What determines population health?

Making the best use of literature to structure a multicriteria population health index

Helena Isabel Rijo da Silva Forte

Dissertation submitted to obtain the Master of Science Degree in

Biomedical Engineering

Supervisor(s): Prof. Mónica Duarte Correia de Oliveira
Prof. Paulo Jorge de Morais Zamith Nicola

Examination Committee

Chairperson: Prof. João Miguel Raposo Sanches

Supervisor: Prof. Mónica Duarte Correia de Oliveira

Members of the Committee: Prof. Ana Isabel Cerqueira de Sousa Gouveia Carvalho

November 2015

Acknowledgements

First I would like to thank Prof. Mónica Oliveira, Dr. Paulo Nicola and Prof. Carlos Freitas, for guiding me through this process as well as the advices and comments that allowed me to learn.

To all at the Departamento de Engenharia e Gestão who helped me providing words of encouragement.

To those who offered me invaluable support, Jörg Delhaes, Filipe Charrua Rodrigues and Mónica Lopes.

To my friends for the best moments during these five years, Tânia Agostinho, Gonçalo Gomes, Tiago Henriques, Duarte Mendes de Almeida, Felipe Henriques, Gil Luís and last but not always least, Pedro Parreira. Vasco Conceição, for being the best unofficial mentor and great friend.

To my family who has accompanied me in all my journeys.
To my mother, for whose support I can always count on, to my father, the proof that distance does not dictate the strength of a bond and to my partner in crime, my sister.

October 2015

Helena Isabel Forte

Abstract

Evidence-based decision-making relies on Health Research Methods such as Systematic Literature Reviews to systematic assemble fragmented data. The application of the methods is laborious, time consuming and usually, only relies on the reviewer's analysis. Population Health (PH) is a complex concept affected by multiple dimensions that go beyond the formal healthcare system. No comprehensive systemic analysis exists on what determines PH. There is though a scope for improving and assisting methods to analyze the literature in general and the application to the PH concept. This thesis proposes a novel multimethodology to assist the review of studies, in a transparent way, relying on technical tools. The ultimate goal was the analysis and translation of fragmented evidence into a structured Systems Map format, and the application to PH. The multimethodology was designed in three stages: a Preliminary Literature Review, for collection and synthesis of the literature, a Content Analysis, to identify dimensions and their structuration, and Systems Mapping, to shape the validated evidence into a Systems Map. The protocol was implemented and programed using different software. The application of the multimethodology to PH reproduced valuable insights concerning which dimensions determine population health and how these interrelate. Income and Education were found to be central dimensions; other relevant dimensions were identified and their separation into nuclear or marginal. The more referred areas were identified. Evidence was found about the type of relationships between dimensions. The high potential for automation of these methods requires additional attention. Further research into PH is needed.

Keywords: Health Research Methods, Literature Review, Population Health, Content Analysis, Problem Structuring Methods, Research Tools

Resumo

A tomada de decisões baseada em evidências apoia-se em Métodos de Investigação em Saúde como por exemplo as Revisões Sistemáticas da Literatura de modo a consolidar evidência fragmentada de uma forma sistemática. A aplicação destes métodos é laboriosa, demorada e geralmente, apenas dependente de análise do revisor. Saúde Populacional (SP) é um conceito complexo influenciado por múltiplas dimensões que vão para além do formal sistema de saúde. Nenhuma análise sistémica existe para determinar a SP. Existe, no entanto, uma possibilidade de melhorar e auxiliar os métodos para analisar conceitos presentes na literatura em geral na aplicação do conceito de SP..Esta tese propõe um nova multimetodologia para auxiliar a revisão de estudos, de uma forma transparente, com base em ferramentas técnicas. Tem como objetivo final a análise e a tradução de evidência fragmentada num formato estruturado de Mapa de Sistemas, e a sua aplicação na SP. A multimetodologia foi estabelecida em três etapas: uma Revisão Preliminar da Literatura, para a recolha e síntese da literatura, a Análise de Conteúdos, para identificar dimensões e sua estruturação, e um Mapeamento do Sistema, para moldar a evidência validada num Mapa de Sistemas. O protocolo foi implementado e programado usando diferentes software. A aplicação do multimetodologia à SP reproduziu informações relevantes a respeito das dimensões que determinam a saúde de uma população e como estas se interrelacionam. O Rendimento e a Educação foram consideradas dimensões centrais; outras dimensões relevantes foram identificadas e divididas entre nucleares ou marginais. Foram identificadas as áreas mais referidas. Foi também encontrada evidência sobre o tipo de relações entre as dimensões. O elevado potencial para a automação requer atenção adicional. Investigação adicional sobre SP é necessária.

