aid)*										
Self-sufficiency		-0.120	**	0.045	0.374	***	0.037	-0.062		0.037
Education (ref.: *Primary school*)										
Middle school		0.261	***	0.034	0.338	***	0.027	0.067	*	0.027
High school		0.444	***	0.034	0.589	***	0.029	0.188	***	0.029
University degree		0.574	***	0.045	0.661	***	0.040	0.312	***	0.040
Residence area (ref.: *North*)										
Centre		-0.232	***	0.032	0.033		0.028	-0.097	***	0.026
South and Islands		-0.447	***	0.030	-0.186	***	0.024	-0.208	***	0.024
Social contacts (ref.: *No contacts*)										
One group		0.035		0.041	0.098	**	0.034	0.095	**	0.032
Two groups		0.031		0.032	0.229	***	0.026	0.142	***	0.025
Constant								NA		
Log-likelihood								-36870.17		
Likelihood-ratio test (Prob > χ^2)								8679.34 (0.0000)		

Notes: observations: 14,760; ***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively. Ordered probit models cut-points: [1] – k_1: 0.27, k_2: 0.62, k_3: 0.97, k_4: 1.66; [2] – k_1: 0.42, k_2: 0.48, k_3: 0.60, k_4: 1.20, [5] – k_1: − 2.19, k_2: − 1.20, k_3: 0.26, k_4: 1.87. The correlations between error terms (off the 1-valued diagonal) of the Σ_S matrix are: $\varepsilon_{LPT}\varepsilon_{Cars} = -.168$; $\varepsilon_{LPT}\varepsilon_S = -.007$; and $\varepsilon_{Cars}\varepsilon_S = .003$.

3.2.5 Discussion and policy implications

This paper aimed at contributing to the literature that considers local public transports not only as a mobility system to reach destinations (Metz, 2000), but also as an *active* way of travelling associated with health conditions of the heterogeneous elderly population. Moreover, by framing the analysis in the Italian context, the study highlights some interesting elements, implying potential policy patterns to improve the elderly's health conditions.

First, for what concerns the usage frequency of local public transports (with respect to private cars) in later life, when people get older than 65 years the usage of cars (as a driver) diminishes, while that of LPT increases (especially until 75 years). This finding is in line with the literature (Chatterjee et al., 2019; Kim and Ulfarsson, 2004) and confirms an overall trend related to physical disabilities, which limit the ability to drive in later life (Sikder and Pinjari, 2012). From the analysis emerges that the elderly men are more likely to be on the car drivers' seat than women. In fact, the percentage of old men holding a driving license is higher than women as affirmed in other studies (Ryan, 2020; Siren and Haustein, 2013). Such tendency seems to be smoothened in the last years as more women are involved in driving (Oxley et al, 2005). Instead, the elderly women are more frequent passengers of public transport than men as already indicated by other researchers (Ryan, 2020; Berg et al., 2015; Kim and Ulfarsson, 2004). Having said that, we emphasize the importance of investing in public transports systems to take care of social groups characterised by ageing-related fragilities and their own mobility needs (Johnson et al., 2017). More, from a social perspective, whereas older adults living in the North of Italy (i.e., the richest part of the country) (ISFORT, 2018), having a bachelor degree and keeping in contact with family members and friends (Ryan, 2020; Sikder and Pinjari, 2012), are conceivably more inclined to use private transport means; instead, living alone (Hess, 2009) and being not financially self-sufficient are conditions which were found to induce older citizens to resort to LPT (Ryan, 2020; Hess, 2009), that are relatively more affordable than cars (Yang 2018; Kim and Ulfarsoon, 2004). The need for infrastructural and/or service-oriented policies tailored to the older population is of primary importance and, thus, highly encouraged for the policy makers' toolkit. This aspect was pointed out in our analysis when LPT accessibility and residential parking issues have been used as instrumental variables to help removing endogeneity problems from the quantitative framework. A well-served public transport system facilitates participation in out-of-home social activities (Nordbakke, 2019). As described in section 3.2.2, relevant research

verifies that the introduction of ageing-targeted transport policies, such as the free bus policy in the UK, will remove the financial burden and will encourage the over 65's to increase the public transport use (Reinhard et al. 2019; Laverty et al., 2018a). Recently, Willstrand et al. (2018) evaluated the effect of subsidized public transport for older citizens in three municipalities of Sweden and confirmed indeed that the lower the income the more the elderly exploit their transport card. Furthermore, Nocera et al. (2020) provide some general guidelines on how to best evaluate first-last mile accessibility of the transport systems, i.e., (a) identify first and last mile, (b) find the problem and perform cost analysis, (c) select the involved stakeholders, (d) spot the critical points of the process and (e) finally go for the best cost reduction strategies. The described process could be applied in an age-friendly transport system as well. Notably, whereas the usage of cars is affected by the supply of residential parking (Guo, 2013) – implying that mobility needs satisfied by motorized private vehicles would ask for additional slots in urban areas, with the consequence of reducing green or traffic-free zones – our results confirm the fact that LPT services should be instead improved in terms of accessibility and connection in residence areas to make public transit a preferable and more frequent mobility choice for ageing people. In this case, the findings are in line with a recent literature (e.g., Chiatti et al., 2017; Ståhl et al., 2013), suggesting that public interventions might effectively increase the resort to LPT by the elderly and enhance their own social inclusion.

Second, regarding the relationship between transports usage and health conditions, it is important to stress the fact that in our analysis, in addition to having an impact on how often LPT and cars are used by the older people, the above-mentioned public transit accessibility and parking issues are alleged to have a mediated effect on health conditions. From a mental health perspective, for instance, since in our study a more intense use of LPT is associated with increasing feelings of joy and happiness (or, reducing anxiety and depression), therefore it would be essential to incentivize more frequent (or perhaps, daily) trips by LPT among the elderly, in order to prevent psychological harms that were found to be linked to a relative lack of social contacts and more present in the central and southern regions of Italy. Our findings are in line with recent British data (ELSA survey, 7th wave) where the LPT usage (enhanced in the UK by free bus passes) acted against depressive symptoms, also as a mediator for community and social participation (Jackson et al., 2019; Reinhard et al., 2018). Similarly, in a Swedish study about over 75 years old people (Chiatti et al., 2017) and in another one from

the Netherlands (Van den Berg et al., 2016), well-organized LPTs (together with age-friendly built environments) were found to be linked to less depressive symptoms.

Turning to physical conditions, while in the Italian case they are reasonably worsened by age (in particular, above 75 years), two aspects which might slow down the ageing process are related to a higher education (presumably because of a better knowledge of health-preserving habits and more financial resources to access healthcare services) and the fact of living in relatively richer regions (in the South of Italy respondents reported worse physical conditions). How could transports have an impact on this? Since in our study driving a private car did not reveal significant effects on physical status, interestingly we found that LPT (especially when used at least some times a week) may have a sound link to better scores related to ageing-related harms, such as Type-2 diabetes, heart diseases and musculoskeletal problems (WHO, 2006). Of course, this relationship should be put in context. Given that being independent and maintain better health conditions is strictly connected to the ability to reach healthcare services and increase own physical activity (Syed et al., 2013; Schwanen et al., 2012), an additional attention should be given to the planning and organization of LPT (e.g., in terms of travel times and capillarity) in order to promote the overall quality of life of older people (Aguiar and Macàrio, 2017; Musselwhite and Haddad, 2010). In general, our findings confirmed the empirical evidence retrieved by not-Italian studies, which showed how LPT usage is associated with better overall physical health. For instance, in Australia, among the elderly aged between 60 and 84 years, LPT usage increased physical activity (ameliorating bones strength and flexibility) up to 33 mins per day (Rissel et al., 2012). Furthermore, although the present Italian survey lacks specific responses on cognitive-based conditions, an intuitive interpretation of the results would suggest that, compared to non-users, public transit users might also perform better in cognitive measures, e.g., memory, cognitive function, etc. (e.g., this aspect was considered in Reinhard et al., 2019).

Helping the elderly people remain healthy and active in our communities is valuable and well established in the scientific literature for the prevention of age-related pathologies such as Parkinson (von Coelln et al., 2019), urinary incontinence (Fritel et al., 2013) and executive function (Tian et al., 2015). It merits here referring to the strong family ties of the southern European countries, also recognized in Alesina and Giuliano (2010). As a result, the longer the older people stay mobile the more they build on their own self-sufficiency (McPhee et al., 2016) and they are less dependent on the younger generations (Petretto and Pili, 2020).

Lastly, as for the self-perceived health of the elderly, similarly to the physical status, getting old and living in Italian southern regions are preconditions for lower subjective health scores. By contrast, having a better education and/or maintaining rather intense social contacts might contribute to lift the overall perception of wellness in later life. For what concerns the usage of transport means, it is interesting to notice that, besides the feelings of independence in daily activities connected to the lack of assistance needs, it is recognized that driving a car is also associated with a sense of accomplishment, and the literature provided evidence that also the elderly may consider the ability to drive a car many times a week a valuable activity in itself (Ory and Mokhtarian, 2005; Meyer, 1999). Whereas our findings are quite in line with that argument, by contrast, we found that the LPT usage is significantly associated to a good perceived health only when the public transit is used every day. Thus, *active* transportation among older people would be probably enhanced by acting on two kinds of policies. On the one hand, 'de-marketing' measures could aim at reducing the symbolic affection to private cars, or the intrinsic value of driving alone (Bergstad et al., 2011; Handy, 2005). On the other hand, transport-oriented policymakers should specifically organize transit systems to allow the elderly to use them with a higher intensity.

3.2.6 Conclusions

Although the present study has a few limitations, we still believe that its findings add evidence to the existing literature about the relationship between transports and health in later life and provide interesting policy implications. To the best of our knowledge, this is the first study covering the Italian case, where the aging population is rapidly increasing and where, as in other EU countries, both the accessibility to public transports and their usage is a key factor to ensure social inclusion and active aging in the future (Shergold et al., 2015). In fact, in the current status, no solid comparisons (where available) can be done at a country level, thus constraining our discussion the evidence in Italy with respect to other European countries. As regards the limitations of our study, they are mainly related to the type of available survey data. First, the used data are only cross-sectional, thus making it difficult to demonstrate causality relationships between variables. Exploiting panel data for different survey waves would therefore be useful to further improve the analysis. Second, referring to the used health indicators, the available data do not allow us to consider the relative weights of different pathologies. Secondary health data measuring the heterogeneous impact of specific diseases on the elderly' status might be retrieved and possibly used in a future analysis. Moreover,

since the general health status is measured by self-perceived assessments, its values could be overestimated or underestimated. The shortage of informative datasets about transport, health and other life aspects therefore underlines the need to further enrich the data collection process, and the preliminary interesting findings of the study encourage more research efforts on this issue (Mulley et al., 2016). The availability of large datasets might allow future extension of the present work, considering for example as outcome not only health but a comprehensive multidimensional indicator of well-being, feeding powerful techniques of data interpretation such as data mining (Tan et al., 2018).

As above highlighted, from a policy perspective, as the population pyramid is changing shape, our paper suggested that including transport systems in the wider toolkit of health promotion actions has become of primary importance. Particularly in urban and residential contexts, local public transports should be promoted as they assure more environmental sustainability than the private cars. Since the current COVID-19 pandemic has highlighted the need to reorganize the transport system (Musselwhite et al., 2020), it would be crucial to take the opportunity to implement specific age-friendly measures, taking in consideration the elderly needs as one of the most fragile and vulnerable social groups. Focusing on the Italian situation, the paper findings also highlight the need to promote a national transport policy for the elderly population, as it happens for instance in the UK (Butcher, 2015). In Italy, since the supply and demand for local public transport services are highly heterogeneous (ISFORT, 2019), also specific regional interventions should be promoted to support all the elderly mobility, wherever it is located. At present, systematic efforts to record the existing ageing-focused policies, exchange paradigms of successful planning and create synergies is missing and thus highly encouraged for the future research. Finally, the elderly mobility is a complex topic which takes place on several space levels as described in Webber et al. (2010) and the attribute factors can be either internal, i.e., psychological factors (Mifsud et al., 2019) or/and external to the older people i.e. the physical environment (Siu, 2019). Thus, a mixture of interventions, e.g., measures which facilitates accessibility to the built environment (van Hoven and Meijering, 2019), and the LPT system (Kim, 2011), actions of forming the elderly's perceptions about public transport (Kizony et al., 2020), etc. (see Section 3.3 for more examples of age-friendly transport policies).

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Appendix

In this appendix, we explicitly derive the three systems of equations which are the basis of the maximum likelihood (ML) estimation for each health outcome we considered in the study. Specifically, we used the mixed-process estimation method developed by Roodman (2011) that suitably applies to *recursive* systems (Greene, 2012), where certain equations use endogenous factors (in our case, the use frequency of transports) as dependent variables and

other ones include them as explanatory variables for other outcomes – i.e., mental, physical and self-perceived health. Starting from the mental health (M), whose system is composed by functions [1], [2] and [3]:

$$\begin{cases} LPT_i = l \text{ only if } k_{l-1} \leq LPT_i^* = \theta_{i,LPT} + \varepsilon_{i,LPT} = \delta_0 \times Z_{i,LPT} + \boldsymbol{\delta}'\boldsymbol{X_i} + \varepsilon_{i,LPT} < k_l \\ Cars_i = h \text{ only if } k_{h-1} \leq Cars_i^* = \theta_{i,Cars} + \varepsilon_{i,Cars} = \tau_0 \times Z_{i,Cars} + \boldsymbol{\tau}'\boldsymbol{X_i} + \varepsilon_{i,Cars} < k_h \\ M_i = \theta_{i,M} + \varepsilon_{i,M} = \alpha_0 + \alpha_1 \times LPT_i + \alpha_2 \times Cars_i + \boldsymbol{\alpha}'\boldsymbol{X_i} + \varepsilon_{i,M} \end{cases}$$

The estimation of the impact of transport use on mental conditions in [3] takes advantage on estimates related to the determinants of the use of LPT and private cars themselves in [1] and [2], respectively. Besides the sequential nature of the process, the used method performs a ML simultaneous estimation, where the link function mapping from (potentially unobserved) predictors to observed values is the vector $\boldsymbol{y_M} = g(LPT^*; Cars^*; M^*) = \big(l \text{ if } k_{l-1} \leq LPT^* < k_l;\ h \text{ if } k_{h-1} \leq Cars^* < k_h;\ \theta_{i,M}\big)'$. Normally-distributed error terms are in the vector $\boldsymbol{\varepsilon} = (\varepsilon_{LPT}, \varepsilon_{Cars}, \varepsilon_M)' \sim N(0, \Sigma_M)$, where Σ_M is the 3 x 3 covariance matrix of random terms related to the three above system equations.

Since errors can be correlated (implying a multidimensional distribution), the likelihood is computed by the integration of the normal probability distribution (whose covariance is Σ_M) over the feasible regions of errors. Hence, for sake of exposition, we define $f_{\varepsilon_{LPT}}(\varepsilon_{LPT})$, $f_{\varepsilon_{Cars}}(\varepsilon_{Cars})$ and $f_{\varepsilon_M}(\varepsilon_M)$ as the probability distribution functions over $(k_{l-1} - \theta_{i,LPT}, k_l - \theta_{i,LPT}]$, $(k_{h-1} - \theta_{i,Cars}, k_h - \theta_{i,Cars}]$ and $(-\infty, -\theta_{i,M}]$, respectively. Given that the integration of normal probability functions of recursive equations implies conditional distributions (i.e., ε_M given ε_{LPT} and ε_{Cars}) of a multivariate normal, by the Lemma 1 in Roodman (2011, p. 172), we can state the likelihood function as follows:

$$\begin{aligned} &L_i\big(\delta_0, \boldsymbol{\delta}, \tau_0, \boldsymbol{\tau}, \alpha_0, \alpha_1, \alpha_2, \boldsymbol{\alpha}; \boldsymbol{y_{i,M}} | \theta_{i,LPT}, \theta_{i,Cars}, \theta_{i,M}\big) \\ &= \int_{k_{l-1}-\theta_{i,LPT}}^{k_l-\theta_{i,LPT}} \int_{k_{h-1}-\theta_{i,Cars}}^{k_h-\theta_{i,Cars}} \int_{-\infty}^{-\theta_{i,M}} \left(f_{\varepsilon_{LPT}(\varepsilon_{i,LPT})} f_{\varepsilon_{Cars}(\varepsilon_{i,Cars})} f_{\varepsilon_M|\varepsilon_{LPT},\varepsilon_{Cars}}\right) d\varepsilon_M d\varepsilon_{Cars} d\varepsilon_{LPT} \\ &= \Phi\left\{\left[\left(k_{l-1} - \theta_{i,LPT}, k_l - \theta_{i,LPT}\right), \left(k_{h-1} - \theta_{i,Cars}, k_h - \theta_{i,Cars}\right), -\theta_{i,M}\right]'; \Sigma_M\right\} \end{aligned} \qquad [A.1]$$

where $\Phi\{\cdot\}$ is the related cumulative normal distribution. Analogously, when dealing with the physical status (P), the related system does include the functions [1], [2] and [4]:

$$\begin{cases} LPT_i = l \text{ only if } k_{l-1} \leq LPT_i^* = \theta_{i,LPT} + \varepsilon_{i,LPT} = \delta_0 \times Z_{i,LPT} + \boldsymbol{\delta}'\boldsymbol{X_i} + \varepsilon_{i,LPT} < k_l \\ Cars_i = h \text{ only if } k_{h-1} \leq Cars_i^* = \theta_{i,Cars} + \varepsilon_{i,Cars} = \tau_0 \times Z_{i,Cars} + \boldsymbol{\tau}'\boldsymbol{X_i} + \varepsilon_{i,Cars} < k_h \\ P_i = \theta_{i,P} + \varepsilon_{i,P} = \beta_0 + \beta_1 \times LPT_i + \beta_2 \times Cars_i + \boldsymbol{\beta}'\boldsymbol{X_i} + \varepsilon_{i,M} \end{cases}$$

and the likelihood function takes the following formulation, like in A.1:

$$L_i\left(\delta_0, \boldsymbol{\delta}, \tau_0, \boldsymbol{\tau}, \beta_0, \beta_1, \beta_2, \boldsymbol{\beta}; \boldsymbol{y_{i,P}} | \theta_{i,LPT}, \theta_{i,Cars}, \theta_{i,P}\right)$$
$$= \int_{k_{l-1}-\theta_{i,LPT}}^{k_l-\theta_{i,LPT}} \int_{k_{h-1}-\theta_{i,Cars}}^{k_h-\theta_{i,Cars}} \int_{-\infty}^{-\theta_{i,P}} \left(f_{\varepsilon_{LPT}(\varepsilon_{i,LPT})} f_{\varepsilon_{Cars}(\varepsilon_{i,Cars})} f_{\varepsilon_P|\varepsilon_{LPT},\varepsilon_{Cars}}\right) d\varepsilon_P d\varepsilon_{Cars} d\varepsilon_{LPT}$$
$$= \Phi\left\{\left[\left(k_{l-1} - \theta_{i,LPT}, k_l - \theta_{i,LPT}\right), \left(k_{h-1} - \theta_{i,Cars}, k_h - \theta_{i,Cars}\right), -\theta_{i,P}\right]'; \Sigma_P\right\} \quad \text{[A.2]}$$

As far as the last outcome is concerned, since in this study self-perceived health conditions (S) are measured in an ordinal way, the following system of equations (including functions [1], [2] and [5]):

$$\begin{cases} LPT_i = l \text{ only if } k_{l-1} \leq LPT_i^* = \theta_{i,LPT} + \varepsilon_{i,LPT} = \delta_0 \times Z_{i,LPT} + \boldsymbol{\delta}'\boldsymbol{X_i} + \varepsilon_{i,LPT} < k_l \\ Cars_i = h \text{ only if } k_{h-1} \leq Cars_i^* = \theta_{i,Cars} + \varepsilon_{i,Cars} = \tau_0 \times Z_{i,Cars} + \boldsymbol{\tau}'\boldsymbol{X_i} + \varepsilon_{i,Cars} < k_h \\ S_i = s \text{ only if } k_{s-1} \leq S_i^* = \theta_{i,S} + \varepsilon_{i,S} = \gamma_1 \times LPT_i + \gamma_2 \times Cars_i + \boldsymbol{\gamma}'^{\boldsymbol{X_i}} + \varepsilon_{i,S} < k_s \end{cases}$$

the related likelihood function incorporates the fact that all the equations are modelled as ordered probit models. As a consequence, we can state this as:

$$L_i\left(\delta_0, \boldsymbol{\delta}, \tau_0, \boldsymbol{\tau}, \gamma_1, \gamma_2, \boldsymbol{\gamma}; \boldsymbol{y_{i,S}} | \theta_{i,LPT}, \theta_{i,Cars}, \theta_{i,S}\right)$$
$$= \int_{k_{l-1}-\theta_{i,LPT}}^{k_l-\theta_{i,LPT}} \int_{k_{h-1}-\theta_{i,Cars}}^{k_h-\theta_{i,Cars}} \int_{k_{s-1}-\theta_{i,S}}^{k_s-\theta_{i,S}} \left(f_{\varepsilon_{LPT}(\varepsilon_{i,LPT})} f_{\varepsilon_{Cars}(\varepsilon_{i,Cars})} f_{\varepsilon_S|\varepsilon_{LPT},\varepsilon_{Cars}}\right) d\varepsilon_S d\varepsilon_{Cars} d\varepsilon_{LPT}$$
$$= \Phi\left\{\left[\left(k_{l-1} - \theta_{i,LPT}, k_l - \theta_{i,LPT}\right), \left(k_{h-1} - \theta_{i,Cars}, k_h - \theta_{i,Cars}\right), \left(k_{s-1} - \theta_{i,S}, k_s - \theta_{i,S}\right)\right]'; \Sigma_S\right\}$$
[A.3]

Again, following Roodman (2011, p. 181), in order to estimate integrals of multivariate normal distributions of dimension 3 or higher (as in our case for each system of equations) for probit models, the likelihood of cumulative distributions is simulated by numerical methods base on the Monte Carlo technique (Train, 2009). In particular, in order to estimate cumulative probabilities over bounded regions, the Stata-based used estimation resorts to the Geweke-Hajivassiliou-Keane (GHK) algorithm (Gates, 2006; Hajivassiliou and McFadden, 1998; Keane, 1994; Geweke, 1989), which samples data in a recursive way (we set 10 draws for each estimation; Drukker and Gates, 2006) from a truncated normal distribution and

approximates the multivariate normal distribution. Details about the GHK algorithm are also provided in Roodman (2011, p. 182; Appendix C, p. 204).

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3.3 Public transport policies for the elderly

Transportation in later age is recognized by health and social service providers between the three most important issues as a want, a need, and a challenge (Kerschner and Silverstein, 2017). The reasons why older people travel and the importance of mobility go beyond accessibility to places and people, to include the satisfaction of higher order needs like expressions of independence, self-esteem or just enjoy the travel in itself (Musselwhite and Haddad, 2010).

When talking about the transport system for the elderly people, it is divided into four alternative categories (Shergold and Parkhurst, 2012; Davey, 2007; Vuchic, 2007; Coughlin, 2001). Firstly, it regards the private transportation means that include privately owned and used vehicles on public space, e.g. the private car, the bike or walking. Secondly, there are contained the special transport services[17] that are provided for hire by operators for user selected trips, e.g. the taxi, the dial-a-bus and the mini-buses. Third, it is the public transport system[18] which consists of fixed route and timetable transport services used by everyone who pays the fare. Furthermore, the fourth category identified in the elderly transport literature is the informally arranged lifts (Shergold and Parkhurst, 2012; Davey, 2007; Coughlin, 2001). The offered or requested lifts bring many benefits with them, as the "*transport service*" provided can be comparable to that of the private car use (Davey, 2007). Shergold and Parkhurst (2012) argue that although it is an important transport option for many elderly people living in rural areas, they are not considered seriously when forming the transport policies. In order to facilitate the comprehension of what has been illustrated in this paragraph, the reader can refer to Figure 3.7 where it is given a brief graphical representation of the four alternative transport modes described so far.