Palavras-chave: Métodos de Investigação em Saúde, Revisão da Literatura, Saúde Populacional, Análise de Conteúdos, Métodos de Estruturação de Problemas, Ferramentas de Investigação

Contents

List of abbreviations

CA	Content Analysis
CM	Cognitive Mapping
DM	Decision maker
MA	Meta-Analysis
QALY	Quality Adjusted Life Year
PH	Population Health
PSM	Problem Structuring Methods
SD	System Dynamics
SLR	Systematic Literature Review
SODA	Strategic Options Decision Analysis
SR	Scoping Review
WHO	World Health Organization

List of tables and figures

Tables

Figures

1. Introduction

Population Health is essential in defining how one can ultimately improve the health of a population. This concept is complex and includes multiple dimensions that are interrelated. Understanding what determines the health of a population, as well as how different policies may impact Population Health is central to informed health policy. Although several studies have discussed the Population Health scope and attempted to measure it in some contexts, the results are not consensual, thus it is relevant to explicitly map how different dimensions contribute and how they are interrelated [1].

Evidence-based decision-making and knowledge synthesis are crucial to inform decision-making and ultimately health policy. Thus, methods to ensure reliable, valid and comprehensive results are imperative. Commonly used Health Research Methods, such as Systematic Literature Reviews, rely on laborious and time-consuming tasks with a high dependence on the reviewers' judgment. Although computer-assisted methods have been developed [2], there is still great potential in using analytical tools in this type of approaches.

To tackle the challenges present in both the area of Population Health and Health Research Methods, a novel multimethodology was developed in this thesis. The primary goals are twofold. Firstly, this study aims to contribute with a review process that is transparent, systematic and with more reliance on automated analysis. For this, different methods and analytical tools will be developed. These methods will enable several analyses, including the determination of central dimensions, the establishment of relationships and including discussions about the extent to which different factors and dimensions are relevant for population health at distinct geographical levels. These instruments here design for PH can be used in other contexts such as hospital efficiency, and complex and multidimensional tasks.
Secondly, the study aims to reliably consolidate the evidence on the subject of Population Health, determine its relevant dimensions, their relationships and present them in a structured format.
Additionally, the obtained results aim to inform the construction of a population health index in the context of the project Euro Healthy "Shaping EUROpean policies to promote HEALTH equitY" which aims to develop tools based on a population health index to evaluate the health and well-being of the European population [3].

Throughout this thesis it will be shown the need, the developed methods and their application to support a Systematic Literature Review. Moreover, the methods are applied and the results to this type of approach are analyzed and discussed. The document is organized as follows. Chapter 2, *Population Health*, provides an overview of the Population Health concept. The

benefits and limitations of using a Population Health approach are discussed. The three main foci of PH – determinants, outcomes and policy – are further described in separate sections, and the Euro Healthy project context is summarized.