[17] There is not a unique term to describe this type of transport services. Instead, there are used many and usually different services according to the cultural context, for instance, paratransit, for-hire, demand-responsive transport, demand-responsive transit, demand-responsive service, services on demand, dial-a-ride transit, flexible transport services (Vuchic, 2007; https://en.wikipedia.org/wiki/Demand_responsive_transport#cite_note-wint-2).

[18] It is called also public transportation or urban transit or mass transit or mass transportation or transit in USA (Vuchic, 2007; American Public Transit Association, 1994).

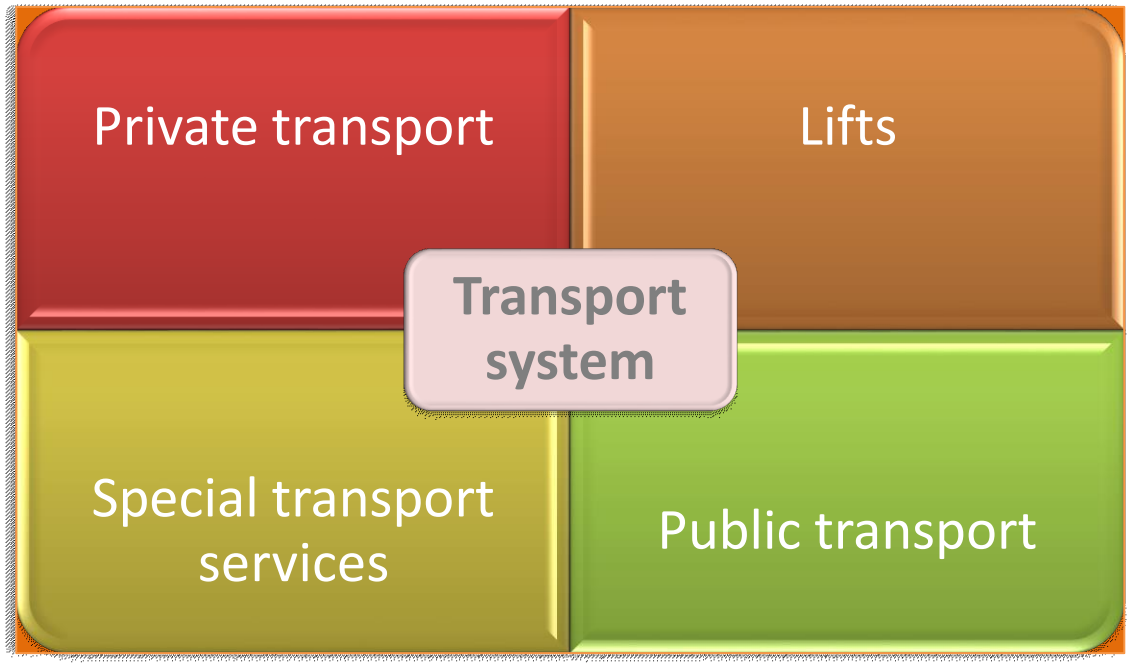

Figure 3.7 *The transport system for the older adults (Author's elaboration)*

Since the successful ageing should be supported by initiatives that enhance mobility, the public transport system can definitely be an alliance (Musich et al., 2018; Chikaraishi, 2017). However, it is even more essential for the elderly who do not drive (Kochera et al., 2005), can no longer drive due to disability or do not have the financial ability to access the private transport means (Windle and Burholt, 2003). Taking into consideration the demographic projections, the elderly will become the majority of the public transport passengers in the future and the transport policies will require appropriate adaptations to meet the needs of an ageing society (Aguiar and Macário, 2017). These adjustments will permit the elderly maintain their personal mobility and independence, the community participation and ultimately a high QoL (see Section 3.1).

Defining the public transport system is not an easy task and a wide range of parameters need to be considered. Around the public transport system there are issues regarding the type of the market in which it operates (open, closed and regulated), the means of transport it operates (buses, rails and subways), the ownership of the vehicles, the political decisions connected to the formulation of public transport policies and some institutional features (e.g. model of governance, financial structures and objectives of the operator) (Glover, 2011). Indicatively, the American Public Transit Association (1994) defines public transportation as the transportation by bus, rail or other transport mode, either publicly or privately owned, which provides to the public general or special services on a regular and continuing basis.

According to this definition, one of the basic characteristics of the public transport is that it should be available to everyone.

Although the transport system should be designed to serve the entire life of the individuals (multigenerational universal transport) (Aguiar and Macário, 2017), it is argued, instead, that the public transport system is designed to serve the needs of the majority of the users (i.e. the working group of the population) (Ryan et al., 2015). At the same time, it is used by other population groups as well, such as the younger, the disabled and the elderly. Bajada et al. (2016) noted that the public transport should be characterised by equity i.e. the population segments that are at a more vulnerable position are provided with the same opportunities as other population segments. Otherwise, there is the risk of creating transport-disadvantaged passengers, such as the elderly, the disabled and the low-income people. Bush (2005) points out that the elderly are usually considered transport disadvantaged together with the disabled and the poor, although they are neither disabled nor poor[19].

The urban transportation includes both the public transport system and the special transport services (Vuchic, 2007; American Public Transit Association 1994). In this sense, the main public transport policies for the elderly found in the literature and presented here, are divided in two groups (Figure 3.8). The first is the transformation of the public transport system to adopt age-friendly characteristics. This approach is supported by the universal design framework. The framework proposes designing the public transport in such a way that everybody[20] can use it at any time and place regardless of the age or capabilities. It is an approach diffused among the Scandinavian countries (particularly in Norway) (Fiedler, 2007) and it has become standard in common planning vocabulary, legislation and management as part of the general accessibility policies (Johnson et al., 2017; Levin et al., 2012).

[19] For similarities and differences with disabled people see Fiedler (2007), pages 61-63.

[20] Of all ages (Kochera et al., 2005; Rantakokko, 2011), gender (Rantakokko, 2011), abilities (Kochera et al., 2005; Rantakokko, 2011; Litman, 2018) and diversity of needs including those with disabilities and special loads (Litman, 2018).

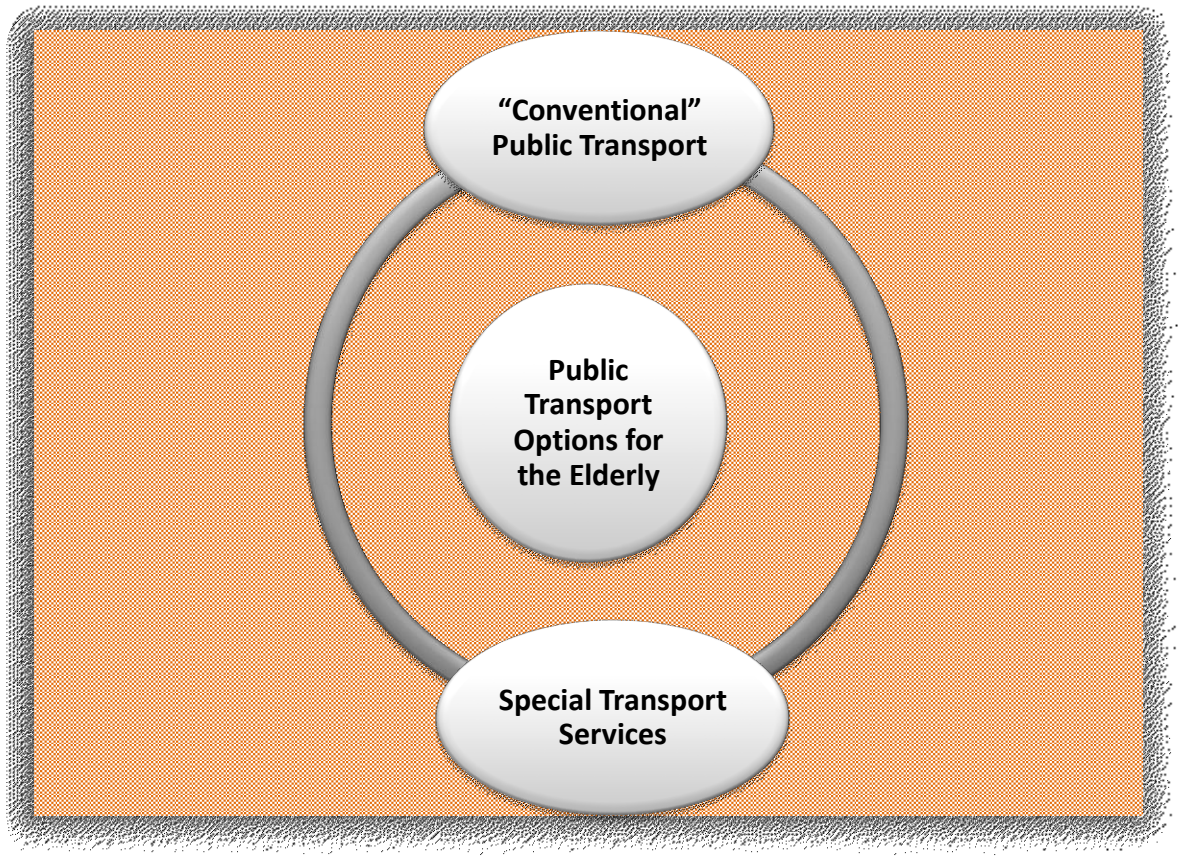

Figure 3.8 *Public transport options for the elderly (Author's elaboration)*

The elderly people is a highly heterogeneous group with respect to their health status and wealth (GOAL, 2012). Also, Akhavan and Vecchio (2018) identified profiles of elderly people according to their mobility/motility capabilities: (a) active, (b) non-motivated, (c) assisted and (d) immobile individuals. As for the disadvantaged people (including the elderly people), may be less likely to handle the transport accessibility issues, their transport needs, regardless of their mobility capabilities, could be best addressed by the universal design approach[21] (Delbosc, 2012; Fiedler, 2007). Other than usability of the public transport system by everyone, the universal design approach serves in avoiding social stigma and should be a priority in the long term (Martens, 2018; Ormerod et al., 2015). The design of the ideal public transport system that connects people to opportunities should fulfill at least four criteria: availability, accessibility, affordability and acceptability (Department for Transport, 2012; Pteg, 2010). In addition, an age-friendly transport system should be characterised by eleven quality dimensions (Johnson et al., 2017). As well as, affordability and availability it should be

[21] It is also called Public Transport for All (Fiedler, 2007), Design for All (DfA) (Rantakokko, 2011) and Inclusive Design (Ormerod et al., 2015; Metz, 2000).

accessible, comfortable, comprehensible, efficient, friendly, reliable, safe, secure and transparent. In each step of the travel experience, the public transport system needs to adopt these characteristics. Notably, these eleven characteristics could apply on the case of other disadvantaged groups of the population, e.g. children, persons with physical disabilities, mothers travelling with babies and/or young children.

The second group of policies presents more targeted interventions for the older population in divergence of the conventional means of public transport. Even if the public transport system incorporates the profile demanded to cover the transportation needs in later age, always there will always exist cases (e.g. rural areas, unprofitable lines) for special services focused on the transport needs of the elderly (Levin et al., 2012).

The main steps in creating a transport policy for the old people is the specification of the stakeholders, the formulation of the policy and the evaluation of it (European Commission, 2011). As regards the stakeholders, in many countries such as Malta (see Bajada et al., 2016) the public transport policy decisions require the fruitful negotiations between public actors which don't always ensure a conclusion. The decision-making procedure becomes even tougher when the responsibility for the transport policy is divided between different authorities. In policy formulation, it is crucial to know why old people stay at home (Mariotti et al., 2018) and also to consider transport policies for different travel purposes and travel distances (Choo et al., 2016). Additionally, the satisfaction of the hierarchy of travel needs is very important in policy decisions, and yet, we do not have enough evidence (Chikaraishi, 2017). Moreover, the transport planners and policy makers should not care only about whether the elderly and disabled travel by public transport but also about the quality characteristics of the travel (Nina and Ralf, 2013). For example, Burlando and Ivaldi (2017) have created an index to measure the quality of the characteristics of the public transport. Although many countries all over the world have implemented transport measures to aid the mobility of the elderly population, there has been limited evaluation of them (Aguiar and Macário, 2017; Levin et al., 2012; European Commission, 2011). Thus, creating a European guide on age-friendly characteristics of the transport system, beyond the obvious, although would be useful, is still an open matter (European Commission, 2011).

The best way to serve the transport needs of the elderly should be investigated further (Brown et al., 2018). A multidisciplinary context including transport, economics, health and

urban design is essential for decision-making about the transport policies (Chikaraishi, 2017). An overview of the best practices at the local level and their implications for the existing EU-policies together with the need of homogeneity in travel surveys to produce an identification of transport needs is a field for research (European Commission, 2011). A critical remark raised by Battarra et al. (2018) is that the findings of the research need more frequently to be applied in practice.

3.3.1 Policies on conventional public transport system

It is underlined in the literature that the transport needs of the elderly are often neglected (Wong et al., 2017). While Chang and Chen (2012) have described the sequence of steps of the air transport experience by the disabled passengers, we got inspiration from them in order to build a similar framework for the public transport policies that target to overcome the barriers faced by the older passengers according to the stages of the public transport trip. A graphical representation of the steps is given in Table 2. In this section, and following the universal design approach, examples of transport policies are identified that aim to overcome the barriers faced by the elderly in each step of the public transport use. Ideally, the adoption of these characteristics will minimise the reliance on special transport services to the minimum such as the case of municipality of Gothenburg (Sweden). The city worked on bus and tram system (project KOLLA) through expansion of a number of flex-lines, adaptation of stops to travel needs, provided travel training and trip accompaniment (Levin et al., 2012; Fiedler, 2007).

Initially, the public transport policies are categorized in two groups (Table 3.12): (a) structural and (b) non-structural. The structural refer to the "heavy" interventions that need to be done to the transport infrastructures in order to become age-friendly such as equipping public transport stops with seats and shelters, using low floor buses, having well-maintained pavements and traffic lights with longer time dedicated to the pedestrians' crossing. On the other hand, with non-structural policies it is intended a "lighter" mixture of policies directed to the offered services, such as appropriate price ticketing, frequent schedules, such as well-served destinations, secured transport stations and travel assistance for the non-familiar elderly public transport users. Since each type of policy intervention targets the improvement

of one or more stages of the travel experience, they are distributed accordingly to (a) pre-travel, (b) pre-board, (c) on-board and (d) after travel.

Table 3.12 *Classification of public transport policies for the elderly organized by travel stage (Adapted version from Chang and Chen (2012))*

Transport Policy	Stage of travel			
	Pre-travel	Pre-board	On-board	After travel
Structural policies				
Investments in age-friendly Infrastructures (e.g. stop shelters/seats, pavements, traffic lights)	✓	✓		✓
Investments in age-friendly vehicles (e.g. low-floor, seats for elderly)	✓		✓	
Non-structural policies				
Price (e.g. ticket discounts)	✓			
Service Quality (e.g. frequency, punctuality, safety, travel information, etc.)	✓	✓	✓	✓
Other measures: travel assistance, security, etc.		✓	✓	✓

3.3.1.1 Structural policies

In order to assess the transport and mobility needs of the older people, the environment in which mobility and transportation are performed has to be considered (Wallace and Franc, 1999). Specifically, according to Banister and Bowling (2004), the locality, the neighbourhood and the social networks are relevant aspects of the transport system. Rosso et al. (2011) reviewed the literature for evidence on the link of the built environment (transportation systems, land use patterns and urban design) with mobility of the older adults. It is demonstrated that, indeed, there are connections but it is not clear whether they are direct or there are intervening factors in between. Although the factors found in the studies differ because of the methodology and the definitions used, the most likely to impact on mobility are the high density of intersections, street and traffic conditions, the proximity to selected

destinations and green space. Furthermore, Aguiar and Macário (2017) point that a complete strategy for the enhancement of the elderly mobility is necessary to consider the political and social context in which it will be applied, and also, requires a change of the priorities, from just increased transport use to mobility that empowers the older adults with all its features.

A few examples of policies both about *the public transport and the physical environment infrastructures* have been found. Basically, as it is quite important to identify the points of difficulty the urban space for the elderly people, in München (Germany) there have been organized guided tours in order to spot the places where the physical barriers[22] to mobility are faced (Fiedler, 2007). In order to improve the accessibility of the public transport, the Swedish municipalities of Helsingborg, Karlskrona and Borås took care of the maintenance of the pedestrian environments and introduced short walking distances to the bus stops (Levin et al., 2012). Fiedler (2007) noted that the UK cities, Manchester and West Bromwich, invested in their bus interchanger stations to improve their accessibility and provision of travel information.

Accessible stops/stations and road infrastructures (especially for pedestrians) are necessary for independent living (Somenahalli et al., 2016). Low-floor buses is a common adopted policy to make the vehicles age-friendly. This was introduced, for example, by the Swedish municipalities of Helsingborg, Karlskrona and Borås (Levin et al., 2012), and also, in Malta (Bajada et al., 2016). Additionally, in Malta road infrastructure improvements were performed (Bajada et al., 2016).

3.3.1.2 Non-structural policies

As regards the non-structural policies, in the recent years, it has been observed a tendency for more diffusion of transport data (Hounsell et al., 2016). The provision of user-targeted *information* is particularly relevant for the elderly. Before deciding whether or not to use the public transport system, the older people need to be informed about the availability of transport options and the fares, so that they can best organize their transport experience. Additionally, even if the accessibility obstacles for the elderly have been overcome, they might

[22] For the older people, the route home - bus stop is important (Fiedler, 2007).

not feel confident to use public transport because of their health condition, unawareness or misconception about the public transport services, or simply because they were not regular users in the earlier years of their life (Urban Transport Group, 2005). The basic factors for a successful open information project are the robustness of the data, the market demand and the interaction between the developers of the applications and those who produce the transport information (Hounsell et al., 2016). As such, in Salzburg (Austria) the adopted initiatives were the advertisements of the transport services through the newspapers, radio, television and public presentations, and an interesting marketing and information initiative called "Mobility Day". During this event, the elderly had the opportunity to test the public transport vehicles and meet representatives of companies that were involved in the production of goods assisting elderly mobility (Fiedler, 2007). In this sense, the public transport authority in Rhine-Main-Area (Germany) updated its website with information about the equipment of stops and stations so that the elderly can be better informed (Fiedler, 2007). Other examples regard, for instance, in Leeds the "Bus Buddying" scheme which is service of voluntary travel assistance to the elderly during their bus experience, thus, letting them remain independent passengers without the need of dedicated services (Urban Transport Group, 2005). In addition, many elderly people face difficulties with ticketing machines or tariff schemes. In Birmingham (UK) the public transport authority collaborates with the local communities to help the elderly familiarise with the use of concessionary bus pass (Fiedler, 2007).

The presence of specialised staff is important not only for providing information and assistance but also *security.* In Midland (UK), the staff was used in the metro for tickets sales and the smooth operation of the trips in the vehicles assisting in keeping the quality and safety of the public transport (Fiedler, 2007). Even if it seems to be a misconception that crime rates are higher for the elderly population (Farrall et al., 2009), Coughlin (2001) notes that many older people are worried to use the public transport in the evenings. The security of the public transport is a key matter for people in later age. For this reason, in Lille (France) the elderly passengers embraced the presence of security groups for (a) surveillance of the metro stations, tramways and buses and, (b) intervention in cases of violence or accidents (Fiedler, 2007).

Falls and accidents in public transport are quite common for the elderly people. Although further research is needed to understand the impact of a fall on subsequent mobility and

independence (Ormerod et al., 2015), in the meanwhile, some transport authorities are adopting measures for their reduction (Fiedler, 2007). For instance, a few initiatives towards falls prevention have been undertaken in Salzburg (Austria). Particularly, these comprise training sessions for the passengers on how to enter the bus, stand safely inside the vehicle or get a seating easily and lessons about safe driving for drivers.

While, nowadays, the elderly are more active and have more free time to travel, the *economic accessibility* might be a restriction for many of them. The literature review of Hodson (2008) revealed that within the European urban transport sector the average percentage discount for the elderly is 46%. As Martin et al. (2012) point, the reasons why governments allow for economic subsidies of the public transport passengers is still vague. Much controversy around this measure exists in the literature. Willstrand and Levin (2018) evaluated the effect of subsidized public transport on physical activity levels of older citizens in three municipalities of Sweden. The study showed that a large number of users (i.e. 61%) increased the use of public transport due to their accessibility to the senior card. In order to get a clearer understanding of the impacts, the authors organized the data according to the area of living (i.e. urban, rural and suburban) and the income of the elderly. This extra disaggregation indicated that the introduction of the card seemed to have positive effects on the use of public transport and physical mobility of the beneficiaries, but it was limited to those who lived in urban areas (where public transport was frequent) and had mobility capability.

As regards Italy, we mention here the example of Milan, which is the most important metropolitan city in Italy with about 3.2 million people (ISTAT, 2017) [23]. Azienda Trasporti Milanesi (ATM) is the company that manages the public transport (underground railway, bus, tram and trolley bus) in Milan and 46 other provincial towns. The ATM provides different categories of discounts to the elderly the so-called program of Senior Citizen Travel Card[24]. It ranges from free transport use (for those elderly with income until 16.000 euros) to 30 euros per month for those who do not meet the requirements.

In UK, the financial[25] provisions for the elderly are quite generous and include free bus use from 9.30 am until 11pm on weekdays, and all day at weekends and bank holidays (Department for Transport, 2012). Apart from the national free bus pass, there are met

[23] http://demo.istat.it
[24] https://www.atm.it
[25] See Butcher (2015) for the evolution and changes of the scheme.

additional local provisions, The Tyne and Wear's 'Nexus'[26] authority entitles free bus use for the people who are eligible for a National Concessionary Travel Pass, and moreover, live in Tyne and Wear. The same measure doesn't hold for the metro transportation. After 09.30 it is given the possibility of the purchase of the Metro Gold Card that allows for discounted fares.

There are a few studies (Butcher, 2015; Green et al., 2014; Jones et al., 2013; Andrews, 2012; Baker and White, 2010; Rye and Mykura, 2009) about the concessionary fares scheme in the UK but the literature shows a mixed picture of the efficiency of this transport policy (Willstrand and Levin, 2018). Mackett (2015) attributes the decision largely to political motives, although, it seems that the transport policy targeted actually the enhancement of accessibility to services and the reduction of social isolation for the aged people. Another justification comes from Webb (2015) and is related with the mitigation of the healthcare expenditures directed to the elderly. The creation of more trips (Laverty and Millett, 2015) will reduce isolation, promote social engagement, improve mental health (Reinhard et al., 2018) and older people's health in general (Webb, 2015). Further research is needed to verify the health benefits (Reinhard et al., 2018; Webb, 2015). The use of longitudinal data could best reveal the direction of the causal relationship, whether the bus pass supports the elderly in staying mobile or whether the mobile elderly use the bus pass (Webb, 2015).

Alternative measures of ticket pricing have been identified in Germany (Fiedler, 2007). In Rhine and Ruhr Area, the 'BearTicket' use is a monthly ticket for those over 60 years old and 'BärenTicket' enables the elderly to be accompanied by a person with the same ticket. In Bremen, the 'BOB-ticket' is a prepaid ticket that charges the passenger only one route (the cheapest) in the day.