Chapter 3, *Review of concepts*, provides a literature review on methods that may be relevant to address the objective of this thesis. From Health Research Methods, three commonly used methods to systematically review the literature are described: Meta-analysis, Systematic Review and Scoping Review. The features of each method are detailed, its advantages and drawbacks and lastly the comparison between them and the argument to use a Systematic Literature Review are presented. A selection of Problem Structuring Methods was discussed; the methods that enabled structuring and providing further understanding into complex issues with a focus on Cognitive Mapping, Causal Loop Diagrams and System Dynamics. These methods are described and subsequently, their usage and applicability to the current approach are debated.

Chapter 4, *Multimethodology*, covers the developed multimethodology and the tools used. Initially the explanation to use a multimethodology is given, followed by the description of the different stages and methods of the multimethodology. The implementation, describes the tools used and their integration.

Chapter 5, *Results*, presents the results from applying each stage of the multimethodology. Initially a categorization and review of the studies is presented. Each category is further described and a first synthesis of the literature is offered. Next, the resulting hierarchical structure, followed by the analysis of the presence and distribution of dimensions in the text, the analysis of possible relationships between dimensions, the dispersion of the areas in the representations, the connectivity of each node with others, the analysis of the areas and a the analysis at different geographical levels. In the last stage, the validated evidence nature is displayed in the format of a Systems Map.

Chapter 6, *Discussion*, presents the discussion of the proposed multimethodology and implementation, its shortcomings and advantages. After, the obtained results are discussed, considering their reliability, representativeness and insight they provide. It closes with a reflection on the contribution of this work as well as possible improvements.

Chapter 7, *Concluding Remarks,* provides the final remarks of this work. It is summarized the challenges encountered and how they were confronted. A brief balance of the work developed is offered. Furthermore the need of future research and developments is identified.

2. Population Health

The relevance of Population Health (PH) lies on the potential to maximize the health and well being of a population; of equal or greater importance has emerged the reduction of disparities in health across different people and groups [1]. Understanding the influence of factors not only specific to health and the determination of favorable influences on population health is essential to improve decision-making in policy and resource allocation. To promote PH one must define future goals and measure the present level as well as the evolution achieved, this will allow keeping track of the developments and determine important driving forces or hurdles on the way to accomplish it. In the absence of such purposes, appraisal of change becomes relatively meaningless, since there is no way of judging whether such change is more or less beneficial than harmful [4]. In order to assess the health of a population, valid, comprehensive, transparent, and standardized ways of measuring and reporting on PH are needed [5], as well as PH concepts.

Population health is a recently established field of research, with multiple views, many advocates but also with some critics [1, 6-8]. Moreover, many terms, like outcomes, disparities, determinants, and risk factors are employed in this context. The usage of the terms varies with different disciplines, such as medicine, epidemiology, economics, and sociology [9]. Thus, this thesis aims to investigate the Population Health concept in order to build a common understanding on what determines the health of a population and with the final goal of informing the construction of a multicriteria health index. This Chapter aims at giving an overview of the concept of Population Health, its evolution and debate. It is organized in an initial introductory section followed by subsection that details the three main elements of PH – determinants, outcomes and policy.

2.1. Population Health concepts and frameworks

Albeit the recent establishment of this concept as it is described here, similar approaches to thinking about factors that influence the health of populations and causalities among these factors and patterns are not new. Already in 19th-century France, Villermé [10] documented the diverging incidence of mortality in different districts of Paris, relating them both to the wealth differentials of the citizens and to variation in sanitary conditions; also, during World War II, Jerry Morris and Richard Titmuss [10] demonstrated that the incidence of several conditions, for instance juvenile rheumatism, rheumatic heart disease, and peptic ulcer all varied according to fluctuating social conditions, such as the rate of unemployment. These represent seminal models of Population Health; the role of determinants was already being recognized, the interactions between social and environment factors analyzed and the health state of a population determined.