A study from Hong Kong (Wong et al., 2018), investigates how the elderly could be motivated to use more the public transport, and additionally, what are the factors that affect the decision-making process. It is support in the literature (Wong et al., 2018; Wong et al., 2017) that in Hong Kong the proportion of the elderly that uses the public transit is already very high (over 90%). Although the policy makers pose emphasis on the fares by setting a HK$2 per trip for people 65+, other factors are revealed by the research of Wong et al. (2018) to play a crucial role on their transport mode decision. Particularly, the most important

[26] https://nexus.org.uk/concessions/older-people

characteristic for the elderly was the seat availability and the authors suggested the distribution of priority cards as applied in London in 2012.

In all the three specific cases described (UK, Sweden and Hong Kong), the policy makers had the willingness to take action in facilitating transport mobility of the elderly people. In the UK (Butcher, 2015; Green et al., 2014; Jones et al., 2013; Andrews, 2012; Baker and White, 2010; Rye and Mykura, 2009), the studies show preliminary evidence of health and social impacts which were not the main objectives of the policy makers. In Sweden (Willstrand and Levin, 2018), the advantages are enjoyed by a portion of the elderly and in Hong Kong (Wong et al., 2018) the requirements of the elderly are not completely in line with the elderly needs. Probably, a good way to comprehend deeper the issues of the elderly mobility is just to ask directly the elderly what they want or what they need. In Salzburg (Austria), a representative of the public transport operator collects the complaints of the old people and in this way their transport requirements can be best taken seriously into consideration (Fiedler, 2007).

3.3.2 Special transport services

Even if the public transport system adopts the principal age-friendly characteristics, the supportive transport services will always be necessary as key factors to ensure independence, health and QoL for the elderly population (Farrell, 2013; Foreman et al., 2003). To help fill this travel deficiency, paratransit or community transport has become relatively common in most industrialized countries (Stanley and Stanley, 2017). These transport services may include (Whelan et al., 2006): (1) door-to-door community transport services, volunteer driving programs and new forms of demand services, (2) subsidised taxi services and (3) independent transport networks and carpooling schemes (Figure 3.9). Given that the elderly people are treated as transport-disadvantaged, together with other transport passenger categories, like the disabled and the low income people, often the special transport services are not directed exclusively to them but to all the members of the transport-disadvantaged group.

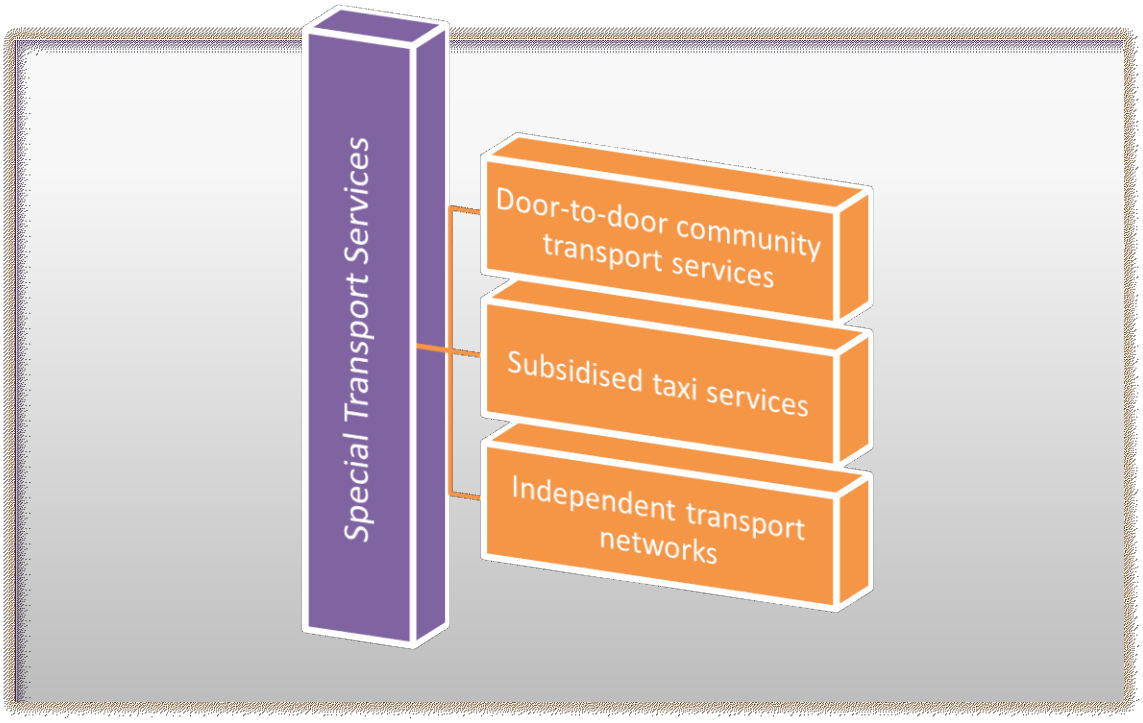

Figure 3.9 *Types of special transport services (Whelan et al, 2006; Author's elaboration)*

The provision of special transport for the elderly is very usual in Scandinavian countries (Levin et al., 2012). More specifically, in Denmark it is known under the Danish term "funktionshæmmede" or "bevægelseshæmmede", a program that offers transport services for the disabled. Under this policy, it is covered a particular transport service provided by the municipalities for the transfers of the elderly to assisted living facilities. In Norway, the offer of special transport services is mandatory by the county councils and are called 'TT-ordningen'. The services regard mainly transfer of the elderly for leisure activities. In the end, in Sweden, there are met two transport programs: (a) special transport services, and, (b) inter-municipal transport services corresponding to the transport needs of the older and disabled people. The special transport services appeal to the disabled individuals regardless of their age, therefore, the elderly people who suffer from disabilities and cannot move autonomously are eligible to use them. Additionally, the inter-municipality services connect the district areas but the organization of the services, the fees and the number of allowed trips per person is regulated by each municipal authority.

Besides, special transport services are widely diffused in the UK. First, of all, we meet the scheme of *community transport services*. They are operating on a non-profit basis/voluntary basis, mostly without fees for the users (Nelson et al., 2017; Ahern and Hine, 2014).

Principally, they are built around the pillar of social values and responsibility, targeting at removing any transport accessibility barriers and straightening the cohesion of the society[27]. Research (Nelson et al., 2017) has shown that there exist substantial health gains for the individuals and the community, even so, it is complicated to quantify them by area of contribution.

Further UK special transport services are listed below. The West Yorkshire's Access Bus service[28] is a mini bus that offers local transport services upon request. Each journey is charged £3 but the elderly over 60 years old and the disabled who are eligible for free bus use are not charged for the service. Also, the Shopmobility service[29] provides services for anyone with restricted mobility with the use of assistive tools like powered scooters or electrical and manual wheelchairs and can be a perfect complementary service for the public transport (Shrestha et al., 2017). The UCAB Shared Taxi[30] (Urban Transport Group, 2005), is sort of taxi transportation which connects every 60 minutes an English city (South Shields) with a densely populated area that distances 10-15 minutes' walk away from the city centre (Lawe Top). As supported in the report of (Urban Transport Group, 2005), this shared taxi made accessible an area where the public transport network was not economic viable. Additionally, the Nexus[31] is a shopper service that undertakes to transfer the elderly for shopping trips. The services are not exclusively dedicated to the needs of the elderly population but to anyone with mobility difficulties (pteg, 2010). Last example is that of Ring and Ride (Manchester) which is offering door-to-door services to those who live in West Midlands and suffer from a kind of disability (Department for Transport, 2012).

An interesting 6 months experimental special transport service for the people over 65 years old is that of the Italian city of Genova, the Silver bus[32]. The transport service operated within

[27] https://ctauk.org/about-cta/

[28] https://www.calderdale.gov.uk/socialcare/wellbeing-hub/service-single-item.jsp?id=1048&ResultIndex=0[29]http://www.shopmobilitybasingstoke.org/about-us

[30]http://www.urbantransportgroup.org/resources/types/documents/transport-and-social-inclusion-good-practice-guide

[29]http://www.shopmobilitybasingstoke.org/about-us

[30]http://www.urbantransportgroup.org/resources/types/documents/transport-and-social-inclusion-good-practice-guide

[30]http://www.urbantransportgroup.org/resources/types/documents/transport-and-social-inclusion-good-practice-guide

[31] http://www.urbantransportgroup.org/

[32] https://cieli.unige.it/node/281

a specific zone of the city where are located places and services frequently visited by the elderly people, e.g. hospitals, recreational centres for the elderly, etc. It was organised with one fixed route line and another available on demand. The users could book their seat through a call centre and, afterwards, they were receiving a confirmation sms on their phones. It is evident that at least some form of technological familiarity was necessary. Nowadays, the connection of the transport services with technology has become closer. In the next chapter (Chapter 4), we analyse the relationship of the elderly people with the Internet activities.

In fact, the ways the special transport services are organized and offered are quite different between the countries, especially, with respect to the purpose of the journeys they permit (e.g. leisure, health accessibility, etc.), the eligibility criteria of the beneficiaries (e.g. age, disabilities, place of residence, income, etc.), the character of the company (e.g., private, non-profit, voluntary organized, etc.). Each company has its own mixture of organization and service provision to the elderly with respect to some aspects. Foreman et al. (2003) suggest that the client outreach, the adequate funding, the costs transferred to the users, the effective use of volunteers, the convenience offered to the older population and the preservation of dignity and independence are crucial areas that will ensure the success of the transport services dedicated to the elderly people. A few examples of existing applied policies in USA about each type of principal element is given in Figure 3.10.

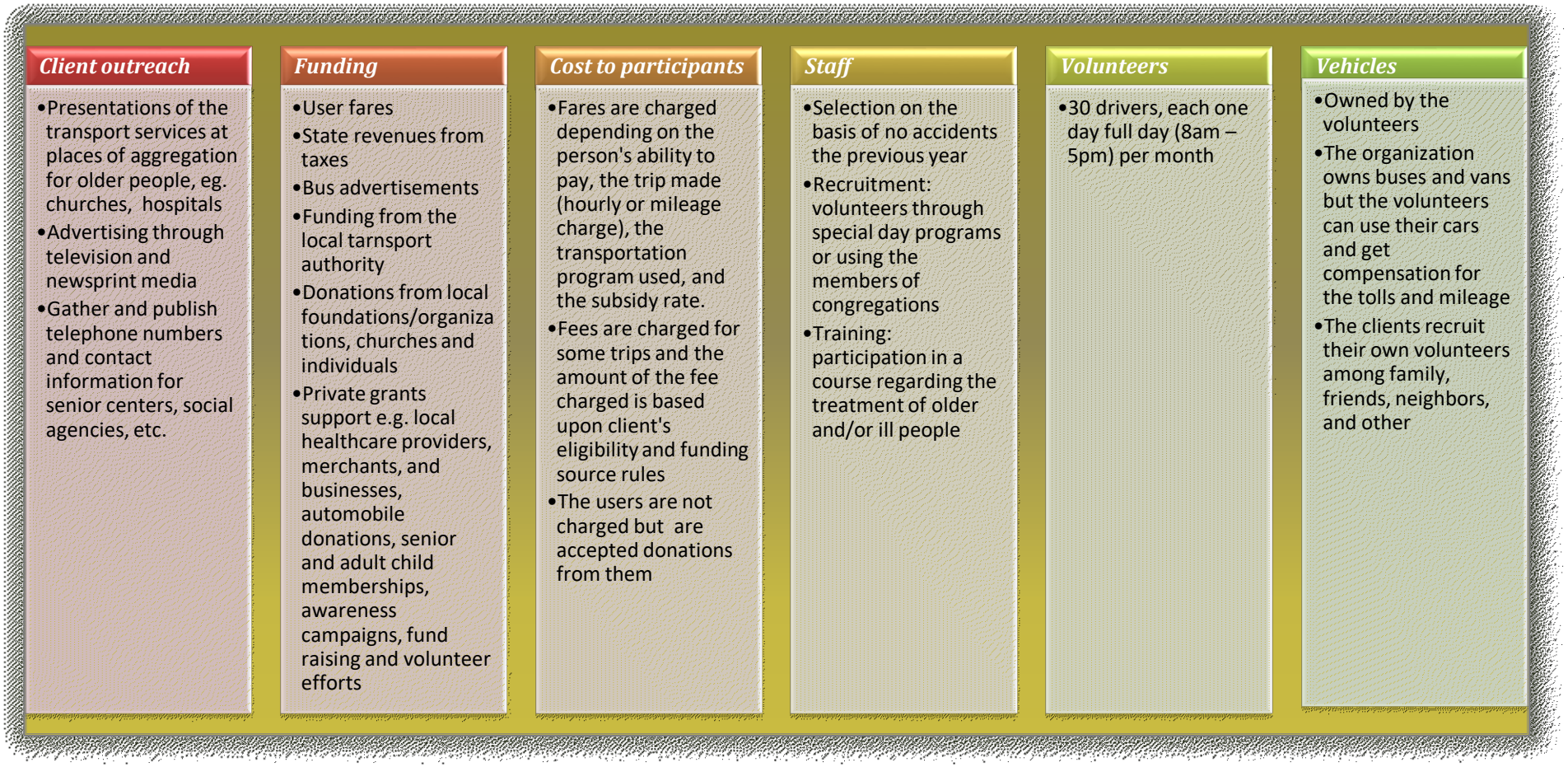

Figure 3.10 ***Examples of elements of success in policies based on special transport services for the elderly in USA (*****Foreman et al., 2003; *****Author's elaboration)***

3.3.3 Conclusions

This section aims to illustrate some examples of public transport policies targeted to the ageing populations in various countries. The examples presented have been focused on the public and special transport services, although, private transport alternatives can be used for daily trips, e.g. car use and lifts. The examples of public transport policies have been divided into structural and non-structural. The diverse measures that have been implemented worldwide, confirm that the policymakers have recognized the special transport needs for the elderly population and have moved towards the direction of satisfying active and healthy ageing.

Based on the idea of transport policy feasibility, we provide a classification of the conventional transport policies in structural and non-structural. Actually, the structural interventions need more time, compared to the non-structural, to be incorporated in the existing transport systems such as substitution of current vehicles with low floor easily accessible, placing bus shelters with seats, etc. At this point, it needs to be stressed that although we found many transport policies, mainly in the grey literature, the evaluation of them is not usually programmed, apart from some papers about the UK free bus pass. Remarkably, this observation makes a bit difficult the collection of feedback and the revisions of the policies accordingly. In general, we would like to underline that do not exist good or bad transport policy measures. What matters more, are the transport needs of the elderly framed necessarily within their cultural background. However, the best way to understand them is simply by asking the elderly to self-report the steps that impede their movements and take action. Additionally, the special transport services seem to complement the core public transport system and recognize that additional services are essential for a specific segment of the passengers, the older people.

In the Italian context, the application of the policies, as described in this section, seems to be dispersed. In the national scale, there do not exist a central guidance but each region reacts according to each own strategy. From a quick judgement, we think that the policies of **Table 3.12** could be implemented without particular difficulties. However, only the real implementation will reveal the results.

Given all the examples covered in the previous paragraphs, and, keeping in mind the changes of daily mobility in the after COVID-19 era, the public transport policies (in general and

specifically for the elderly people) should be implemented in a complex environment which causes huge pressure to the policy makers (Chikaraishi, 2017). Whether improvements in mobility levels can increase the social welfare is still debatable. In some cases the improvements of the individual QoL can contradict the collective QoL, e.g. the use of private cars instead of public transports could have an impact on the air and environment pollution (Aguiar and Macário, 2017; Chikaraishi, 2017). Social, environmental, and economic objectives may conflict each other but could also complement depending on the efficiency of the alternative solutions (Kanaroglou et al., 2008).

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3.3 Conclusion

To sum up, Chapter 3 treated the topic of public transport in later age as a key facilitator mobility. In Section 3.1, it was synthesised the literature about the role of public transport services as part of the well-being/QoL of the older adults, feelings of independence and social inclusion. The existing gaps in the literature have been stressed and further research directions have been sketched. Since health status is deteriorating quickly with age increase, Section 3.2 has been devoted to the association of public transport with various health indicators. The chapter concludes with the description of some specific age-friendly transport policies.

CHAPTER 4

TECHNOLOGY

Working Paper

INTERNET AND AGEING: A LATENT CLASS ANALYSIS

Abstract

This chapter is an empirical work on the digital implications of healthy ageing. Yet, growing concerns about Italy (as it is the European country with the highest percentage of the over 60's) raise questions on how the life of the elderly population might be shaped under the so-called "New-Normal" in the after COVID-19 era. Little is known about the digitalization of the Italian elderly and the space it occupies in their daily life. As such, the paper explores descriptively the diffusion of Internet use as a supportive tool for healthy ageing, the devices that mostly facilitate the Internet accessibility of the over 60's, as well as what type of activities are performed digitally by the elderly population. Based on an Exploratory Factor Analysis (EFA), we identified latent dimensions of several online activities, and based on the results, we created indexes of digital connectivity. Subsequently, these indexes of online activities were used together with various sociodemographic variables in a Latent Class Analysis (LCA) in order to test for the existence of discrete groups (classes) with similar online activity profiles and associate them with determinant individual characteristics. The paper ends with further research directions and policy guidance.

Keywords: Older people; Internet activities; Exploratory Factor Analysis, Latent class Analysis

4.1 Introduction

The ageing of the worldwide population is a concerning issue for the policy makers. Considering the elderly population more vulnerable to health issues compared to the younger population groups, the recent pandemic of COVID-19 dictated protective measures such as social distancing to secure their health, and thus, their life (Banerjee, 2020). It is contested that isolation is a two-sided coin and, as a result, extended periods can be proved harmful for their psychological health (Plagg et al., 2020).

During the last few years, the technological advancements and the wide diffusion of the Internet use have transformed the ways of executing traditionally daily tasks. For the elderly people, the digital technology is perceived basically as the use of computers and telephones (Betts et al., 2017). Despite the fast and strong digital transformation in the last two decades, the people in later age cope with technological progress, harder than the younger generations. Some scholars have addressed the challenges that hinder the elderly from the full potential of the digital world. According to Lee and Coughlin (2014), the factors affecting the technology adoption in later life derive from the interaction of four sources (see Figure 4.1). Some research in the UK (Betts et al., 2017) found that the elderly people express strong interest in acquiring more digital skills through personalized one-to-one learning sessions. Nevertheless, this population group remains still less competent in using the technologies.

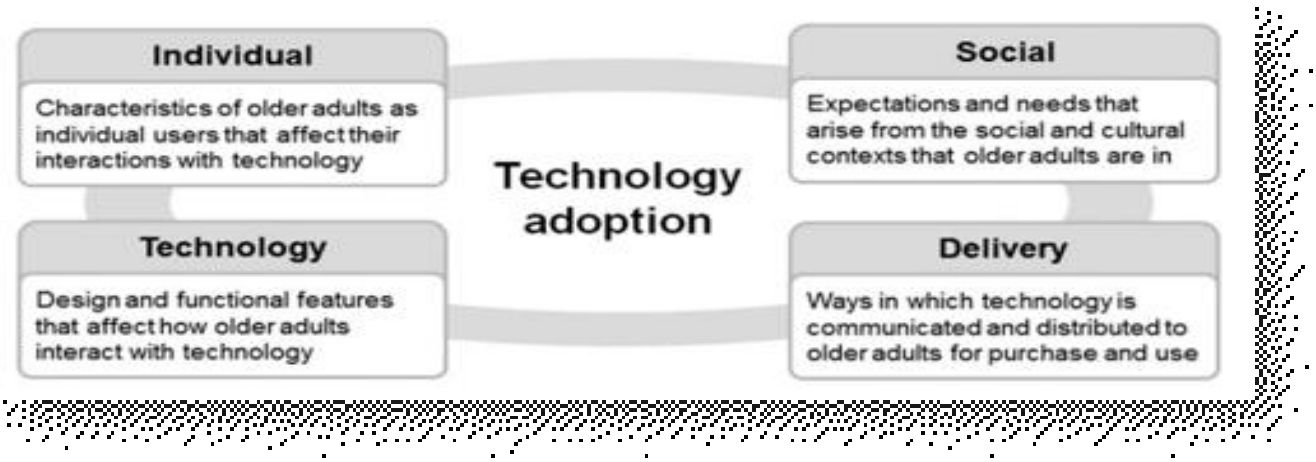

Figure 4.1 *Factors affecting technology adoption in later life (Lee and Coughlin, 2014)*

The growing concerns about ageing in Italy, as it is the European country with the highest percentage of the over 60's (United Nations, 2019), raise questions on how the elderly population will live under the so-called "New-Normal" that COVID-19 imposed. It has been underlined by Italian scholars (Facchini and Sala, 2019) that little is known about the

digitalization of the Italian elderly and the space it occupies in their daily life. In fact, in the existing literature there are some studies about the impact of Internet use on psycho-physical health conditions, either analysing Italian data together with other countries or Italian data separately e.g. about cognition (Kamin and Lang, 2020), loneliness (Silva et al., 2020), and social isolation (Zaccaria et al., 2019; Cannito et al., 2019). One study has been found about the relationship of the educational background as a determinant factor for the Internet use (Kämpfen and Maurer, 2018) and further have compared the general Internet use by the Italian elderly with other countries (Sala, 2019; König et al., 2018) or have investigated the factors affecting the start and increase of Internet use (König and Seifert et al., 2020). Additional Italian studies have mainly looked at the levels of Internet use (Facchini and Sala, 2019; Sartori, 2011), levels, devices and sociodemographics (Carlo and Vergani, 2016), frequency of use and devices (Colombo et al., 2014), places of Internet use, profiles of users and types of activities (Colombo and Carlo, 2015), and finally, devices and very briefly a small number of Internet activities (Pirone et al., 2008).

However, neither of these papers has provided a wide range of Internet activities nor have performed a complete empirical analysis. Detailed research about the online activities of the elderly is still sparse not only about the Italian elderly but widely speaking in later life (Schehl et al., 2019; Vroman et al., 2015). More, in previous recent studies (Leukel et al., 2020) it has been stressed the need for further studies on additional sources of inequalities (emerging from specific individual characteristics) among the elderly people who use the Internet activities. Considering the aforementioned existing gaps in the literature, in this paper we focus on the individual factors' dimension, as described in Lee and Coughlin (2014). More specifically, the following research questions are addressed:

RQ.1 What looks like the picture of Internet use as regards the frequency and preferred devices among the Italian adults over 60 years old?

RQ.2 What specific online activities attract the elderly Italian people to use the Internet?

RQ.3 As many Internet activities are interrelated, how can the online activities of RQ.2 be grouped to create indexes of digital performance that capture uniquely the digital behavior of the elderly people in Italy?

RQ.4 Are there any latent groups (classes) among the Italian elderly people over 60's based on the online activity habits?

RQ5. How are the socioeconomic characteristics of the older Italian people together with the digital infrastructure accessibility related to latent classes of elderly Internet users?

The paper is organized as follows. After the brief introduction to the topic, it is presented the literature review of the existing scientific evidence. It is specifically about the prevalence of Internet use, the patterns and the characteristics of Internet use among the elderly population (Section 4.2). Afterwards, in Section 4.3 it is illustrated the dataset and the methodology applied. Subsequently, the results of the analysis are provided in Section 4.4. In Section 4.5 it is provided the discussion of the findings, and in Section 4.6 the strengths, the limitations and further research directions. The paper ends with some concluding remarks and policy guidance in Section 4.7.

4.2 Literature Review

As it has been reported by several scholars (EUROSTAT, 2020; Macdonald and Hülür, 2020; Facchini and Sala, 2019; Friemel et al., 2016; Luger et al., 2016; Gell et al, 2013; Morris et al., 2007), there is a clear-cut relationship between Internet use and ageing: as age increases the people tend to use it less. Facchini and Sala (2019) reported that the Internet use (even sporadic) in 2016 was 56.50% for the Italian elderly of 60-64 years old, 32.30% between 65 and 74 years old and drop dramatically at 9.30% for the over 75 years old. A closer look of the statistics reveals alarming trends. Remarkably, in 2017 the percentage of the people aged 65-74 years (in the EU-27) who had never used a computer has reached 44.00% (EUROSTAT, 2020).

Apart from the scarse Internet use by the older people, in general, it has now been demonstrated a huge gap among the elderly individuals[33] who are using the Internet and are coming from very diverse cultural backgrounds. The studies described in the next paragraphs are presented briefly in Table 4.1. König et al. (2018) elaborated representative data[34] about the Internet use of the over 50's in 17 European countries. The authors provided evidence for a substantial divergence between the countries of the North/West and South/East Europe. In this study, Croatia records the lowest percentage of elderly people being online (27.00%) and Denmark the highest (83.00%). Remarkably, Italy scores 35.00% and is below the average of 49.00%. It should be noted that the discrepancies of Internet use can be attributed, on the one

[33] The individuals were asked about the Internet use within the past 7 days.

[34] The data come from survey SHARE - Survey of Health, Ageing and Retirement in Europe http://www.share-project.org/home0.html.

hand, on individual indicators such as age, gender, and social class, previous experience with Internet use and Internet use among an individual's social network , and on the other hand, on wider contextual factors, such as the area of residence and country-specific wealth and communication technology infrastructures.

Even, among the elderly people who do not refrain from using the Internet, the access frequency strongly varies. Indicatively, Sum et al. (2009) traced the habitual Internet use of 222 Australian Internet users aged 55 years or more. The authors highlighted that most participants used the Internet between 4 and 10 hours per week and only one-third reported using it for more than 16 hours per week. The findings of Van Boeckel at al. (2017) originating from 1418 individuals aged 65 years and older, who have access to and use the Internet (the data derived from the Dutch Longitudinal Internet Study for Social Sciences (LISS) panel survey) show a range of 1.6 and 3.4 hours per week of Internet use. However, the study of Luger et al. (2016) about the reported ability of 266 older Veterans' to access technology through their close social ties, reveals that even if almost 50.00% of the older people do not use the Internet, they argued that they could ask for help from the people of their social network and reported to have on average two people to whom they could refer for that type of assistance.

The studies that describe in details the specific online activities that perform the elderly people are only a few (Schehl et al., 2019). In these studies, the reported activities are not following a universal approach, thus, missing an equal basis and rendering difficult any reliable cross-study comparison. In addition, the preferences of the elderly people for the online activities appear very diversified, probably because they are affected by the specific cultural and geographical context considered in the studies or/and the different age cutoff when defining a person as old (usually the studies start from the minimum age of 50 years old). More recently, a report of EUROSTAT (2020) presented relevant research on the EU-27countries both about the use of some Internet activities and a comparison with the trends 10 years back. Firstly, it is demonstrated a clear increase of Internet use by the elderly adults (55-64 and 65-74 years old). Secondly, both the younger and the older elderly focus on (by order of % frequency): (a) sending/receiving e-mails and (b) seeking for health information[35].

[35] Only four Internet activities were explored in the report EUROSTAT (2020): send/receive e-mails, seek for health information, use Internet banking services and make telephone/video calls.

Primarily, some studies have found that the Internet is used by the elderly for communication purposes and on a secondary basis for additional activities. A study (Selwyn et al., 2003) about 352 adults aged over 60 years old in four local authorities in the west of England and South Wales, reports that sending/reading e-mails and writing or editing letters, reports and other documents are the two types of more frequent activities that are performed by a subsample of 352 adults aged 60 or more years in England and Wales. In the explorative study of Russel et al. (2008), the in depth interviews of 30 Australian Internet users aged 55 years old showed that sending e-mails with family and friends is the most predominant digital activity in later life. Also, this observation is confirmed in Hasan and Linger (2016) from qualitative data of about 30 participants over 50 year old data in two aged-care facilities, in regional Australia over a 2-year period of project. The authors using Australian data argue that together with Skype, e-mails are particularly popular for keeping in touch with family and friends. Similarly, results are found by Dziuba et al. (2019) for the elderly people in Poland even if the sample of the survey was not representative Through a more wide activity analysis, Sum et al. (2009) collected data from Australian elderly, and using principal component analysis for 27 online activities concluded that the Internet is used mainly for communication activities followed by seeking information, online purchases and just for pleasure.

The findings of other literature have, indeed, identified informational activities as of major significance for the older people. In this sense, more recently Schehl et al. (2019) argue that their sample of 1222 older adults aged 65 and over living in three districts in Mönchengladbach (Germany) preferred informational online activities, i.e. searching the web, viewing pictures/videos, among social (writing e-mails, writing comments/reviews) and other instrumental activities (banking, shopping). Notably, the elderly people who were younger, with higher education, and with higher perceived behavior control were more likely to perform all online activities. Also, men were more probable than women to perform informational and instrumental rather than social activities. In the same line, Pirone et al., (2008) through descriptive statistics analysis studied the relationship of elderly people with ICT among adults between residents of 50-70 years old in two Italian cities (Bologna and Napoli). Access to Internet or to computers, reason for not using Internet, activities performed through Internet way of acquiring ICT use knowledge were the basic variables elaborated. Remarkably, it is demonstrated that 81.40% of the interviewed elderly preferred to search information for personal interests and 70.00% information about the daily news. However, in the same paper it is stressed that the Italians are classified among the other Europeans with

the lowest Internet use. Additional literature have identified priority to a mixture of activities. An interesting classification of Internet use is given by Colombo and Carlo (2015), where the activities are related to the availability of time. After collecting data of 900 Italians (aged between 65 and 74 years of age) with a face-to-face questionnaire administered to a statistically representative national sample (December 2013 - January 2014), and 20 family in depth interviews in Milan area they performed an ethnographic analysis. According to that, some elderly Italian people reported to use the Internet for activities such as banking and shopping when they wanted to save time, or, just for pleasure when they had more free time to spend. Furthermore, ICTs and the Internet play an important role in the life of the young elderly not only with regard to the time they occupy but also the space in their homes. Moreover, the adoption of ICT is affected by socio-demographic characteristics and inter-generational experiences.

Gell et al. (2013), analysing 7,609 data from the 2011 US National Health and Aging Trends Study (NHATS), showed that in the last month 56.00% of the Internet users executed personal tasks such as shopping or banking, 49.40% reported using the Internet for health-related tasks and 40.20% for e-mails or texting messages for communication. The Internet was used mainly by the younger elderly, men, educated and married while the physical limitations seem to prevent the elderly from it. Also, Nimrod (2018) with the scope to explain the technophobia faced in later age, performed a factor analysis on 12 online activities performed by 537 Israeli Internet users aged more than 60 years old. The author ended up that what names "*Native activities*", i.e. functions that required high trust and/or high digital presence, such as posting opinions to forums and blogs and shopping/banking, were capturing mostly the digital behaviour of the elderly individuals (they explained 23.49% of the overall variance of a four-factor solution). However, since technophobia and satisfaction with life are strongly associated, training programs that will make the elderly more familiar with technology are highly encouraged.

Many attempts have been made by the scholars in order to deeply comprehend what tasks the elderly people opt for online by highlighting the background sociodemographic determinant parameters related to separate and more specific Internet activities. Notably, Matthews et al. (2018) elaborated data from six waves (2002 - 2014) of the English Longitudinal Study of Ageing (ELSA) and reported that across all the age cohorts of the elderly people in their sample, the rates of Internet use are lower for women (compared to men) and for poorer

individuals (compared to the wealthier). Sartori (2011) frames the Internet use in Italy, comparing data for the Italian households retrieved from Istat, "Aspects of daily life" survey for various years and notes that the gender digital divide has not been diminished between 2003 and 2010. Similar gender related results have been detected in the report of EUROSTAT (2020) as regards the EU-27 population. In the same report the technological familiarity of men has been attributed to the technology exposure derived from job in their earlier life stages. Building on the same activity categorization used by Schehl et al. (2019) i.e. informational, social, and instrumental online activities, Leukel et al. (2020) used a logistic regression approach to analyse 1079 data from a survey conducted during the summer 2017 among all older adults (65+) living in three districts of a city in Germany. Various inequalities were uncovered as regards the sociodemographic characteristics of the elderly Internet users. Roughly speaking, they reached the conclusion that informational, social, banking and shopping activities were preferred by men, more educated and healthier individuals. In the same sense, Gell et al. (2013) beyond sociodemographic characteristics, examined the health status for its influence on Internet activities. As expected, the Internet use is decreased for the older age cohorts, hence, the findings verify what has more recently reported in Matthews et al. (2018).

Similarly with the previous studies, Van Deursen and Helpser (2015) used data concerning senior Internet users obtained through a nationally representative online survey in the Netherlands and investigated few specific online activities (i.e. e-mails, information search, reading news, shopping, social entertainment, downloading music/video, using civic and health services) with respect to age, gender, educational levels, household composition, traditional literacy, Internet experience and attitude. The study remains highly informative and highlights that profiling the elderly people according to the specific online activity tasks is a more realistic approach than investigating the general Internet use. In general, considering the elderly people similar to all the other Internet users is very simplistic and probably unreliable for policy actions. Given that the literature review presented in this section contains studies between 2003 and 2020, it needs to be underlined that the results of the studies published in earlier years might not hold as such at the moment (as it might have been the case during the period of their publication) because the technological advancements evolve in growing rates. Also, the future generations of elderly people will be probably more involved and familiar with ICT use as they are more frequently exposed technological devices e.g. smartphones.

Table 4.1 *Literature review studies*

Study	***Aim***	***Sampling strategy***	***Internet measure***	***Country***	***Statistical/ econometrical analysis***	***Results***
Colombo and Carlo (2015)	Research the relationship between the young elderly (65–74 years old) and the use of technologies on active ageing.	900 Italians aged between 65 and 74 years of age, face-to-face questionnaire administered to a statistically representative national sample (December 2013 - January 2014), and 20 family in-depth interviews in Milan area.	Use of ICT in spare time, personal story for starting using ICT, physical location of ICT's, time of using the Internet coupled with the activities performed.	Italy	Ethnography analysis	ICTs and the Internet play an important role in the life of the young elderly not only with regard to the time they occupy but also the space in their homes. The adoption of ICT is affected by socio-demographic characteristics and inter-generational experiences.
Dziuba et al. (2019)	Study the use of the Internet of older adults in Poland.	131 complete questionnaires from adults over 60 years old who in 2018 were the participants of the University of the Third Age at the University of Economics in Wrocław, Poland.	Use or not of the Internet, use by gender and age, purpose of Internet use	Poland	Descriptive statistics	The majority of the participants was using the Internet but the authors report that they haven't use a representative sample.
Gell et al. (2013)	Focus on Internet use by the over 65's with physical disabilities.	7,609 data of adults 65 years old and more from the 2011 National Health and Aging Trends Study (NHATS).	13 questions related to the use of technology e.g. Use of e-mail/text messages and the Internet the last month.	USA	Multivariate analysis (Poisson regression)	42.7% used the Internet and 40% for e-mail or text messaging. The Internet was used mainly by the younger elderly, men, educated and married while the physical limitations seem to prevent the elderly from it.
Hasan and Linger (2016)	How the social well-being of the elderly in aged-care facilities can be enhanced through the use of ICT.	Qualitative data collected over 30 participants in two aged-care facilities, in regional Australia over a 2-year period of project	Sessions on how to use the devices provided what they could be used for and assistance with use problems.	Australia	Thematic network analysis approach	The most popular ICT uses were e-mail and Skype in particular for keeping in touch with family and friends all over the world. With increasing experience many elderly were selecting activities of their own preference.

König et al. (2018)	Determinants of Internet use among European countries.	61,202 Europeans aged ≥ 50 from Survey of Health, Ageing and Retirement in Europe (SHARE).	During the last 7 days, have you used the Internet, for e-mailing, searching for information, making purchases or for any other purpose at least once?	17 European Countries	Multilevel logistic regression models	The Internet use by the elderly people is very different among the European countries, with an average level of 49%. There are many factors that affect the Internet use: age, gender, social class, and previous experience with computers during one's time in the workplace, the Internet use among an individual's social network, the area of residence, the country's wealth and communication technology infrastructure.
Leukel et al. (2020)	Sociodemographics and Internet activities	1079 data from a survey conducted during the summer 2017 among all older adults (65+) living in three districts of a city in Germany.	Questions about the frequency of various online activities.	Germany	Logistic regressions	Men, younger elderly, educated with better perceived health were more probable to perform all types of online activities included in the study.
Luger et al. (2016)	Examine older Veterans' reported ability to access technology through their close social ties.	266 Veterans aged 65 years and older, data collected via mail survey.	How do you currently access the Internet?	USA	Descriptive statistics and chi square tests	Almost half (44.0%, 117/266) of the sample reported having no Internet access. Those without current access, reported having a median of 5 close social ties with home Internet access and 2 that can refer for help with Internet accessibility.
Matthews et al. (2018)	Internet in relation to age and period effects.	10390 (Wave 1:2002-2003) and 4627 (Wave 6: 2012-2014) adults over 50 years old from the English Longitudinal Study of Ageing (ELSA).	Using or not the Internet (Wave 1-Wave 6) Frequency of Internet use (Wave 6)	UK	Multi-level growth curve models	Internet use is higher for the younger elderly and declines with age increase. Other factors regard poor health and financial conditions as well as being woman predict lower use of Internet.
Nimrod (2018)	Technophobia and Internet use patterns.	Online survey of 537 Israeli Internet users aged 60 years and over, deriving from an online panel of 50,000 Internet users owned by a commercial company.	Questions about Internet use: duration (in years), typical use hours per week, and technological platform/s used for Internet access (computers and mobile phones). Also, response to how much time (in minutes) they spent using 12 Internet-based functions (e.g., e-mail, social networking, and online games) during the previous day.	Israel	Factor analysis and linear regression analysis	Technophobia and satisfaction with life are strongly associated, thus, training programs that will make the elderly more familiar with technology are highly encouraged.

Pirone et al. (2008)	The relationship elderly people with ICT.	Adults between 50-70 years old residents of the provinces of Napoli and Bologna.	Access to Internet or to computers, reason for not using Internet, activities performed through Internet, way of acquiring ICT use knowledge.	Italy	Descriptive statistics	Italy it is classified between the countries with the lowest use of ICT.
Sartori (2011)	The relationship of the Italians with ICT.	Italian households (including the elderly people as well).	Analysing data from Istat, "Aspects of daily life" survey for various years 1997 - 2010	Italy	Descriptive statistics	The author observes the development of the electronic devices used to access the Internet, the reasons why the Italian households do not use it and finally, gender differences
Russel et al. (2008)	Sociodemographic characteristics and online use patterns of older Australian Internet users.	In depth interviews with 30 Internet users aged 55 years or older coming from a purposive sample.	Activities of Internet use, years of being Internet user, weekly frequency of Internet use.	Australia	Exploratory study using Nvivo software	Most of the participants made use of the Internet for communication and for staying in touch with friends and family.
Schehl et al. (2019)	Explore the factors that predict informational, social, and instrumental online activities.	1222 older adults aged 65 and over living in three districts in Mönchengladbach, data collected through a questionnaire-based survey.	How often do you use digital technology for (a) informational (searching the web, viewing pictures/videos), (b) social (writing e-mails, writing comments/reviews), and (c) instrumental activities (banking, shopping)? (1/never, 2/few times, 3/several times per month, 4/several times per week, 5/daily).	Germany	Ordinal regression analyses	The elderly people who were younger, with higher education, and with higher perceived behaviour control were more likely to perform all online activities. Men were more probable than women to perform informational and instrumental rather than social.
Selwyn et al. (2003)	Extent and nature of ICT access and use by elderly people.	352 adults aged over 60 years old in four local authorities in the west of England and South Wales completed a 36-page structured-survey.	Access to technological devices, electronic device used to access the Internet, site of access, potential and actual support from family and children for ICT support, use of computers by social or health characteristics, types of Internet activities performed, reasons for not using ICT.	UK	Descriptive statistics	The use of Internet by the elderly people is not only less frequent by it is related to gender, age, marital status and education status.

Sum et al. (2009)	Explore how Australian older adults use the Internet.	222 Australian Internet users aged 55 years or more, purposive (non-probability) sample who completed the online questionnaire over a 6-month-period.	Frequency of Internet use: How many hours in the last week did you use the Internet? (1/less than 4 hours – 4/more than 16 hours). History of Internet use: How long have you been using the Internet? (1/ less than 1 year -4/'over 7 years) Internet applications: (e.g. search engines, web cam, email, games, etc. they most commonly used Breadth of Internet use: participants were also asked to identify the extent to which they used the Internet for each of 27 different purposes (1/never - 7/ several times a day).	Australia	Principal Component analysis, ANOVA, t-tests	Participants primarily used the Internet for interpersonal communication, followed by information seeking, commerce and entertainment.
Van Boeckel at al. (2017)	Describe the diversity of Internet activities and the role of social or health-related variables for Internet use.	1418 aged 65 years and older, who have access to and use the Internet from Longitudinal Internet Studies for Social Sciences (LISS) panel survey.	Doing or not 10 web-based activities.	Netherlands	Latent Class Analysis	Older adults are a diverse group in terms of their Internet activities and four clusters were identified: "practical users" (36.88%, n=523), "minimizers" (32.23%, n=457), "maximizers" (17.77%, n=252) and "social users" (13.11%, n=186).
Van Deursen and Helpser (2015)	Reasons for Internet use and non-use by older individuals.	Data concerning senior Internet users were obtained through a nationally representative online survey.	Internet attitude, time online, online activities engaged in and breadth of Internet use.	Netherlands	Hierarchical logistic regression analyses, Logistic and linear regression analyses, Factor analysis.	Different types of older adults were found to adopt different Internet behaviours.

4.3 Materials and Methodology

The ultimate goal of our paper is to identify subgroups aged over 60 years old in the Italian population, discriminating them according to the online activities they perform. The first partial focus is to explore conceptual overlaps between the online activities (executing an Exploratory Factor Analysis) and, then, create indexes of the Internet connectivity. The second partial target is to use the indexes found in the first step together with further sociodemographic characteristics and classify the elderly people into latent groups based on their digital behavior.

4.3.1 Dataset

The dataset for the analysis was provided by the Italian National Institute of Statistics (ISTAT) "Multipurpose Survey 2018" (ISTAT, 2020). Every year ISTAT collects information on several life aspects (totally 691 questions in this year's survey) from a representative sample of the Italian households. The full dataset involved 44,672 individuals, but for the scope of the paper we kept only the data for the people over 60 years old, i.e. 13,597 individuals.

Table 4.2 summarizes the characteristics of the sample. It is classified into three age categories: (a) 60-64 years old, (b) 65-74 years old and (c) more than 75 years old. Importantly, it is relatively balanced as regards the representation of the two genders. The percentage of the married people (61.67%) exceeds the remaining civil status categories. As regards the levels of education, the majority (41.56%) do not hold any schooling certificate or has finished only the primary school. As expected, 74.17% of the participants earn their living from pensions. With respect to the health status variable, 52.17% of the interviewed people in the sample report not having any physical limitations (caused by health problems) in doing their daily activities. Furthermore, variables about the digital infrastructures were included: the fixed broadband Internet connection is widely diffused (42.45%), followed by the broadband mobile phone network with cell phone or smartphone (21.65%). Finally, considering the geographical dispersion of the sample, it is represented at 42.33% by the Northern areas (West and East), 19.67% by the Central areas, 27.92% by the Southern and 10.08% by the Islands.

4.3.2 Measures

The Internet use was measured with the question "*Have you ever used the Internet?*" coded as categorical variable (4=in the last three months, 3=more than three months, 2=between three months and one year ago, 1=never).

The frequency of Internet use was measured with the question "*In the last 12 months, how often have you used the Internet*?" coded as categorical variable (5=all the days, 4=sometimes a week, 3=one time per week, 2=sometimes a month, i.e. less than 4 times, 1=less than one time per week).

The devices used to access the Internet were assessed by the question, coded as binary variable (1 =Yes/0 = No): "*In the last three months which of the following devices have you used to access the Internet: (a) desktop, (b) laptop/netbook, (c) tablet, (d) mobile phone and (e) other devices (media or games player, e-book reader or smart watch)*?".

The survey includes 41 questions about various online activities, coded as binary variable (1 =Yes/0 = No). It seems that instant messaging (74.71%), sending/receiving e-mails (66.97%) and reading newspapers, information or online magazines (58.05%) are the three top preferred activities when the Italian elderly people are navigating online. The remaining activities score lower and more details about the frequency and type of each one are illustrated in Table 4.4.

Furthermore, several sociodemographic variables that are traditionally used in the scientific literature were considered (Leukel et al., 2020; Yoon et al., 2020; Matthews et al., 2018; Van Deursen and Helpser, 2015; Vroman et al., 2015; Yu et al., 2015; Gell et al., 2013): age, gender, civil status, level of education, main source of income, physical limitations, type of Internet connection and place of residence location (see Table 4.2).

Table 4.2 *Descriptive statistics of the sample*

Variable	Responses	Type of Variable	N (%)	Mean (SD)
Age (N=13,597)	1 = 60-64 years old 2 = 65-74 years old 3 = ≥75 years old	Categorical	2,971 (21.85) 5,295 (38.94) 5,331 (39.21)	14.17 (0.76)
Gender (N=13,597)	1 = Male 0 = Female	Binary	6,110 (44.94) 7,487 (55.06)	0.45 (0.50)
Civil status (N=13,494)	1 = Not married 2 = Married 3 = Divorced 4 = Widowed	Categorical	914 (6.77) 8,322 (61.67) 958 (7.10) 3,300 (24.46)	2.49 (0.94)
Level of Education (N=13,515)	1 = Elementary school/no qualification 2 = Middle school 3 = High school 4 = University degree	Ordinal	5,617 (41.56) 3,599 (26.63) 3,161 (23.39) 1,138 (8.42)	1.99 (0.99)
Main source of income (N=13,377)	1 = (Self)-employment 2 = Maintenance family 3 = Pension 4 = Allowances 5 = Property income	Categorical	1,677 (13.00) 1,367 (10.22) 9,922 (74.17) 303 (2.27) 108 (0.81)	2.69 (0.75)
Physical Limitations (N=13,058)	1 = No limitations 2 = No serious limitations 3 = Serious limitations	Ordinal	6,813 (52.17) 4,496 (34.43) 1,749 (13.39)	1.61 (0.71)
Internet connection: fixed broadband (N=13,597)	1 = Yes 0 = No	Binary	5,772 (42.45) 7,825 (57.55)	0.42 (0.49)
Internet connection: broadband mobile phone network with cell phone or smartphone (N=13,597)	1 = Yes 0 = No	Binary	2,944 (21.65) 10,653 (78.35)	0.22 (0.41)
Internet connection: broadband mobile phone network via SIM card or USB key (N=13,597)	1 = Yes 0 = No	Binary	1,024 (7.53) 12,573 (92.47)	0.08 (0.26)
Internet connection: fixed or mobile narrowband connection (N=13,597)	1 = Yes 0 = No	Binary	274 (2.02) 13,323 (97.98)	0.02 (0.14)
Place of residence (N=13,589)	1 = North-West 2 = North-East 3 = Center 4 = South 5 = Islands	Categorical	2,995 (22.04) 2,757 (20.29) 2,673 (19.67) 3,794 (27.92) 1,370 (10.08)	2.83 (1.32)

Table 4.3 shows more details about the Internet accessibility at region levels. It is evident that the population of the northern Italian regions has higher Internet accessibility levels mostly, at all types of Internet connection (fixed broadband - North-West/44.64%, North-East/45.30%, phone network with cell - North-West/27.49%, North-East/23.10%, phone network via SIM card or USB key - North-West/10.24%, North-East/9.58%, fixed or mobile narrowband connection - North-West/3.40%, North-East/2.36%), compared to the remaining regions. Notably, the Central regions consist an exception to that observation with respect to the fixed broad connection. More specifically, 47.66% of the population in our sample that lives in Central Italy uses fixed broadband Internet connection.