Population Health is referred in tandem with terms such as outcomes, determinants, and inequities and, to a lesser extent, policy (Figure 2.1). Expanding the scope of an outcome-focused health, from only keeping score of the health state of individuals within stipulated intervals of time, allows the assessment of their evolution including the understanding of the factors that can influence this health state – the determinants. With this inclusion, Population Health was seen as part of a wider dynamic picture that contains other components of a society (e.g. physical environment, social behavior, education).

Figure 2.1 - Population Health word cloud generated
(using NVIVO[11] and as sources [1, 6, 9, 12-15]).

Since its policy adoption in Canada around 1990, the term Population Health has met with some critiques [1, 6-8] and instigated debate around the topic [1, 6, 9, 14]. Despite the dialogue around the subject, there is still absence of consensus about how to best define Population Health [15] and it is regularly stated that it does not yet have an agreed-upon definition [16] (Table 2.1).

The dialogue around PH was not exempt from critiques. Coburn et al. [7] pointed out the limitation of the analyses of the determinants of health at the macro-level over an evaluation at the micro-level, as it fails to adequately conceptualize possibilities for actual change. Concerning this point, Kindig advocates that “the development and validation of such measures for different purposes is a critical task for the field of Population Health research.” [1]; generally PH will be concerned with the more general system so it can reason the overall health of a population and delimit areas of action.

The extensive latitude of the concept raises some concerns regarding the utility of PH [1]. In order to overcome this, it is necessary to clarify the scope of the study, as Cohen et al. support that the clarification of conceptual and operational definitions of the term PH method is essential [6].

Some of the caveats have already been overcome with the development and detailing of the concept; others like the understanding of relevant population health determinants and the utility and impact of this type of approach need further investigation.

Table 2.1 - Population Health definitions.

Public Health Agency of Canada 1998 **[12]**- “Population Health is an approach to health that aims to improve the health of the entire population and to reduce health inequities among population groups. In order to reach these objectives, it looks at and acts upon the broad range of factors and conditions that have a strong influence on our health.”
Young 1998 **[13]**- “A conceptual framework for thinking about why some populations are healthier than others, as well as the policy development, research agenda, and resource allocation that flow from it.”
Dunn and Hayes 1999 **[14]**- “the health of a population as measured by health status indicators and as influenced by social, economic, and physical environments, personal health practices, individual capacity and coping skills, human biology, early childhood development, and health services”
Kindig & Stoddart 2003 **[1]**- "the health outcomes of a group of individuals, including the distribution of such outcomes within the group”
Kindig 2007 **[9]**- “Population Health use many terms, such as outcomes, disparities, determinants [...] establishing clear and definitive causal relationships between broad determinant categories or specific programs and policies that predict with relative certainty their short- and long-term impacts on a variety of Population Health outcomes of interest… What is the optimal balance of investments (e.g., dollars, time, policies) in the multiple determinants of health (e.g., behavior, environment, socioeconomic status) over the life course that will maximize overall health outcomes and minimize health inequities at the population level?”
Hacker & Walker 2013 **[15]**- “populations are defined by geography of a community (or) the Population Health connotes a “panel” of patients served by the organization...reorient from a disease focus to a wellness focus
Cohen et al 2014 **[6]**- “Core elements of the Population Health approach included focusing on health and wellness rather than illness, taking a population rather than individual orientation, understanding needs and solutions through community outreach, addressing health disparities/health in vulnerable groups, addressing the social determinants of health and intersectoral action and partnerships.”

Throughout time some attempts have been made to clarify the Population Health concept [1, 6, 9, 12-15] (Table 2.1). The selected explanations represent the variety of advances in the definition and discussion around the topic. Young [13] first approached the subject considering why some people where healthier than others: Population Health, as the term states, aims at dealing with the health of an entire population, with the objective of maximizing well-being and minimizing inequities [12]. Later approaches mention patterns and distribution of determinants and outcomes [1], and increase the focus in the necessary collaboration among sectors for effective action towards population wellness [6].

Due to the central role of the three distinct elements - determinants, outcomes and policy – these will be further clarified in succeeding sub-sections.