Table 4.3 *Type of Internet connection by region of residence*

Place of residence	***Fixed broadband***		***Phone network with cell***		***Phone network via SIM card or USB key***		***Fixed or mobile narrowband connection***	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
North-West	1,337	44.64	631	27.49	235	10.24	78	3.40
North-East	1,249	45.30	637	23.10	264	9.58	65	2.36
Center	1,274	47.66	586	21.92	200	7.48	62	2.32
South	1,378	36.32	779	20.53	210	5.54	50	1.32
Islands	529	38.61	305	22.26	110	8.03	19	1.39

Notes: *N represents the number of actual users for each type of Internet connection, % represents the N of actual users for each type of Internet connection with respect to each region's total population. In our sample: North-West=2,995 North-East= 2,757, Center= 2,673, South=3,794, Islands=1,370*

Table 4.4 *Descriptive statistics of the online activities*

Type of activity	Reported question about online activity	N	Frequency (%)
COMMUNICATION ACTIVITIES	In the last 3 months have you used instant messaging (e.g. WhatsApp), sent messages on chats, blogs, newsgroups, forums?	4,113	74.71
	In the last 3 months have you participated in social networks (e.g. create a user profile, post messages or other on Facebook, Twitter, etc.)?	4,085	33.98
	In the last 3 months have you made phone calls/video calls?	4,072	31.34
	In the last 3 months have you participated in a professional network (e.g. create a profile, post messages or other contributions on LinkedIn, Xing, etc.)?	4,142	20.71
	In the last 3 months have you uploaded content of your own creation?	4,082	18.08
	In the last 3 months have you expressed opinions on social or political issues on the web (e.g. through blogs, social networks, etc.)?	4,068	11.92
LEISURE ACTIVITIES	In the last 3 months have you read newspapers, information, online magazines?	4,126	58.05
	In the last 3 months have you watched video content from sharing services (e.g. YouTube)?	4,108	42.96
	In the last 3 months have you listened to music through Internet?	4,107	25.27
	Are you getting informed for political issues through the Internet?	9,969	19.06
	In the last 3 months have you watched streaming television?	4,102	14.85
ECONOMIC ACTIVITIES	In the last 3 months have you sent or received e-mails?	4,105	66.97
	In the last 3 months have you used Internet banking services?	4,091	40.26
	Have you ever bought or ordered goods and or services for private use on the Internet?	4,958	33.88
	In the last 3 months have you used payment services (e.g. PayPal, Braintree, etc.) to purchase goods or services on the Internet?	4,098	23.96
	In the last 3 months have you used Internet storage/sharing services to save?	4,142	20.71
	In the last 3 months have you downloaded software (other than games)?	4,081	11.54
	In the last 3 months have you carried out financial transactions for private use on the Internet (excluding email): buying/selling stocks, bonds, funds or other financial services?	4,371	3.02
ECONOMIC ACTIVITIES	In the last 12 months have you used the Internet to obtain information from websites of the public administration or public service operators?	4,358	21.94
	In the last 12 months have you used the Internet to send completed online forms for private use to the public administration or public service operators?	4,372	14.64
	In the last 3 months have you booked an appointment with a doctor?	4,097	10.69
	In the last 3 months have you watched video on demand?	4,097	9.03
	In the last 12 months have you used a website/app that allowed you to get a paid job (e.g. Freelancer, Upwork, etc.)?	4,364	0.18
TRANSPORT &	In the last 3 months have you used travel or accommodation services?	4,105	29.16

ACCOMODATION ACTIVITIES	In the last 3 months have you used special websites or apps to find accommodation by contacting a private individual directly (e.g. AIRBNB, Home way etc.)?	4,366	10.17
	In the last 3 months have you used other websites or apps to find accommodation by contacting a private individual indirectly (including social networking sites)?	4,349	5.70
	In the last 3 months have you used special websites or apps to take advantage of a transport service by contacting a private individual (e.g. UBER)?	4,362	2.27
	In the last 3 months you have used other websites or apps to use a transport service by contacting a private individual indirectly (including social networking sites)?	4,351	1.98
ELIMINATED ACTIVITIES	In the last 3 months have you consulted a wiki to obtain information (e.g. Wikipedia, other online encyclopedias)?	4,086	49.90
	In the last 3 months have you searched for health information?	4,106	48.30
	In the last 3 months have you searched for goods and services?	4,107	47.94
	In the last 3 months have you searched for information on educational activities or courses?	4,098	19.50
	In the last 12 months have you used the Internet to download forms from the public administration or public service operators?	4,355	18.81
	In the last 3 months have you played or downloaded games?	4,102	14.80
	In the last 3 months have you downloaded pictures, movies, music from the Internet?	4,098	14.49
	In the last 3 months have you read or downloaded online books or e-books?	4,099	9.08
	In the last 3 months have you sold goods or services?	4,086	5.19
	In the last 12 months have you used a website/app to order food at home or book catering services directly from a private individual (e.g. purchasing groups, Deliveroo, Foodora, Gnammo, Home Restaurant, etc.)?	4,375	3.66
	In the last 3 months have you been looking for work or sent a job application?	4,087	2.20
	In the last 12 months have you carried out financial transactions for private use on the Internet (excluding email): obtaining a loan/credit from banks or other financial service providers?	4,368	0.66

Notes: *For homogeneity reasons, the descriptive statistics of the activities have been grouped based on the results that emerged from the Exploratory Factor Analysis (see Section 4.4.2.1). The group of the eliminated activities regards the activities that have been removed from the final analysis during the procedure of definition of the number of factors, as described in Section 4.4.2.1. We decided to include them in the descriptive statistics' section only for informative purposes.*

4.3.3 Data analysis

The methods of the data analysis have been adapted to address each one of the research questions of the study. First, we calculated descriptive statistics for the investigation of the Internet diffusion, its frequency of use and the devices through which the digital connection is achieved (RQ.1 and RQ.2). An Exploratory Factor Analysis (EFA) (principal components method of extraction, varimax rotation) was employed to explore potential similarities among the online activities (RQ.3). As a consequence, the 41 activities were reduced to 30, and created five composite indexes representing wider separate categories of Internet activities experienced by the older users. Then, a series of tests with the value of Cronbach's alpha were run to measure the interitem consistency reliability of all the 30 included activities and the separately resulted factors. The factors that contained an Eigenvalue of 1.00 or above, and included at least 3 items with a loading greater than 0.40 were kept as interpretable index variables (Samuels, 2016).

Finally, in order to test for the existence of discrete groups (classes) of elderly with similar online activity profiles, we conducted a Latent Class Analysis (LCA) (RQ.4 and RQ.5). LCA is a methodology that requires four basic steps: (a) identification of LCA indicators, (b) estimation of the latent class models, (c) evaluation of the latent class models and, at the end, d) interpretation of the results (Li, 2017). The most important stage of LCA is to decide upon the number of latent classes. We fitted separately and compared six class models using Akaike Information Criterion (AIC) (Akaike, 1987) and the Bayesian Information Criterion (BIC) (Schwarz, 1978). AIC and BIC are descriptive fit indices in which the model with the smallest value in either of the two is preferred.

The data analysis was performed with STATA 16 software.

4.4 Results

4.4.1 Prevalence, frequency and devices of Internet access

In terms of Internet use, it is evident (and expected) that the younger elderly (60-64 years old) are the most frequent users compared to the remaining ageing groups, claiming that 55.20% of the females and 62.30 % of males have used, in general, the Internet in the last 3 months (Figure 4.2). Indeed, the tendency sounds quite logical, because as age increases, the physical capabilities decrease and, as such, the Internet use.

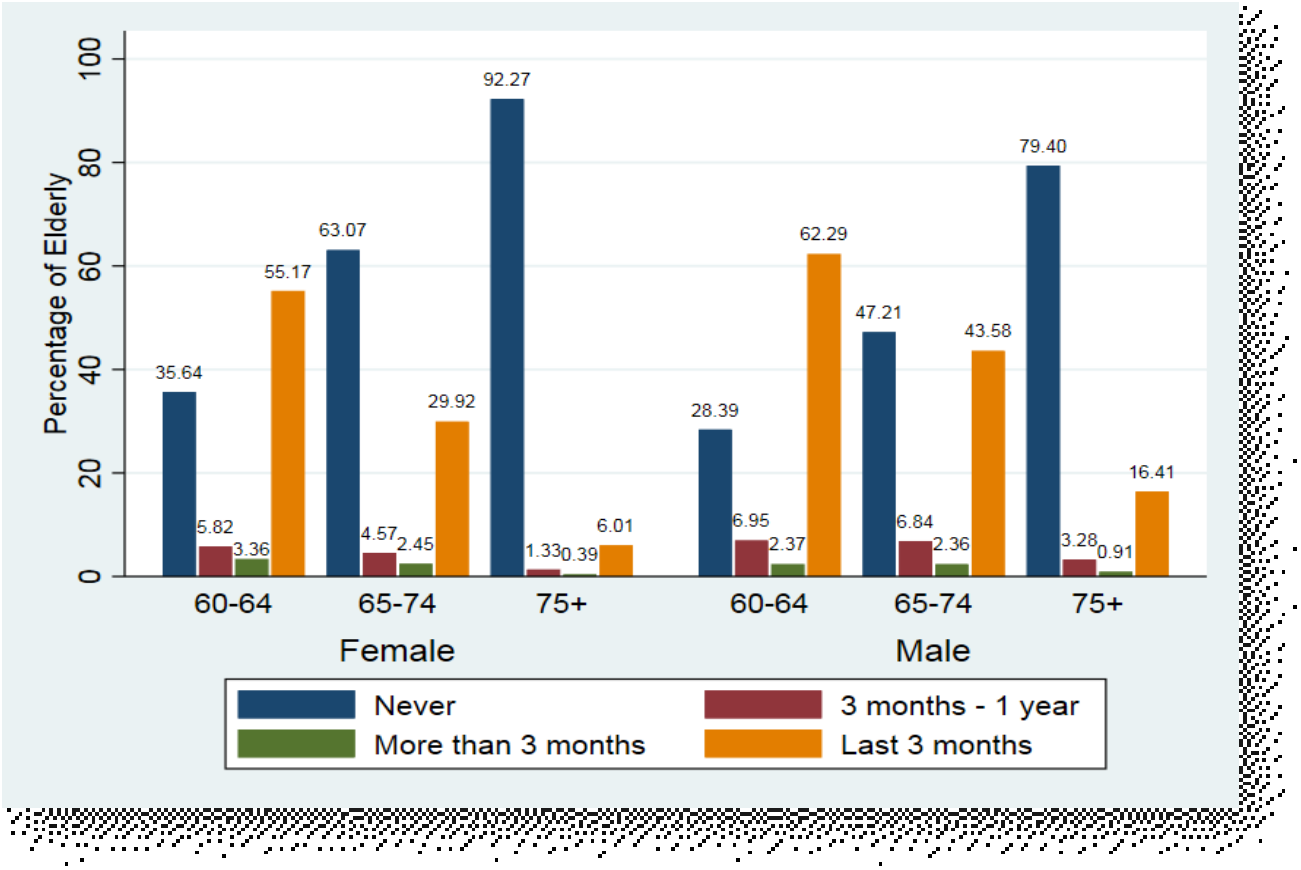

Figure 4.2 *Internet use of the individuals over 60 years old, by age and gender (Data: Multipurpose Survey 2018, Author's elaborations)*

Figure 4.3 illustrates the frequency of Internet use in the last 12 months. Two important findings can be extracted. The first is definitely in line with Figure 4.2, which confirms the declining percentages of Internet use for all age groups and for both genders of the over 60's. Obviously, there are activity-related divergences from the overall tendency (see Section 4.4.2.2). As for the second comment, the males seem to present slightly higher frequency levels of Internet connectivity than females regardless of their age.

Seeking a more detailed map of the Internet behavior in later age, Figure 4.4 depicts the electronic devices preferred by the Italian elderly to perform any Internet activity. Differences are observed both in terms of age and gender. The women between 60-64 years old use widely the cellphones, while men of the same age prefer tablet devices. Afterwards, between 65 and 74 years old women prefer other devices and men tablets. In the late ageing phase (75+), men are turning to desktops, probably because the digital screens are usually larger and easier to read. On the other hand, women of the same age prefer either cellphones or tablets and other types of devices.

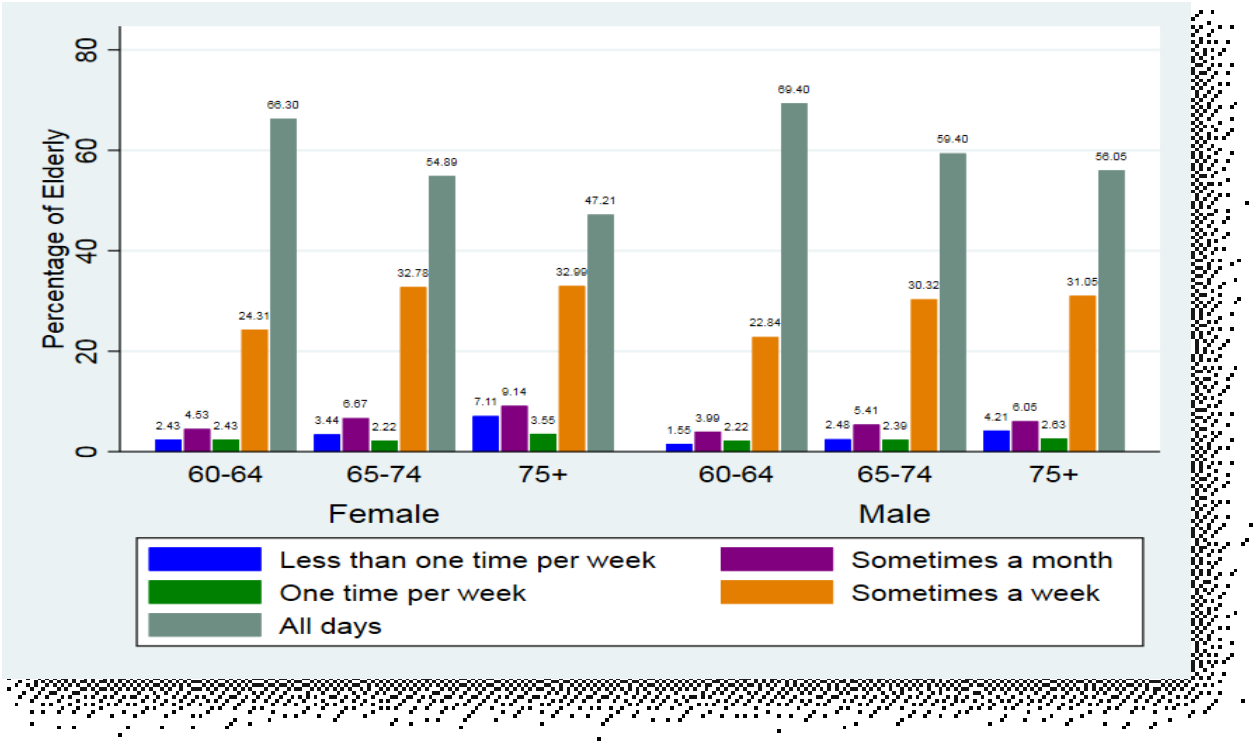

Figure 4.3 *Frequency of Internet use among the over 60 years old users, by age and gender (Data: Multipurpose Survey 2018, Author's elaborations)*

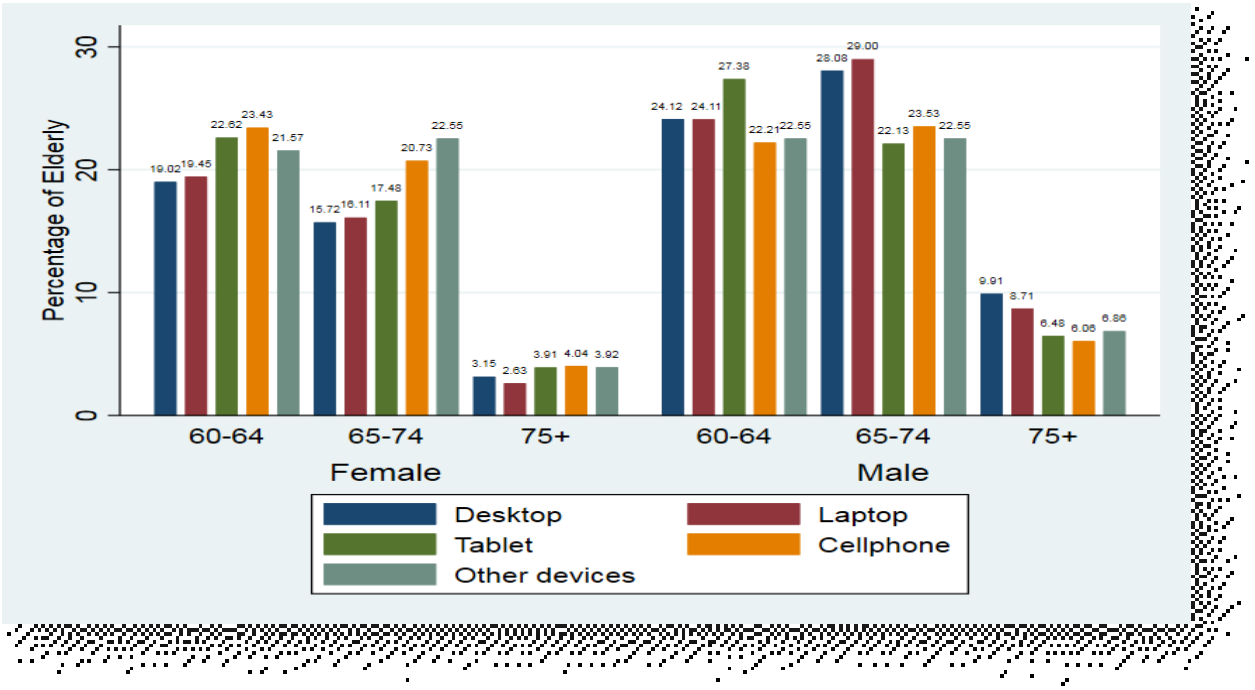

Figure 4.4 *Devices used for the Internet connection among the over 60 years old users, by age and gender (Data: Multipurpose Survey 2018, Author's elaborations)*

4.4.2 Exploratory Factor Analysis

4.4.2.1 Determining the number of factors

The steps that we followed for the EFA are as described in Samuels (2016). First, we ran a bivariate correlation matrix of all the 41 items. Field (2013) suggests removing one of a pair of items with bivariate correlation scores more than 0.80. More, Tabachnick and Fidell (2019) recommended using 0.30 as the lower bound of correlations and preferring any over than that. As it does not exist a precise quantitative rule on how to select which item to exclude among the pairs of highly correlated, instead, Samuels (2016) proposes to base the decision on qualitative intuition judgement. As such, we excluded the variable which had the highest correlation (0.88) "*Downloading forms of the public administration*", among the other variables related to the public administration procedures, *"Send completed online forms"* and *"Obtain information".* Additional tests were undertaken to validate the suitability of our data structure for factor analysis (including only the 40 remaining online activities). Specifically, the Bartlett's test of sphericity (Pett, 2003) checked that the observed correlation matrix diverged significantly from the identity matrix at a= 0.05 with a p-value of 0.00 (χ^2 = 23143.97, degrees of freedom (df) = 780). Subsequently, the Kaiser–Meyer–Olkin sample adequacy ratio was calculated and its value was 0.90, thus indicating that the sample was considered meritorious for factor analysis (Dziuban and Shirkey, 1974).

The second step in factor analysis is to decide upon the rotation method. In order to find which method gives more acceptable results, both varimax and promax rotation were tested. The findings of the varimax method were kept as definitive because they gave as factors with much better values of Cronbach's a (compared to promax). Afterwards, we run the factor analysis and optimized the number of factors by looking for as many factors as possible with at least 3 items with a loading greater than 0.40. This procedure resulted in six factors.

The third step in factor analysis regards controlling for the communalities as it is suggested to exclude these items with values less than 0.20 (Samuels, 2016). The variable "*Have you played or downloaded games*" falls in this category with communality value of 0.15. Thus, 39 items remained for the rest of the analysis. As some of them were cross-loading, a stepwise procedure was followed until we reached the criterion of as many factors as possible with at least 3 items with a loading greater than 0.40. During this procedure, we removed any items with no factor loadings > 0.30 and also any items with cross-loadings >75.00% starting with

the one with the lowest absolute maximum loading on all the factors. We re-run the analysis several times. Furthermore, since each factor needs to have at least three items with loadings > 0.40, it was necessary to reduce the number of factors from 6 to 5. The stepwise exclusion of items (which failed to exceed the predefined factor loading thresholds), yielded a stable solution after 12 steps with a total of 30 items.

These remaining 30 items clustered into a five-factor solution (Table 4.5). The first factor, *Economic,* consisted of eight items and explained 20.20% of the scales variance. The second factor, *Transport and accommodation*, consisted of 5 items and explained 12.80% of the variance. The third factor, *Communication,* consisted of six items and explained 12.63% of the variance. The forth factor, *Leisure,* consisted of five factors and explained 10.86% of the variance. The last factor, *Daily practical,* consisted of five items and explained 10.39% of the total variation. The scale's total Cronbach's alpha was 0.84 and the total explained variance was 66.97%. This part of the analysis was concluded with the creation of indexes of online activities. Simply explaining, for every factor that emerged from the EFA, we calculated the mean i.e. we added up the responses (1=Yes/0=No) of the included online activities and divided by how many activities were included in the factor.

Although the detailed analysis of the frequencies of the online activities (as presented in Table 4.4) might be more informative, the analysis of the created indexes from the factor analysis presents equal interest. The created indexes get values that range from 0.00 to maximum 0.80 or 0.88 or 1.00[36]. The value ranges of them are not equal because, on the one hand, the number of the contained online activities differs and, on the other hand, there are not existing individuals that have performed all the activities included in some indexes i.e. *Economic* and *Daily Practical Activities.*

[36] We note here that the factors, instead, have a mean value of 0 and variance 1.

Table 4.5 *Factor loadings of the reported online activities*

Items	Economic	Transport & accommodation	Communication	Leisure	Daily practical
Send or receive e-mails	0.80				
Use Internet for banking services	0.79				
Use payment services (e.g. PayPal, Braintree, etc.) to purchase goods or services	0.73				
Buy or order goods and/or services for private use	0.69				
Carry out financial transactions for private use on the Internet (excluding email): buying / selling stocks, bonds, funds or other financial services	0.67				
Carry out financial transactions for private use on the Internet (excluding e-mails): purchase/renew insurance policies	0.64				
Use Internet storage/sharing services to save	0.54				
Download software (other than games)	0.51				
Use special websites or apps to take advantage of a transport service by contacting a private individual (e.g. UBER)?		0.83			
Use other websites or apps to find accommodation by contacting a private individual indirectly (including social networking sites)?		0.77			
Use special websites or apps to find accommodation by contacting a private individual directly (e.g. AIRBNB, Home way etc.)		0.71			
Use other websites or apps to use a transport service by contacting a private individual indirectly (including social networking sites)?		0.63			
Use travel or accommodation services		0.54			
Social network participation			0.83		
Express opinions on social or political issues			0.73		
Upload content of own creation			0.64		
Send instant messages			0.62		
Participation to professional networks			0.57		
Make phone calls/video calls			0.47		
Listen to music				0.69	
Getting informed for political issues				0.67	
Watch streaming television				0.66	
Reading newspapers, information, online magazines				0.66	

Watch video content from sharing services (e.g. YouTube)				0.59	
Used a website/app that allowed to get a paid job (e.g. Freelancer, Up work, etc.)					0.95
Send completed online forms for private use to the public administration or public service operators					0.63
0btain information from websites of the public administration or public service operators					0.63
Watch video on demand					0.56
Book an appointment with a doctor					0.54
Eigenvalue	9.76	2.72	2.45	1.51	1.26
% of explained variance	20.21	12.80	12.63	10.86	10.39
Cronbach's alpha	0.74	0.56	0.59	0.68	0.49

Notes: *The scale's total variance explained was 66.97% and the total Cronbach's alpha was 0.84.*

4.4.2.2 Description of the factors

In general, the age group of the 75+ scores low in all the indexes and seems to be less digitally connected compared to the other two younger age groups, while often the other two age groups express very similar digital behaviours. This finding does not seem to be odd or unexpected, as both health status and digital capabilities are at lower levels during the later life stages. However, there are cases in which no differences are observed in all the three age groups.

More particularly, the two extreme results in terms of including activities that are actually executed are, on the one hand, the *Leisure Activities Index* (Figure 4.5) and, on the other hand, the *Transport & Accommodation Activities Index* (Figure 4.6). The first category of activities is primarily executed by all the elderly age categories and the second are less frequently seeking for digital satisfaction by the elderly Internet users. For this last one, as the index includes activities accommodation services or transport means booking, it is quite normal to find low values. With age increase, the choices of accommodation are almost stabilised and the mobility is restricted either to smaller geographical ranges or decreased. Thus, the need to search for these specific kinds of information is more rarely desired.

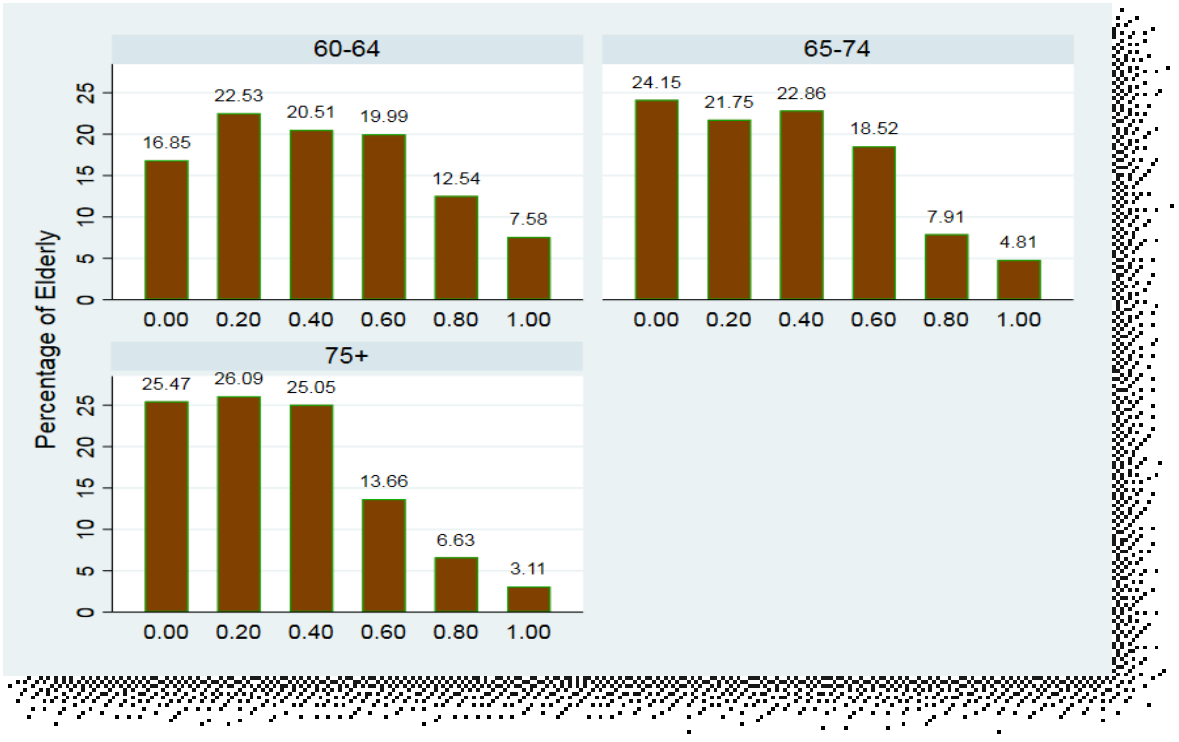

Figure 4.5 *Index of Leisure Activities*

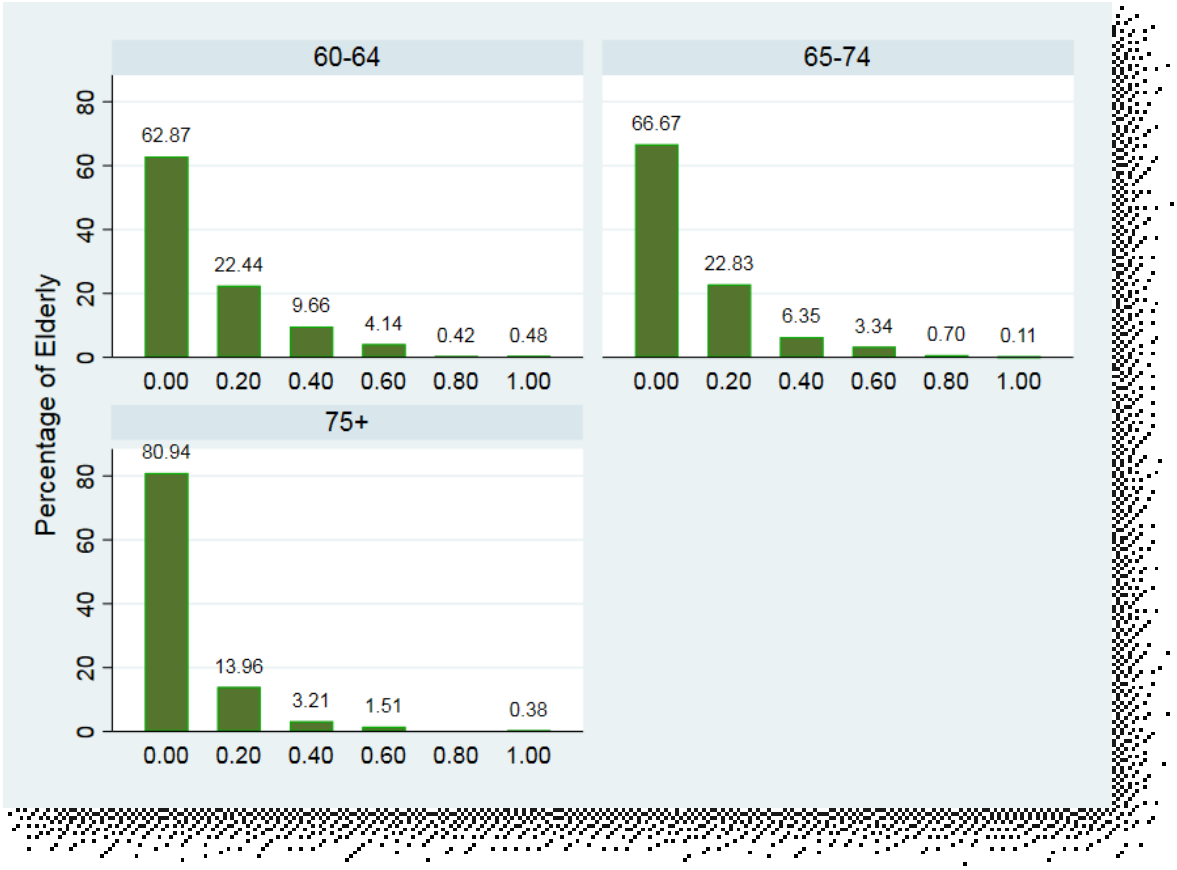

Figure 4.6 *Index of Transport & Accommodation Activities*

Between the two extremes, the data analysis showed that there are placed the *Communication* (Figure 4.7), *Economic* (Figure 4.8) and *Daily Practical Activities Indexes* (Figure 4.9), respectively. Various communication activities such as participation to social networks, e.g. Facebook, sending instant messages or making (video) calls are gathered under the factor communication activities. As the digital ways of communication have become more diffused among the younger generations, the elderly people are trying to keep up with the technological developments. Under this factor, key position occupies the use of the Internet for sending instant messages and very similar outcomes are observed for both age groups of 60-64 and 65-74 years old. Not very different results have been identified for the *Economic Activities' Index.* The levels of the online purchases, the use of banking services and the communication with banking institutions (included in the *Economic Index*) are mainly exploited by the elderly under 74 years old. Still, the older elderly people lack behind in both aforementioned indexes.

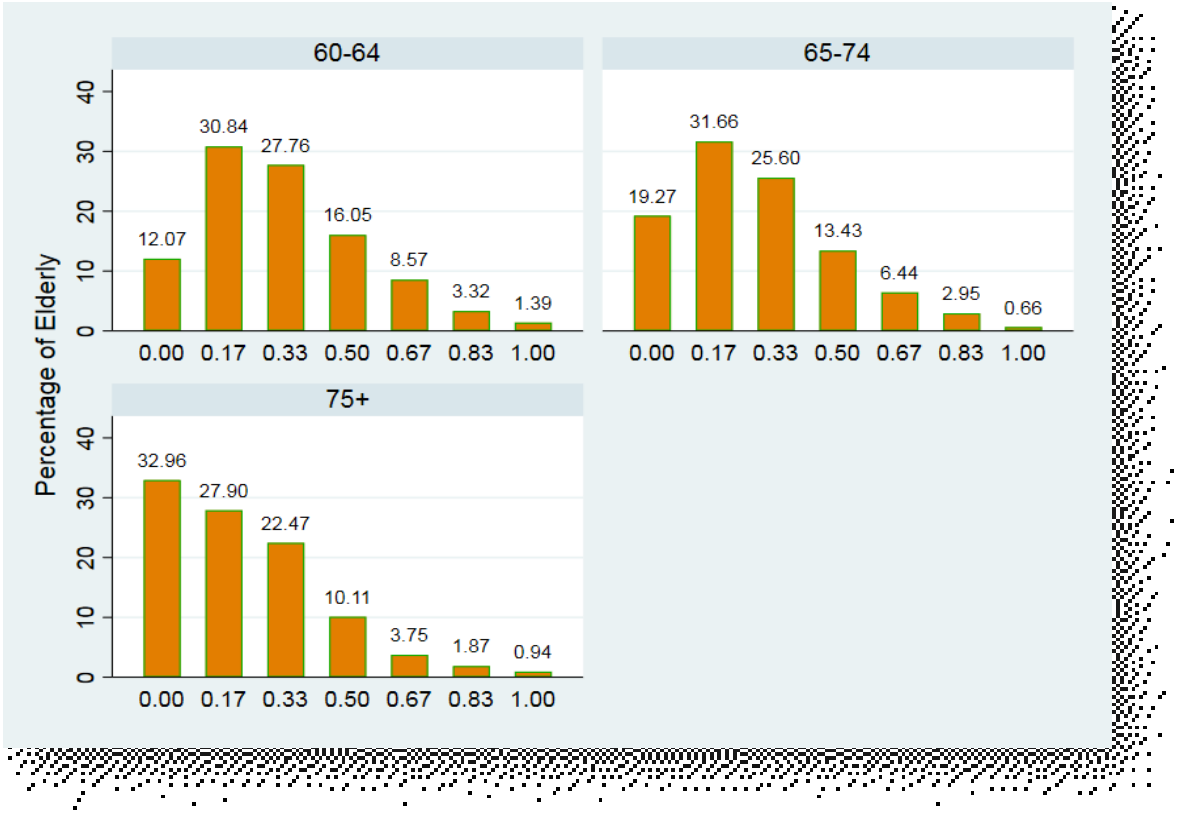

Figure 4.7 *Index of Communication Activities*

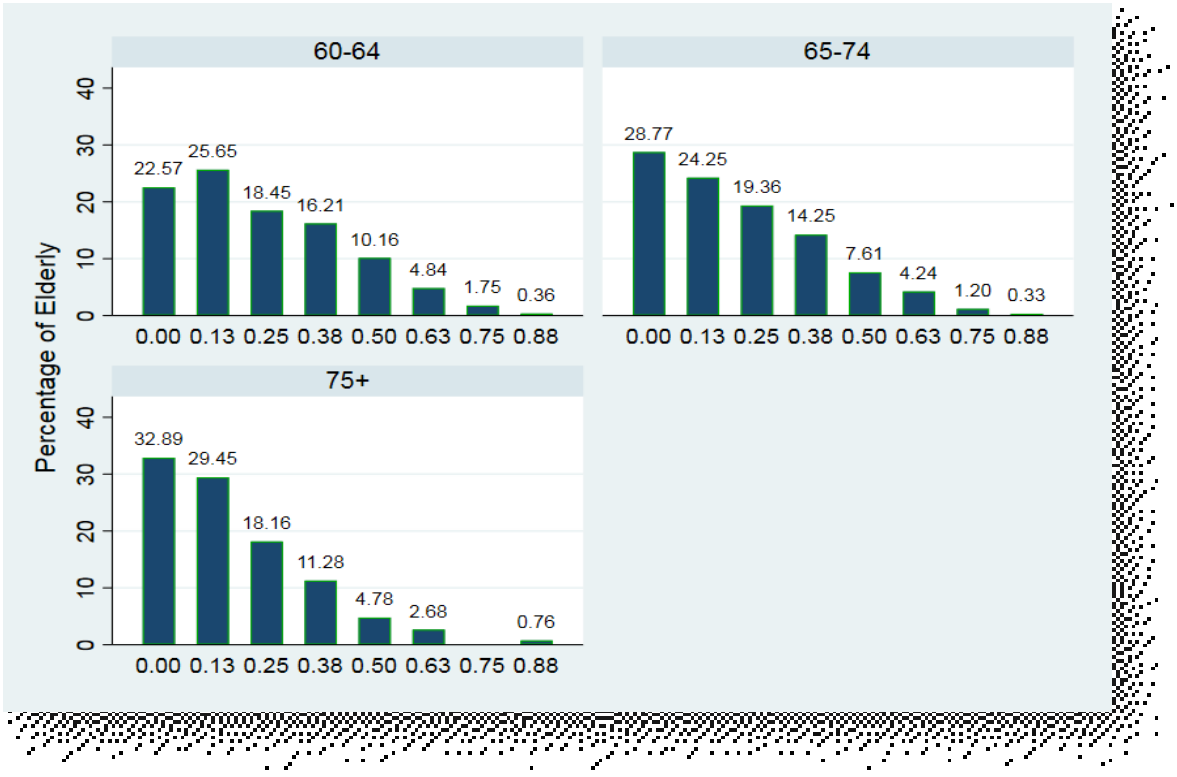

Figure 4.8 *Index of Economic Activities*

Remarkably, the activities that are grouped under the factor *Daily Practical,* e.g. communication with public offices, booking of medical visits, etc. can give us interesting takeaways. Although, the elderly over 75 years old have so far been presenting a lack of accordance with the online activities performed by the under 75's (as included in the other indexes), the *Index of Daily Practical* shows that the behaviour with regard to these specific digital activities converges. Probably, because the index includes mainly activities that satisfy primary needs of daily life that the older old people cannot avoid, thus, pushing themselves to become more involved with technology.

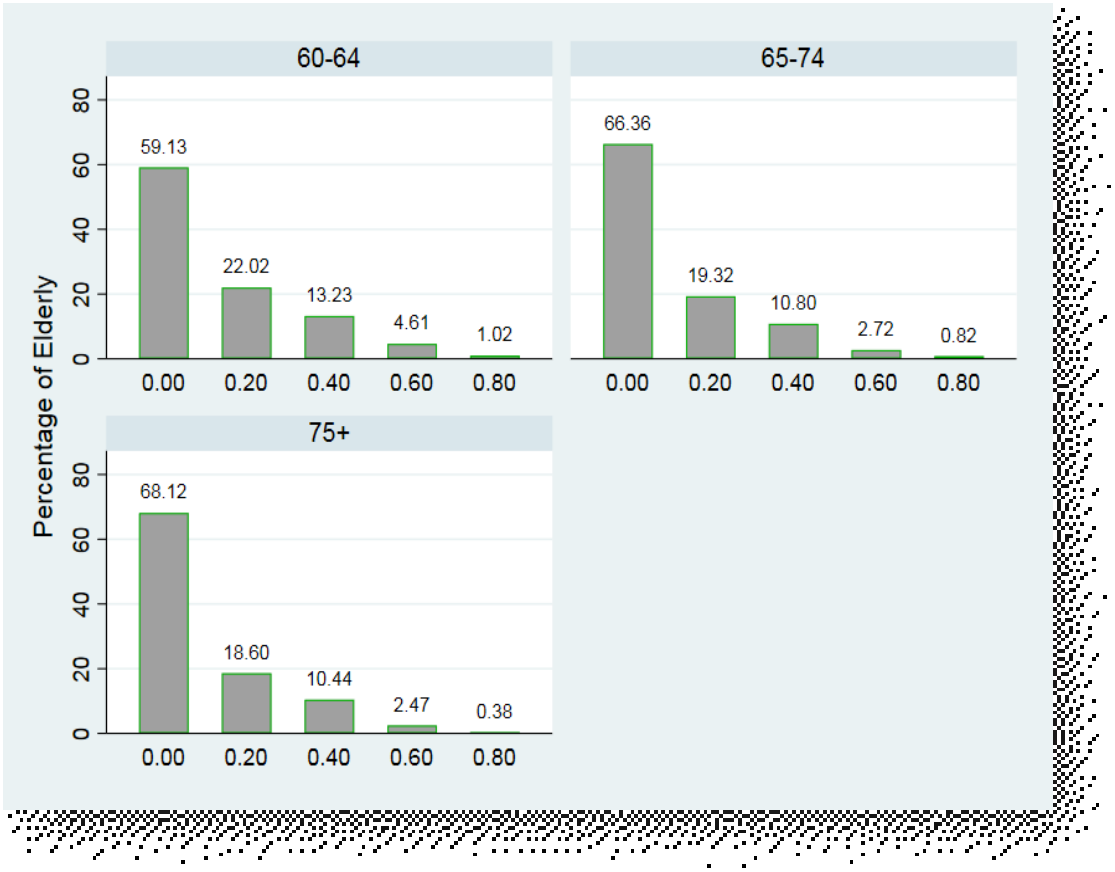

Figure 4.9 *Index of Daily Practical Activities*

4.4.3 Latent Class Analysis

4.4.3.1 Determining the number of latent classes

The LCA was used to identify groups of elderly people based on the indexes of the online activities. Initially, we tested the correlations between the indexes that were constructed by the EFA (see Section 4.4.2.1). Table 4.6 gives the pairwise correlations as calculated with Pearson's correlation coefficients.

Table 4.6 *Correlations among indexes of online activities*

Internet Index	Economic activities	Transport & accommodation activities	Communication activities	Leisure activities	Daily practicalities activities
Economic activities	1				
Transport & accommodation activities	0.47*	1			
Communication activities	0.32*	0.28*	1		
Leisure activities	0.45*	0.33*	0.37*	1	
Daily practical activities	0.48*	0.33*	0.23*	0.38*	1

Notes: **p < .1, **p < .05, ***p < .001.*

All the correlations were found to be statistically significant and ranged between 0.23 and 0.48. The *Daily Practical Activities Index* shows the highest correlation (0.48) with the *Economic Activities Index,* while the lowest (0.23) with *Communication Activities Index.*

In order to decide upon the ideal number of latent classes, we tested 6 different specifications each with its own number of classes, starting from 1 class and increasing consecutively by one the number of classes until 6. Each model was evaluated based on three goodness-of-fit measures: log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC). We chose the specification with three classes because it resulted in the lowest BIC value. The summary of model fits for each is shown in Table 4.7.

Table 4.7 *Latent Class Analysis fit statistics for indices of online activities*

Number of classes	N	Log-likelihood	df	AIC	BIC
1 Class	4,117	-11384.40	5	22778.78	22810.40
2 Classes	4,117	-10672.20	11	21366.46	21436.01
3 Classes	4,117	-10646.90	16	21325.83	21427.00
4 Classes	4,117	-10636.00	21	21314.07	21446.85
5 Classes	4,117	-10629.37	29	21316.74	21500.11
6 Classes	4,117	-10628.82	32	21321.64	21523.98

Notes: *df=degrees of freedom, AIC=Akaike Information Criterion, BIC=Bayesian Information Criterion*

4.4.3.2 Description of the latent classes

After the identification of the appropriate number of classes, the synthesis of the classes was analysed more in depth. Two types of structures were identified: (a) one plain, with the indexes of online activities exclusively (no covariates included as shown in Figure 4.10) and (b) one extended, to embrace possible covariate-related influences as shown in Figure 4.11. The sociodemographic factors that were contained in the analysis are the same already presented in Table 4.2, i.e. age, gender, civil status, level of education, main source of income, physical limitations, type of Internet connection and residence location.

Generally, controlling for sociodemographic parameters the findings of the conditional probabilities of the indexes in the latent classes, except from the *Communication Index* in class 3, did not change substantially. Practically, after the consideration of the covariates the probability of performing *Communication Activities* launched from almost zero (0.000022) (see Table 4.8) to 0.46 (see Table 4.9) for the individuals belonging to class 3. More precisely, Tables 4.8 and 4.9 show the estimations of the probabilities of Internet activities indexes (with and without control of the covariates) for each one of the three classes.