2.1.1. Determinants

Determinants of health (sometimes referred as social determinants of health) are, as defined by the WHO, “the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life” [17]. Determinants include all factors that might, directly or indirectly, bring about change to the health condition of an individual [18].

In some cases, “determinant” and “risk factor” are used interchangeably. A risk factor is normally associated with a personal behavior or lifestyle, an environmental exposure, or an

inborn or inherited characteristic that, on the basis of epidemiologic evidence, is known to be associated with the incidence (and with its consequent increase) of certain health conditions [9]. Some determinants are considered to be modifiable by mediation, thus reducing the probability of disease or other outcomes.

Determinants are usually organized into categories; slight differences exist between categorizations. Examples of the classes are: social determinants, related with the social environment (e.g., income, education, occupation, class, social support), physical environmental determinants, which include both natural and built environment (e.g., air and water quality, lead exposure, the design of neighborhoods), healthcare determinants associated with the provision of healthcare services and system (e.g., access, quantity, and quality of health care services), behavioral or lifestyle determinants, encompassing individual personal choices of lifestyle or habits (e.g., diet, exercise, and substance abuse) and less common such as a genetic or biological determinants, related with the genetic composition of individuals or populations (for example, the predisposition to certain types of cancer) or a biological mediator variable between a determinant and an outcome (for example, the role of endocrine and immunologic processes in stress) [9].

2.1.2. Outcomes

Health outcomes generally represent how healthy a population is. As defined by Last [18] they correspond to “all the possible results that may stem from exposure to a causal factor from preventive or therapeutic interventions; all identified changes in health status arising as a consequence of the handling of a health problem”.

Normally they are divided into two types of outcomes: how long people live (length of life) and how healthy people feel while alive (quality of life). The first is fairly direct, recurring to publicly available data, collected at national level, and the indicators used are varied: life expectancy, all-cause mortality rates, premature death, infant mortality are a few examples. The second, quality of life is subject to many more nuances, seen that it involves individuals perceptions of their life quality which is inherently related with expectations. Culture and other factors influence how this quality is perceived and determined, being also subjected to different subjective measurement tools, usually making use of QALYs (quality-adjusted life year) which is a measurement that assigns to each period of time a weight, from 0 to 1, equivalent to the health-related quality of life throughout that period, a weight of 1 corresponds to optimal health and a weight of 0 corresponds to a health state equivalent to death; and then aggregated across the time periods [19].

2.1.3. Policy

Policies work as a set of forces that can influence both determinants and outcomes, selected with the aim to do it in the most effective way. A paradigm shift in policy making has been emerging with this concept: the fact that health encompasses factors as diverse as air pollutants, infrastructure, disability and burden of disease, makes Population Health a

transversal concern and for that reason decision-making in policy should be inter-sectorial [20]. Policy entails a variety of decisions that affect, in a direct way determinants and indirectly outcomes. Decision-making include allocation of resources and the extent of commitment to a certain area of concern [9]. Examples are in sanitation of cities which can influence the spread of some illnesses and is linked to water quality and incidence of diarrhea, or even policies that promote education, ensuring access to all, these will be essential for health promotion through the increase of future career opportunities and ensure income even for the less favored and ultimately health outcomes.

The relationships between determinants were represented in a model first by Evans & Stoddart [21](Figure 2.2). These connections between different dimensions, external to the healthcare environment (e.g. education, physical infrastructure, etc.), as well as the introduction of the distinction drawn between disease (recognized and responded to by the health care system), 'health and function' (experienced by the individual person) and the category of 'well-being' (the sense of life satisfaction of the individual) were an innovation in the field of then not yet called PH; furthermore, well-being was postulated as the ultimate objective of health policy, on top of the thermostatic model of health: health as absence of disease, and health care as response to its emergence, connected in loop [21].