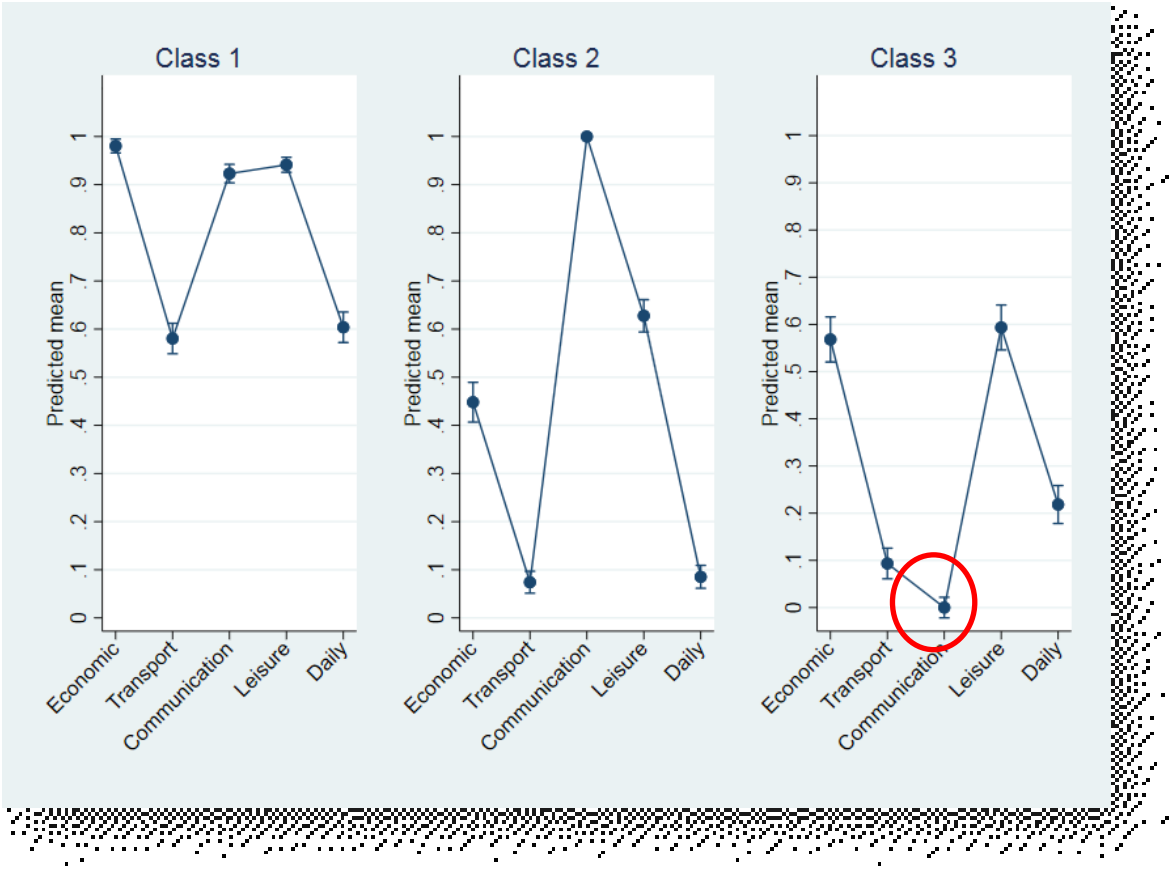

Figure 4.10 *Conditional probabilities of online activities' indexes (no covariates)*

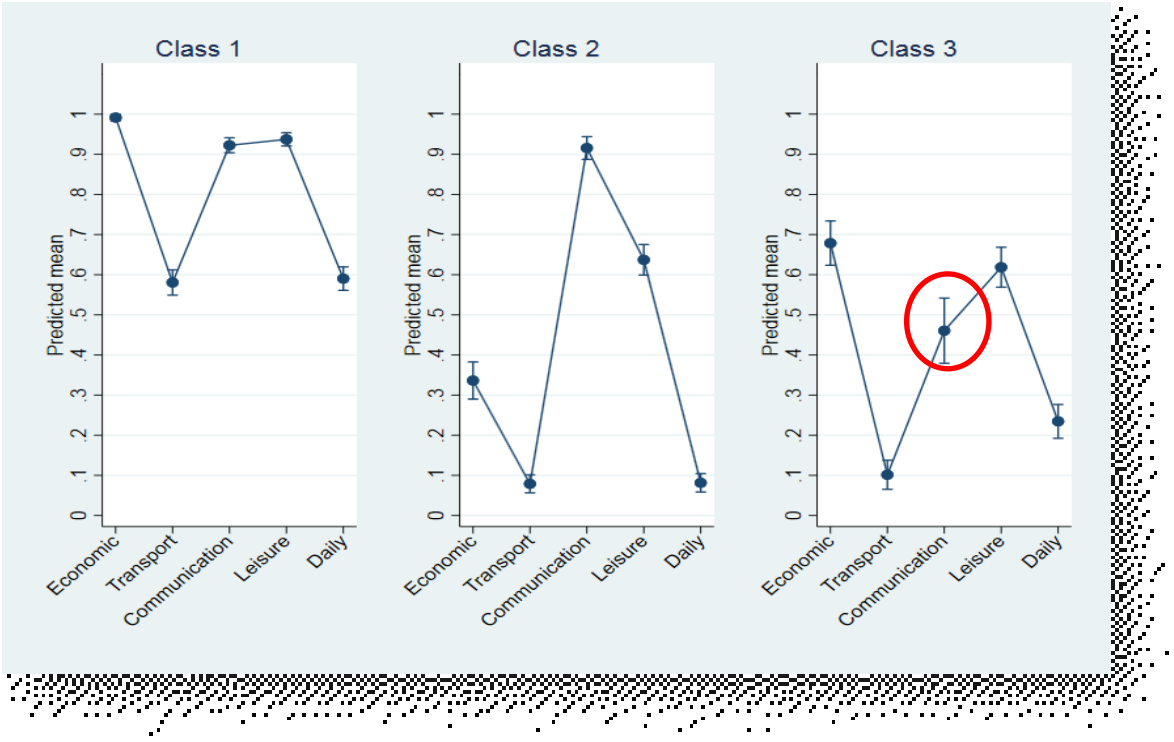

Figure 4.11 *Conditional probabilities of online activities' indexes (with covariates)*

In Table 4.9, Group 1 shows a high conditional probability on all the included indexes: *Economic* (0.99), *Leisure* (0.94), *Communication* (0.92), *Daily practical activities* (0.60) and *Transport & accommodation* (0.58). This group was given the name *Familiar users* and accounted for 49.00% of the sample's Internet users. Group 2 has a high item response conditional probability for *Communication* (0.92) and *Leisure activities* (0.64). This group was labeled *Enjoyment users* because it was performing low in all the other activities. It counted for 29.00% of the sample. With the lowest conditional probability in *Communication activities* (0.46), Group 3 was labeled as *Utilitarian users* since its members were scoring relatively high probabilities in *Economic* (0.68) and *Leisure activities* (0.62). Group 3 accounted for 23.00% of total cases.

Table 4.10 shows the distribution of sociodemographic, physical limitations and digital infrastructure characteristics separately and on the overall sample of the latent groups of online activities. Some 52.16% of people were classified as being in the *Familiar user's* class. This percentage corresponds to 2,029 individuals coming from northern regions of Italy (North-west:27.94% and North-east: 26.37%). The majority of them belongs to the younger elderly i.e. 60-64 years old (49.48%), males (60.67%), married (72.15%), have a high school (50.52%) or university degree (30.21%), are pensioners (56.23%) or (self)-employed (35.93%). As regards their physical capabilities, 68.36% do not have any physical limitations. The prevailing type of Internet connection is the fixed broadband (87.24%) while the mobile (34.30%), SIM/USB key (11.68%) and narrowband (3.45%) are less common.

On the other hand, considering the *Enjoyment users* class (28.48%), most individuals come from the middle-age group of elderly people, i.e. 65-74 years old, (50.09%) and are females (66.88%). Even if the residents of northern Italy dominate the group (West and East 40.35%), the southern Italians follow (28.70%). Compared to the other groups (*Familiar* and *Enjoyment users*), the majority of the southern population is classified in this group. The high presence of married persons (66.43%) is also met here. Interestingly, the participants have mostly attended the middle school (51.53%) and are earning their living through their pensions (60.11%). Similarly with the *Familiar users*, the elderly do not face physical health disabilities (62.09%). On the contrary, they prefer almost equally to get connected to the Internet either through fixed broadband (54.69%) or they opt for mobile phones' network (54.06%).

Finally, the lowest levels of individuals' frequency were observed in the *Utilitarian users' class* i.e. 19.36%. Most of the users belong to the age group of 65-74 years old (47.41%) and are

males (71.98%). Notably, comparing the over 75's with the same age group of the two aforementioned classes (*Familiar* and *Enjoyment users*), it results that most of them, are members of the *Utilitarian users'* group. The same observation is valid for the people with physical limitations (11.42%). As the total sample of the study is dominated by married persons and pensioners, it doesn't sound odd that married persons (75.70%) and pensioners (74.50%) are prevailing this group among the elderly in the same categories accordingly. Ultimately, the fixed broadband connection (75.83%) is the principal way of getting online and the majority of the elderly come broadly from the North of Italy (West: 29.48%, East: 26.43%).

Table 4.8. *Estimation of probabilities of online activities' indexes (3 class model) not controlling for covariates*

	Range of values	***Mean (SD)***	***Group 1***	***Group 2***	***Group 3***
Class Probability	0.00 – 1.00	.	0.50	0.36	0.14
Economic activities	0.00 – 0.88	0.22 (0.19)	0.98	0.45	0.57
Transport & accommodation activities	0.00 – 1.00	0.10 (0.17)	0.58	0.07	0.09
Communication activities	0.00 – 1.00	0.29 (0.22)	0.92	1.00	0.00[a]
Leisure activities	0.00 – 1.00	0.38 (0.29)	0.94	0.63	0.59
Daily practical activities	0.00 – 0.80	0.12 (0.18)	0.60	0.09	0.22

[a] The real value is 0.000022. As the numbers are approximated on 2 decimals, it is represented here with 0.00.

Table 4.9 *Estimation of probabilities of online activities' indexes (3 class model) after controlling for covariates*

	Range of values	***Mean (SD)***	***Group 1 Familiar users***	***Group 2 Enjoyment users***	***Group 3 Utilitarian users***
Class Probability	0.00 – 1.00	.	0.49	0.29	0.23
Economic activities	0.00 – 0.88	0.22 (0.19)	0.99	0.34	0.68
Transport & accommodation activities	0.00 – 1.00	0.10 (0.17)	0.58	0.08	0.10
Communication activities	0.00 – 1.00	0.29 (0.22)	0.92	0.92	0.46
Leisure activities	0.00 – 1.00	0.38 (0.29)	0.94	0.64	0.62
Daily practical activities	0.00 – 0.80	0.12 (0.18)	0.60	0.08	0.24

Table 4.10 *Baseline characteristics of the overall sample and people assigned to three classes (with covariates)*

Variable	Responses	*Familiar users*		*Enjoyment users*		*Utilitarian users*		Total	
		N=2,029	(52.16%)	N=1,108	(28.48%)	N=753	(19.36%)	N=3,890	(100%)
Age	60-64 years old	1,004	(49.48)	435	(39.26)	148	(19.65)	1,587	(40.80)
	65-74 years old	875	(43.12)	555	(50.09)	357	(47.41)	1,787	(45.94)
	≥75 years old	150	(7.39)	118	(10.65)	248	(32.93)	516	(13.26)
Gender	Male	1,231	(60.67)	367	(33.12)	542	(71.98)	2,140	(55.01)
	Female	798	(39.33)	741	(66.88)	211	(28.02)	1,750	(44.99)
Civil status	Not married	147	(7.24)	54	(4.87)	59	(7.840)	260	(6.68)
	Married	1,464	(72.15)	736	(66.43)	570	(75.7)	2,770	(71.21)
	Divorced	276	(13.60)	118	(10.65)	51	(6.77)	445	(11.44)
	Widowed	142	(7.00)	200	(18.05)	73	(9.69)	415	(10.67)
Level of Education	Elementary school/no qualification	41	(2.02)	268	(24.19)	74	(9.83)	383	(9.85)
	Middle school	350	(17.25)	571	(51.53)	165	(21.91)	1,086	(27.92)
	High school	1,025	(50.52)	226	(20.40)	411	(54.58)	1,662	(42.72)
	University degree	613	(30.21)	43	(3.88)	103	(13.68)	759	(19.51)
Main source of income	(Self)-employment	729	(35.93)	171	(15.43)	148	(19.65)	1,048	(26.94)
	Maintenance family	93	(4.58)	223	(20.13)	27	(3.59)	343	(8.82)
	Pension	1,141	(56.23)	666	(60.11)	561	(74.50)	2,368	(60.87)
	Allowances	38	(1.87)	36	(3.25)	9	(1.20)	83	(2.13)
	Property income	28	(1.38)	12	(1.08)	8	(1.06)	48	(1.23)
Physical Limitations	No limitations	1,387	(68.36)	688	(62.09)	474	(62.95)	2,549	(65.53)
	No serious limitations	581	(28.63)	343	(30.96)	193	(25.63)	1,117	(28.71)
	Serious limitations	61	(3.01)	77	(6.95)	86	(11.42)	224	(5.76)
Internet connection: fixed broadband	No	259	(12.76)	502	(45.31)	182	(24.17)	943	(24.24)
	Yes	1,770	(87.24)	606	(54.69)	571	(75.83)	2,947	(75.76)

Internet connection: broadband mobile phone network with cell phone or smartphone	**No**	**1,333**	**(65.70)**	**509**	**(45.94)**	**692**	**(91.90)**	**2,534**	**(65.14)**
	Yes	**696**	**(34.30)**	**599**	**(54.06)**	**61**	**(8.10)**	**1,356**	**(34.86)**
Internet connection: broadband mobile phone network via SIM card or USB key	**No**	**1,792**	**(88.32)**	**948**	**(85.56)**	**656**	**(87.12)**	**3,396**	**(87.3)**
	Yes	**237**	**(11.68)**	**160**	**(14.44)**	**97**	**(12.88)**	**494**	**(12.7)**
Internet connection: fixed or mobile narrowband connection	**No**	**1,959**	**(96.55)**	**1,078**	**(97.29)**	**724**	**(96.15)**	**3,761**	**(96.68)**
	Yes	**70**	**(3.45)**	**30**	**(2.71)**	**29**	**(3.85)**	**129**	**(3.32)**
Place of residence	**North-West**	**567**	**(27.94)**	**226**	**(20.40)**	**222**	**(29.48)**	**1,015**	**(26.09)**
	North-East	**535**	**(26.37)**	**221**	**(19.95)**	**199**	**(26.43)**	**955**	**(24.55)**
	Center	**450**	**(22.18)**	**207**	**(18.68)**	**168**	**(22.31)**	**825**	**(21.21)**
	South	**331**	**(16.31)**	**318**	**(28.70)**	**115**	**(15.27)**	**764**	**(19.64)**
	Islands	**146**	**(7.20)**	**136**	**(12.27)**	**49**	**(6.51)**	**331**	**(8.51)**

4.4.3.3 The relevance of socio-demographic factors of class membership

To identify potential determinants associated with membership among the three latent classes, various sociodemographic variables were entered into a multinomial logistic regression model. The less likely latent class (Group 3: *Utilitarian users*) was used as the reference category. Also, *p-values* are reported for the overall effect of each covariate controlling for the others and the significance level of $p<.05$ was used. A number of differences with respect to sociodemographic factors were observed between the group of *Utilitarian users*, on the one side, and the groups of *Familiar* and *Enjoyment users*, on the other. The results are presented in Table 4.11.

From the first pairwise comparison of the reference group with the *Familiar users*, resulted that the age (all subgroups of elderly), the education levels (only for those of high school and university degrees), the civil status (only being divorced), having only serious limitations and all types of Internet connections were significantly different. Conversely, the variables gender, level of education (only middle school), civil status (being married or widowed), not having serious physical limitations, income (all sources) and the place of residence were among the non-significant predictors.

Similarly, comparing *Utilitarian* with *Enjoyment users*, there appeared significant differences in terms of age, gender, education levels (only for those of high school and university degrees), civil status (for divorced), having income resources from family and allowances, being connected on the Internet through mobile and living in the South or Islands of Italy were significantly different. However, as shown in Table 4.11, there were not observed significant differences, between *Utilitarian* and *Enjoyment users*, when the elderly had middle school education, were married or widowed, had limitations (all categories), were maintained through pension and property resources, had any type of Internet connection (excluding mobile one) and were living in the North-East and Center of Italy.

Table 4.11 *Multinomial logistic regression models between sociodemographic variables on latent class membership comparisons*

Determinant Factors	***Group 1 Familiar users***						***Group 2 Enjoyment users***				
Reference group: *Group 3 Utilitarian users*	**Coef.**	**S.E.**	**P**	**95% CI Lower - Upper**			**Coef.**	**S.E.**	**P**	**95% CI Lower - Upper**	
Gender	**-0.09**	**0.17**	**0.60**	**-0.42**	**0.25**		**-1.53**	**0.24**	**0.00**	**-1.99**	**-1.07**
Age (60-64—ref.)											
65-74	**-0.95**	**0.19**	**0.00**	**-1.32**	**-0.57**		**-0.62**	**0.26**	**0.02**	**-1.13**	**-0.12**
75+	**-2.26**	**0.26**	**0.00**	**-2.77**	**-1.75**		**-1.52**	**0.36**	**0.00**	**-2.22**	**-0.82**
Education (primary—ref.)											
Middle school	**0.69**	**0.37**	**0.06**	**-0.03**	**1.41**		**-0.30**	**0.33**	**0.36**	**-0.95**	**0.34**
High school	**0.97**	**0.36**	**0.01**	**0.26**	**1.67**		**-2.22**	**0.37**	**0.00**	**-2.96**	**-1.49**
University degree	**1.99**	**0.39**	**0.00**	**1.21**	**2.76**		**-2.47**	**0.45**	**0.00**	**-3.36**	**-1.58**
Civil Status (not married—ref.)											
Married	**0.08**	**0.28**	**0.78**	**-0.48**	**0.63**		**0.52**	**0.43**	**0.24**	**-0.34**	**1.37**
Divorced	**0.81**	**0.36**	**0.02**	**0.11**	**1.52**		**1.11**	**0.52**	**0.03**	**0.08**	**2.13**
Widowed	**0.24**	**0.37**	**0.52**	**-0.49**	**0.97**		**0.93**	**0.53**	**0.08**	**-0.10**	**1.97**
Limitations (no limitations—ref.)											
No serious	**0.20**	**0.16**	**0.22**	**-0.12**	**0.53**		**0.15**	**0.23**	**0.52**	**-0.30**	**0.60**
Serious	**-1.24**	**0.31**	**0.00**	**-1.85**	**-0.63**		**-0.76**	**0.40**	**0.06**	**-1.54**	**0.02**
Income ((Self)-employment —ref.)											
Family	**-0.05**	**0.41**	**0.91**	**-0.86**	**0.76**		**1.62**	**0.51**	**0.00**	**0.62**	**2.61**
Pension	**0.02**	**0.21**	**0.94**	**-0.39**	**0.43**		**0.61**	**0.32**	**0.06**	**-0.01**	**1.23**
Allowances	**0.73**	**0.68**	**0.28**	**-0.60**	**2.05**		**1.82**	**0.82**	**0.03**	**0.23**	**3.42**
Property	**0.10**	**0.66**	**0.88**	**-1.20**	**1.39**		**0.07**	**1.02**	**0.95**	**-1.93**	**2.06**
Internet connection											
Fixed broadband	**1.66**	**0.28**	**0.00**	**1.11**	**2.20**		**-0.21**	**0.34**	**0.54**	**-0.87**	**0.46**
Broadband mobile phone network with cell phone or smartphone	**1.77**	**0.29**	**0.00**	**1.21**	**2.34**		**2.18**	**0.32**	**0.00**	**1.55**	**2.81**
Broadband mobile phone network via SIM card or USB key	**0.83**	**0.30**	**0.01**	**0.25**	**1.41**		**0.28**	**0.37**	**0.45**	**-0.44**	**1.01**

Fixed or mobile narrowband connection	**1.34**	**0.47**	**0.00**	**0.42**	**2.25**		**0.08**	**0.64**	**0.90**	**-1.17**	**1.33**
Place of residence (North-West —ref.)											
North-East	**0.08**	**0.19**	**0.68**	**-0.30**	**0.46**		**0.12**	**0.29**	**0.67**	**-0.45**	**0.69**
Centre	**-0.15**	**0.21**	**0.46**	**-0.56**	**0.25**		**0.57**	**0.32**	**0.07**	**-0.05**	**1.19**
South	**-0.29**	**0.24**	**0.23**	**-0.75**	**0.18**		**1.62**	**0.34**	**0.00**	**0.96**	**2.28**
Islands	**-0.02**	**0.32**	**0.95**	**-0.64**	**0.60**		**1.39**	**0.42**	**0.00**	**0.56**	**2.22**

Notes: N=3,890; Log likelihood = -9429.30; SE = standard error; CI = confidential interval

4.5 Discussion

This study sought to describe profiles of elderly Internet users using LCA methodology in a representative sample of Italian elderly adults over 60 years old. Descriptive statistics analysis explored the use, the frequency and the devices of Internet accessibility. Through an EFA we examined 41 online activities and ended up with 30 of them, which formulated five indexes of online patterns. Then, an LCA procedure was performed and were recognized three latent classes of elderly people. Having as a reference base, what online activities were performed by the individuals, the classes were given the names *Familiar, Enjoyment* and *Utilitarian users.* The latent classes generated by the LCA were significantly related to several sociodemographic factors and types of digital connection, showing simultaneously similarities and variability in a few aspects.

As regards an overall assessment of the links of the aged people with the Internet usability, our findings reproduce what has already been supported by scholars in other geographical contexts (EUROSTAT, 2020; Macdonald and Hülür, 2020; Facchini and Sala, 2019; Friemel et al., 2016; Luger et al., 2016; Gell et al., 2013; Morris et al., 2007). That said, as people age they tend to keep distance from using technology. Nevertheless, up to now, the scholars have not reached a consensus on whether older women or men are more frequently online. Our analysis found that it is most likely for the elderly men to use the Internet rather than elderly women. This is in good agreement not only with evidence from the Italian studies (Carlo and Vergani, 2016; Colombo et al., 2014; Sartori 2011) but also additional literature (König et al., 2018; Gell et al., 2013; Selwyn et al., 2003). However, on the contrary, Yu et al. (2015) argue that women use more the Internet and explain the contrast either as driven by the dominance of younger participants in their dataset or because the tendency of Internet dominance by men have been smoothened in favour of women since the 2000's.

Interestingly, as regards the digital devices, we found that men between 60 and 74 years old connect on the Internet through tablet devices and over 75 years old through desktops. Younger-old women prefer, mainly, cellphones, the middle-aged other devices and the older-old again mobile phones. In comparison with Italian studies (Carlo and Vergani, 2016; Colombo et al., 2014), among the Internet users women preferred laptops and men preferred desktops. However, Comunello et al. (2016) interviewed 51 interview Italian elderly between 60 and 95 years old (in Rome and areas of Lazio and Umbria) about the age and gender-based sterotypes of technology. Interestingly, the authors reported that men of this sample

perceived women as less capable with technology compared to them and especially with regards to the mobile phones. In our study, instead, we found that women use more the cellphones with respect to men for Internet activities. Furthermore, our results cannot be compared directly with other existing studies, as we didn't find literature about gender-based information for the digital tools used among the elderly population. More generally speaking, Nimrod (2018)[37] reported principally Internet use from the elderly people (regardless of gender) through desktop computer (86.77%), followed by smartphone (82.87%), laptop computer (62.01%), and tablet (53.82%). On the other hand, Vroman et al. (2015)[38] provided a slightly different preference ordering, appearing as phone (87.00%), computer (78.00%), tablet (20.00%) and smartphone (22.00%). Further heterogeneity is derived by Luger et al. (2016)[39], where 37.80% of the elderly preferred the desktop computer in the past month, 20.20% the laptop computer, and 9.90% the tablets. Nevertheless, it could be argued that ethnic and sample peculiarities are definitely present in the studies, and, as a consequence, our conclusions could not be interpreted as contradictive or odd with this respect.

Concerning our EFA of 41 online activities reported in the ISTAT "Multipurpose Survey 2018", it ended up with 30 activities that formed five separated sets of online activities (*Economic activities, Transport & accommodation activities, Communication activities, Leisure activities, Daily practical activities*). Until now, some researchers (Nimrod, 2018; Boeckel et al., 2017;Van Deursen and Helpser, 2015; Vroman et al., 2015; Choi and DiNitto, 2013; Gell et al., 2013; Sum et al., 2009; Russell et al., 2008; Selwyn et al., 2003) have addressed a large scale of online activities that the older people conduct through the Internet connectivity. Out of these studies only two (Nimrod, 2018; Van Deursen and Helpser, 2015) have used a factor analysis methodology similar to ours. Remarkably, Nimrod (2018) distinguished 12 of the activities that we have already considered and concluded with four online activity factors named as *Native activities*, *Old media*, *Interpersonal communication* and *Entertainment*. The basic difference with our analysis lies on the factors *Native activities* and *Old media*. As we have surveyed a more extended list of activities, the factor analysis provided a diverse grouping pattern, thus, indicating another appropriate factor labelling for our case than those proposed by Nimrod (2018). A slightly broader number of activities were explored by Van Deursen and Helpser (2015), summing up to totally 23. Unfortunately, a direct comparison is not feasible

[37] The results derived from data analysis of 537 Israeli Internet users aged 60 years and over.
[38] The study was based on 198 individuals over 64 years old in the USA.
[39] The conclusions refer to a sample of 266 US Veterans aged 65 years and older.

with our methodology, as there are provided only partial technical information in the paper. From what is described in the study, eight factors emerged under the terminology: (1) e-mail, (2) information, (3) news, (4) shopping, (5) social entertainment, (6) music/video, (7) civic services and (8) health services. From a superficial judgement, this classification couldn't match with ours, because our own research developed a structure which mixed together some items provided by the analysis of Van Deursen and Helpser (2015).

Referring to the LCA procedure, it generated three classes of elderly people according to the online activities that they select to do online. Based on the mixture of the conditional probabilities of the online indexes they were tagged as *Familiar users, Enjoyment users* and *Utilitarian users.* Previous studies conducting LCA analysis in order to describe latent profiles of elderly people based on online activity habits are almost nonexistent. To the best of our knowledge, firstly, Van Boeckel et al. (2017) classified a representative sample of 1,418 people aged ≥65 years and living in the Netherlands into four latent groups, based on 17 online activities. Their analysis produced the following names for the classes: *Practical users, Maximizers, Minimizers* and *Social users*. Although our analysis included almost the double number of online activities, an approximate correspondence with our given names is the practical Internet users with our *Utilitarian group* and the maximizers with the *Familiar users*. More recently, Park and Kim (2020) analysed data from a nationally representative sample of 1,919 South Korean individuals aged ≥65 years suffering from diabetes. Using 10 Internet activities, three classes emerged: *Non-users, Communicating users* and *Smart users.* Despite having three classes as our study, perfect terminology links cannot be found as, in substance, they have started from a different online activity listing. Only the class of *Smart users* might be considered similar to the *Utilitarian users* of our analysis.

We spotted two other studies (Chiu, 2019; Colombo and Carlo, 2015), which although haven't use an LCA methodology, have instead identified profiles of elderly Internet users. Chiu (2019) recognized subgroups of elderly people through a factor analysis approach. Using 10 habitual online activities and applying this technique, managed to distribute the elderly people into four groups: *Eager, Instrumental, Leisure and Sporadic users*. Given that the starting point for the analysis, as regards the activity classification, and the technique is different from ours, a perfect correspondence is not possible. More or less, the *Eager users* are similar to our *Familiar users*, the *Instrumental users* with our own *Utilitarian* and the *Leisure* with our *Enjoyment users*. In addition, Colombo and Carlo (2015) presents three groups of

elderly of 65–74 years old, with respect to their relationship with Internet use: (a) the elderly who lived in homes with computers owned by their children, not were users in younger ages and starting to be in later age, (b) the elderly who did not have computers at home and bought them only recently, and, (c) those who were active users when they were younger and continued to be in later life, as well.

Finally, with respect to the various sociodemographic characteristics of the elderly people in sketching their preferences for online activities, we have detected important variability between the Italian elderly Internet users. Notably, as pointed out in the review of Hunsaker and Hargittai (2018), the results in the existing literature have been inconclusive for many of these aspects apart from some exceptions. Particularly, as a regards the *age* it has already been mentioned in the beginning of this section that as people age they tend to use less the Internet. This observation is well-established in the literature and it has been confirmed (as expected) by our data analysis. Some researchers (Schehl et al., 2019; Yu et al., 2015) have associated the younger elderly with more presence on the social networks or banking and shopping activities. In fact, this observation is verified in our study as the *Communication and Economic Index* is higher for the elderly under 75 years old.

As previously stressed, it does not exist unanimous consensus among the scholars whether males or females are more frequent Internet users. Having said that, we found that *gender* is significant between *Enjoyment-Utilitarian users* and not between *Familiar-Utilitarian users*. Our finding is in alignment with existing literature (Yu et al., 2015). Additionally, previous findings (Chiu, 2019) confirm our result i.e. women are more actively involved with enjoyment activities rather than men, as the majority of the *Enjoyment users* group are women. Furthermore, Schehl et al. (2019) collecting data from German elderly found that gender did not allow the prediction of involvement with social activities. On the contrary, Vošner et al. (2016) support that females in Slovenia are more frequent users of social networks compared to males.

As it has been hypothesized by other researchers (Leukel et al., 2020; Macdonald and Hülür, 2020; Chiu, 2019; Kämpfen and Maurer, 2018; König et al., 2018; Luger et al., 2016; Yu et al., 2015; Gell et al., 2013; Sum et al., 2009; Selwyn et al., 2003) the higher the *education level* of the elderly the most likely the Internet use is. Our study is in perfect agreement with this literature. Kämpfen and Maurer (2018) analysed data for the Internet use of 2,160 Italians (aged 50 or more years old) from the SHARE survey and concluded that one more year of

education in earlier life stages, increased by 8.00% the probability of using a computer in later age. Also, consistent with Chiu (2019), that have used data from 248 Taiwanese older people (more than 50 years old) living in urban and rural zones, we found that the more educated elderly (i.e. high school or university degree) belong to the *Familiar users'* class, i.e. *Eager users* in Chiu (2019). On the contrary to Chiu (2019), where the more highly educated selected leisure activities and the less educated were not frequent Internet users at all, the elderly Italian with education level of middle or primary school opted for online enjoyment activities.

When talking about the *civil status*, it has been found in the literature that the unmarried elderly are less likely to be online (Luger et al., 2016) or search specifically for health information (Yoon et al., 2020). The other way round, the married (or living with a partner) elderly individuals are most likely to use the Internet more generally (Macdonald and Hülür, 2020), and particularly, for e-mail/texting messages (Gell et al., 2013). Similarly, Leukel et al. (2020) correlated the elderly who live with two or more persons in a household as being inclined to using the Internet and the similar results were found in Carlo and Vergani (2016) from a representative sample of Italian elderly (65-74 years old). More, Sum et al. (2009) noted that the elderly people who live with other people or the new Internet users used the Internet more often for entertainment purposes. Our results do not seem to conform to what has been found by the previous literature. Although, the descriptive analysis of the classes (see Table 4.10) demonstrates that married elderly people belong to the class with the more *Familiar Internet users*, the multinomial logistic regression analysis (see Table 4.11) did not returned statistically significant findings except for the divorced elderly. In another work, Yu et al. (2015) supports that widowed and elderly housewives prefer to use the Internet for socialization.

Regarding the assessment of *health status*, it has been included in many studies as a control variable. However, it has been conceptualised through various measures, e.g. self-perceived health (Leukel et al., 2020; Yoon et al., 2020; König et al., 2018; Gell et al., 2013), multimorbidity (Gell et al., 2013) or limitations of instrumental activities of daily living, cognition and depression (Macdonald and Hülür, 2020). As such, Gell et al. (2013) found strong relations between increased health status levels and frequent Internet use or sending emails/texting messages. Notably, they argue that technology use did not vary by the presence of other disabilities such as hearing impairments while, instead, the technology use emerged to be higher for those with breathing difficulties. Other studies (Yu et al., 2015)

demonstrated that the better health evaluation the most probable becomes to use the Internet for social purposes. More, Yoon et al. (2020) suggests that for the individuals with poor self-assessed health levels it is rarer to search specifically for health information. Our study confirms partially what has already been found by the scholars. When contrasting *Familiar-Utilitarian users*, the existence of physical health limitations emerges significant and in line with the literature. However, when searching the *Utilitarian* with *Enjoyment users* the effects are not statistically significant.

The *income* as a determinant factor has been included in many studies (Macdonald and Hülür, 2020; Carlo and Vergani, 2016; Luger et al., 2016; Sum et al., 2009). It has been concurred that for higher economic resources it is more common to use the Internet. Moreover, Carlo and Vergani (2016) noticed that the Italian elderly who started recently using the Internet at were those with lower economic resources. Unfortunately, since we did not have information about the exact amount of income but only the source of income, our results are not directly comparable with existing evidence. Intuitively speaking, finding that *Utilitarian-Enjoyment users* differ substantially when maintained by their family or receive state allowances, we can say that the income is indeed an important factor in determining the Internet behaviour of the Italian elderly.

As for the *place of residence*, it has been incorporated in a few studies (Sum et al., 2019) as a control variable. However, it could be said that scholars have revealed lower frequency of Internet use for the people who live in rural areas, while, notably, the older people from urban areas are more likely to use the Internet to communicate with unknown people (Sum et al., 2019). Unfortunately, since to the best of our knowledge, no other Italian studies exist we could not compare our results. What is widely known is that in general the Southern regions of Italy are lacking behind in Internet accessibility when compared to the North.

4.6 Strengths, limitations and further research

To the best of our knowledge, this is the first study to analyse in depth the digital performance of the elderly Italians and associate it with sociodemographic parameters. Its main strength is considered the wide range of the online activities analysed. This allowed us to map relatively precisely the digital behavior of the Italian elderly people over 60 years old. Basically, we managed to capture the main types of activities performed online by the individuals as reported in international surveys on information communication technology (ICT) (see for

example OECD, 2015; Eurostat, 2016; Statistics Denmark, 2017; Statistical Service of Cyprus, 2018). Nevertheless, we noted that the registration of the online activities demonstrates high heterogeneity among the scientific literature and the statistical authorities. Hence, we point out the need for future research towards a more unified classification system. As a result, more reliable cross-cultural comparisons could be achieved and more systematic recording of the digital preferences of the ageing populations.

A limitation of the study that needs to be mentioned is that, despite the plurality of the included online activities, the frequency of performance of each activity is not documented. This information, although important, was missing from the dataset used, and thus, suggested for further research studies. Also, all the variables about the several online activities were self-reported by the elderly, which means that a sort of underestimation or overestimation of the real online activity might be present. More, additional variables, such as the traditional literacy or previous experience with computers, were not collected by the survey on which we based our analysis. Importantly, as pointed out by Van Deursen and Helpser (2015) it is fundamental to consider the reading and writing abilities of the elderly population as it will increase our understanding about the real factors of low levels of Internet use in later life. Notably, König et al. (2018) confirmed that previous experience with personal computers during the working life might shape significantly the relationship with Internet in later age, while Friemel et al. (2016) has underlined, more broadly, the pre-retirement Internet use. Additionally, apart from a few longitudinal studies (see for example Matthews et al., 2018), the researchers have principally used cross-sectional data in their research, as it was in our case. However, the analysis of longitudinal data would be more enlightening in understanding whether from time to time the elderly present any changes in the latent classes of digital patterns they belong.

With the exception of some well-documented facts about the realities of the Internet and ageing association, still, the involvement of the elderly with Internet activities remains a research field that has not been studied in depth. As some controversies exist in the literature with respect to determinant sociodemographic characteristics e.g. devices of Internet use, gender differences etc. and full description of the online activities, future research studies need to shed further light on ambiguous aspects of the elderly's digital behaviour. Finally, when comparing our study findings with existing literature, it is evident that the cultural context need not to be ignored when framing the determinants of Internet use. Thus, we

suggest that our methodology is used in a different geographical context and compared with these cross-study findings.

4.7 Conclusions and policy implications

Nowadays, the constantly increasing tendency in Internet usage for daily tasks by the general population, inevitably carries away the elderly people. The recent pandemic of COVID-19 evidenced that the elderly people who are not familiar with the Information, Communication Technology use (ICT) run high risk of being not only socially but also digitally excluded (Seifert et al., 2020). While the elderly support that in any case the Internet is not possible to replace the intimate contacts, nevertheless, they admit that it facilitates to annihilate the physical distance and enlarge the social range (Russel et al., 2008). Actually, relevant research (Silva et al., 2020; Cotten et al., 2013) has validated the function of the Internet in tackling sufficiently the feelings of isolation by the aged adults or be a relief from loneliness for those who live alone. Furthermore, other researchers (Kamin and Lang, 2020) using longitudinal data from a representative sample[40] of older people over 50 years old from 14 countries, have pointed out that Internet use in later life is a substantial tool against cognitive decline. Thus, gerontechnology might be proved of great benefit in daily life manifestations for the elderly people (Hsu, 2016).

We would like to stress that our study entails an innovative approach to the topic, as regards the Italian evidence. Apart from the use from other colleagues of the ISTAT "Multipurpose Survey" of previous years (mainly with descriptive statistics analysis), the scope of the analysis, the methodology, the data analysis and the results are for the first time applied on Italian data. Therefore, an accurate comparison with other Italian studies was not possible to be performed. On the other hand, there have been reported a few studies about European countries that could offer us a point of reference as illustrated in the Literature Review (Section 4.2) and Discussion (Section 4.5) Sections.

There are important policy implications which can be taken from our study. First and foremost, it is essential to identify the reasons why the elderly people do not use Internet and, as such, provide targeted interventions. For instance, some identified groups in Gallistl et al. (2020) are: "younger non-users", "male non-users", "urban non-users" and "non- users with

[40] The data come from survey SHARE (http://www.share-project.org/home0.html.) and the 14 countries are Austria, Germany, Sweden, Spain, Italy, France, Denmark, Switzerland, Belgium, Israel, Czech Republic, Luxembourg, Slovenia, and Estonia (Kamin et al., 2020).

health limitations". Evidently, each group has its own reasons and needs tailor-made policy directions. In this sense our paper is highly informative. We have identified three groups: *Utilitarian, Familiar* and *Enjoyment users.* Therefore, from a policy perspective the interventions need to be focused to the specific needs of the elderly people included in each group and according to their particular sociodemographic characteristics. More precisely, it is underlined that it is needed to take precious care for the Internet involvement of the disadvantaged groups of the older population such as women, widowed, low-income, low-educated, living alone and those with existing comorbidities.

However, other researchers have underlined that the basic sociodemographic characteristics have been proved not fairly enough to map the entire links of ageing with Internet activities. More on that, Peral-Peral et al. (2015) argue that the psychological dimensions, i.e. feeling younger, confident and familiar with technology, could more comprehensively than sociodemographic factors illuminate the deep incentives behind Internet socialization. Hence, some scholars involve additionally various health-related issues when unfolding the outline of old social Internet users, for instance cognition levels (van der Wardt et al., 2012), functional capabilities (Medeiros et al., 2012), or/and basic common age-related chronic diseases and the psychological state (Choi et al., 2013). Thus, further research could be done in the future.

Equally important, it is to specify what the elderly people prefer when they are using the Internet. Among the few studies on the topic, Schehl et al. (2019) have studied informational, instrumental and social activities but our paper is rather more complete, with respect to this aspect, as we have evaluated 41 activities grouped in five factors: *Economic, Transport and accommodation*, *Communication, Leisure and*, *Daily practical activities.* As Gallistl et al. (2020) stressed, after analysing the policy documents for digital inclusion of the elderly in Austria, learning and training programs, although these are very common interventions, nevertheless, are not enough for the digital inclusion in later life. Rather than targeting individual-related parameters, digital infrastructural issues need to be incorporated in the policy agendas, e.g. Internet availability in rural areas. Italy, in this aspect, lags behind when compared to the other European countries and still much progress needs to be done. The COVID-19 pandemic accelerated the development of the digital infrastructures but remains to see in the future if the actions will be long lasting. Considering this last point and concluding this research, we point out that the digital policies for the elderly need to have a long-term prospective

(Petretto and Pili, 2020) and, also, to follow specific principles for ICT interventions (see Castrorojas et al., 2018).

Abbreviations

AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
EFA	Exploratory Factor Analysis
ICT	Information, Communication Technology
ISTAT	Italian National Institute of Statistics
LCA	Latent class analysis
SHARE	Survey of Health, Ageing and Retirement in Europe

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CHAPTER 5

CONCLUSIONS

5.1 Discussion and contributions

As the world is showing tendencies to ageing populations, the policymakers will have to face a range of social, economic and health issues. Hence, targeted research is necessary to guide all the challenges happening. Introduced in 2002 by the WHO (revised in 2015) and widely accepted by many countries all over the world so far, the approach of active and health ageing prioritizes the disposability of life opportunities and the sufficient level of physical functionality as people age. Building on this concept, the thesis investigates mobility, public transport and technology as meaningful sectors to tackle prosperity in later life.

The elderly mobility plays a critical role in the formulation of the human well-being and QoL. According to WHO (2002), mobility is part of the independence and independence is part of the QoL. The addictions of various kinds (or dependence on others), the loss of autonomy, the presence of negative feelings and lack of meaning in life is what actually worsens the QoL of the elderly people (Hudakova and Hornakova, 2011). Hence, mobility[41] is crucial in active ageing in order to continue experiencing an independent life and this is why it is largely studied among other disabilities in later age (Ullrich et al., 2019; Parker and Thorslund, 2007; WHO, 2007). Poor mobility is a substantial burden not only for the elderly, but also for their families and the community and, thus, improving elderly mobility can be beneficial both for the individuals and the society (Levin et al., 2012; Whelan et al., 2006).

The second Chapter of the thesis is mainly contributing to the literature with respect to the following aspects:

- it shows some existing theoretical models of mobility and presents a critical synthesis of them;
- it highlights the strong diversity between health, general, economic and social sciences and sometimes also within the same discipline in (a) measuring mobility, (b) defining mobility, (c) showing mobility effects and (d) selecting specific case study countries;

[41]Both in- and out-of-home (Ullrich et al., 2019).

- it is the first systematic and multidisciplinary literature approach to the topic of elderly mobility effects;
- it underlines the priority given within disciplines in studying mobility effects with respect to health, independence and social inclusion (3 dimensions of the AAI).

Public health researchers are promoting exercise as part of the everyday life as it is more easily welcomed, compared to prescribed specific physical exercise (Bailey, 2004). Walking can provide a low-impact physical activity for the elderly people and at the same time it is a way of reaching desired people places (Montarzino et al., 2007; Bailey, 2004). Additionally, the transport system appears to be closely linked with a person's overall well-being, especially for the elderly people (Mizokami et al., 2014). As the public transport facilitates the accessibility to closed people and vital services and, more, reaching the transport infrastructures entails some physical exercise (walking), it could definitely make part of successful ageing strategies.

The third Chapter of the thesis is raising issues around the public transport use as a special instrument for the elderly mobility, after driving cessation or when the physical capabilities have declined. Its innovativeness is based on:

- embracing the public transport in later life and demonstrating the state of the art literature for what concerns well-being/QoL, independence and social inclusion;
- focusing particularly on showing associations of three indicators of health status (physical, mental and self-perceived health) with public transport use for the Italian elderly people, a not well-studied topic in the scientific literature and neglected at the country level;
- showing that the frequent public transport use by the Italian adults over 60 years old is more probable to related to psycho-physical benefits compared to the car use, confirming in that way that LPT needs to be considered not only as an instrument for mobility but as an active way of traveling for health support and environmental sustainability;
- proposing a classification of the conventional public transport policies for the elderly in structural and non-structural;
- finding examples of public transport policies for the elderly people.

Nowadays, the technology has become an integral part of the everyday life. The COVID-19 pandemic has just accelerated a tendency that was evident in the society correlations already two decades ago. Traditional operations that serve the daily needs are transferred online, bringing facilitations and challenges at the same time. How to cope with the ageing of the populations worldwide is one demanding and complex question to answer. Especially currently, the digital evolution cannot be seen separately from what the older people carry out to content needs and desires for happier lifes. In order to prevent undesirable outcomes of digital and social isolation (Seifert et al., 2020), or additional not identified yet, we need to comprehend completely what implies the digital presence for the elderly.

The forth Chapter of the thesis is bridging the gap of our understanding with respect to the online behaviour of the Italian adults of 60 or more years old. Yet, as the scholars have not illustrated precise details on the topic, we cover the following aspects:

- review empirically various aspects of the Internet connectivity, i.e. use or not of the Internet, frequency of use and preferred devices;
- analyse 41 Internet activities through an Exploratory Factor Analysis and create indexes of online performances for the older Italian people;
- recognize that there is heterogeneous online performance of the elderly Italian people with respect to key sociodemographic indicators;
- identify latent groups of old Internet users according to sociodemographic variables.

5.2 Limitations and future research

Complementary to the contributions mentioned in Section 5.1, there are some research limitations that need to be recognized and, at the same time, they can provide inspiration for further research.

As regards Chapter 2, it is confirmed that elderly mobility is a multidisciplinary research topic and should be treated in that way by the researchers. Other than encouraging multidisciplinary collaborations, we suggest that in the future researchers from countries different from USA undertake research on the topic of elderly mobility, as we found that the field is dominated by American datasets. More, the Chapter 2 is not giving an exhaustive description of the definitions and terminology of elderly mobility that is being used in the scientific literature, neither an exhaustive presentation of theoretical mobility models. As the terminology of mobility has been taken from the systematic review of the elderly mobility effects, which has its specified criteria, it would be insightful to find targeted multidisciplinary research for the elderly mobility terminology and definitions. Hopefully, it could lead to the creation of a multidisciplinary measure of elderly mobility. Remarkably, we suggest for further research an analysis of sensitivity of the results of mobility effects to the measure selection. Additionally, more empirical testing of the existing theoretical models of mobility and more inclusive studies using the elements we analysed in Section 2.1.4 will enrich the knowledge about key drivers of elderly mobility and will improve substantially the way it is perceived in research. The final point raised for this chapter, are the limitations of our systematic review of mobility effects which can trigger future research papers. Extending the library databases (we used 4 commonly used), the selection of the keywords, the search of the key terms not only in the article titles and extend the period of reference before 2010 are some of the indicated proposals.

Concerning the Chapter 3, we point out that the evidence on the effects of public transport use by the older people is sparse and more literature is found on the assessment of the free bus pass in the UK – a costly (~ 1 billion £/year) transport policy- which caused increased bus use by the elderly. Future research with longitudinal data will clarify the role of public transport and will show whether the healthier elderly people use the public transport or the public transport make elderly people healthier. Our paper used a cross-sectional dataset because of the scarcity of informative transport, longitudinal datasets in

Italy. Also, as most of the literature on the public transport policies for the elderly population can be found in the grey literature i.e. government reports, research reports, policy statements, newsletters, municipalities' websites etc., rather than in peer-reviewed studies, we strongly support systematic recording of the public transport policies for the elderly population as well as the issuance of a European guide of age-friendly characteristics of the public transport system.

Ultimately, in Chapter 4 we captured a wide range of online activities and sketched the profiles of the Italian elderly Internet users. However, the variables in our dataset were derived from self-assessed responses, implying that a sense of under or over evaluation might exist. Also, no further information were available about the frequency of performing each online activity. We judge this detail is equally important and will permit targeted age-friendly digital policies. Although we didn't have available variables about the digital literacy and skills we strongly suggest that adding covariates of this type will strengthen the analysis. Before starting the data analysis, we realised that it doesn't exist a set of standard questions usable by the researchers and the statistical authorities to record the online activities. Working towards the standardization of the collected data will allow more precise comparisons. Equally interesting would be to apply our methodology into various geographical contexts and investigate whether the results change with respect to ours.

Overall speaking, the thesis underlines that the process of ageing is a multidimensional and multidisciplinary topic. The framework of healthy ageing has very rightly welcomed seemingly distant sectors and linked them under one main scope: the promotion of a sufficient degree of well-being for the elderly people. The research gaps stressed in this section denote that healthy ageing is a wide and very promising research topic for the future scientific contributions.

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