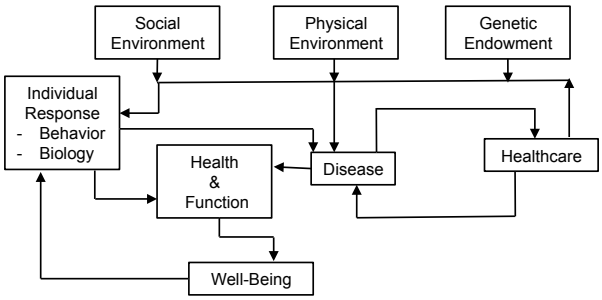


Figure 2.2 - Seminal framework about Population Health
(adapted from Evans & Stoddart [21]).

Following the Evans & Stoddart model (Figure 2.2), a simpler version was presented by Kindig [1](Figure 2.3), focusing on the interaction of the three PH concepts (determinants, outcomes and policy). In this framework, a concern with the distribution of the outcomes throughout the population is present as well as the search for the suitable patterns of determinants over time as to make possible the most advantageous influence on the outcomes. The role of policy in this scheme is to impact the determinants and how they influence the outcomes.

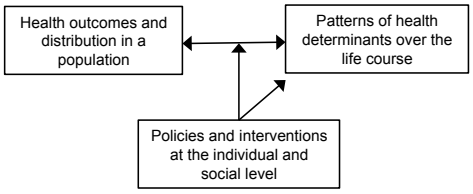


Figure 2.3 - Population Health schematic definition
(taken from Kindig [1]).

More recently, an adapted version is presented on the Improving Population Health website [22](Figure 2.4). This last representation details the areas of both outcomes and determinants. Another two developments arose, the first is concerned with the bi-directionality of the connection between the outcomes and determinants, the argument being that the influence relationship is not only from the determinants to the outcomes but in the opposite sense as well, although in a lesser extent (e.g. someone with a better level of education will have a better level of health, because, among other factors, will be more informed about healthy behaviors and courses of action when needed; conversely, if a person does not have a good health, has a chronic disease or some type of disability, this will affect her scholar achievement), this is designated by some as reverse causality [9].

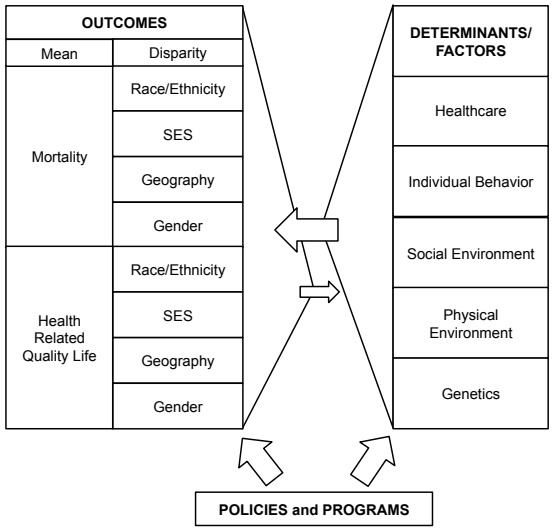


Figure 2.4 - Detailed Population Health schematic definition
(taken from the Improving Population Health website [22]).

Conclusively, Population Health represents a dynamic system comprising a group of individuals (defined by a geographical area, served by the same provider, of the same ethnicity or other common characteristic), the healthcare system in place, the physical environment, socio-economic aspects, and to some extent genetic endowment and other factors. Each of these determinants will influence and be influenced by consequent risks and outcomes. PH explores the set of policies to select, desirable patterns of determinants/risks and the distribution of outcomes throughout the population to ensure the most equitable health with the resources available and multi-sectorial collaboration.

Up to this point, no article has yet comprehensively defined what determines Population Health. This work, by making use of the literature, intendeds to elucidate this gap, and define the relevant Population Health dimensions with the ultimate goal of informing the construction of a Population Health multicriteria index.

2.2. Euro Healthy project

The present work is developed in the context of the Euro Healthy: "Shaping EUROpean policies to promote HEALTH equitY" project. The project aims to develop tools based on a population health index that evaluates the health and well-being of the European population [3]. The index will be informed by evidence on the relationship between multiple determinants as well as health outcomes where this thesis aims to make a contribution. The index will be based on a multi-criteria model structure, and will be developed through a socio-technical approach: integrating the technical elements of a multicriteria value model and the social elements of interdisciplinary and participatory processes [3]. The aggregate measure will be applied to assess the population's health in 273 European regions and 9 selected pilot metropolitan areas, covering the population of 28 EU countries [3]. Previous work to develop a population health index have been achieved [23, 24]. The development of the present index has some basis on these.

2.3. Research objectives

In this thesis the intermediate goals are twofold. Firstly, is to aggregate and structure the evidence on the topic of Population Health. Secondly, the development of tools and methods that aid in a transparent and systematic review of the literature. The ultimate goal is to inform the structuration of a multicriteria Population Health index developed in the context of the project Euro Healthy. In the consolidation of the fragmented evidence on Population Health, it is intended to answer questions such as "What dimensions are relevant in the context of Population Health?", "How are the dimensions interrelated?" and "Which areas are more present in Population Health?".

For the development of techniques to review and structure the evidence, the purpose was to enable a transparent and more automatic review of studies and an alternative that depends less on the reviewer and rely more on technical tools for analysis.

The end product intends to provide a comprehensive way to display the evidence and inform the selection of dimensions to include in the future multicriteria Population Health index and the developed methods can be applied to other contexts.

Although the methods were applied to the concept of Population Health they can be applied in other contexts.

Having introduced the concept of Population Health, it is necessary to review and consider the existing methods for its analysis and structuration; this is presented in the following chapter.

3. Review of concepts

In decision-making and in the creation of knowledge, evidence plays a central role.
Evidence-based decision-making is generally associated with medicine in terms of using a synthesis of internal and external evidence composed by knowledge assimilated through formal education and training, experience gathered from daily practice, and specific experience obtained from an individual doctor-patient relationship –(internal evidence); and the accessible information from research (external evidence) [25]. An evidence-based approach can be used in diverse areas; particularly in policy, choices in program adoption or resource allocation are grounded on evidence. It is imperative to ensure reliable methods of defining and developing such methods.

This Chapter offers a review of the concepts that exist for synthesis and structuration of literature in a specific area, such as Population Health. Different methods will be analyzed in order to have a framing of the available options to tackle issues such as the present one, to identify shortcomings and scope for improvement.

The present purpose of synthetizing, identifying and structuring concepts with the ultimate goal of informing decision-making, led to the selection of research methods in Health, in Problem Structuring Methods and Content Analysis to be explored in the following sections.
Research methods in Health will allow a systematic and objective way to summarize and consolidate the evidence on the area of Population Health.
Problem Structuring Methods will provide the tools for dealing with the complexity of real world problems such as PH, structuration and the relations between the multitudes of existent dimensions.
Content Analysis will enable the identification and interconnection of relevant dimensions.

3.1. Research Methods in Health

When analyzing a topic making use of the literature on the field, one can use different methodological approaches for literature survey. Examples of these are Meta-analysis, Systematic Literature Reviews and Scoping Reviews. Albeit having several steps and aims in common, their approaches still differ in some aspects.

3.1.1. Meta-analysis

A Meta-analysis, as defined by Gene V. Glass [26], is the statistical analysis of a large collection of results from individual studies with the purpose of integrating their findings. Individual studies are grouped according to their similar attributes and analysis: they focus on a single outcome variable, the relationships between variables or in one intervention. Through the reduction of heterogeneous research into an integrated overview, it intends to extract

quantitative parameters, improve the power of small or inconclusive results, attempt to uncover patterns among study results, sources of divergence or even relevant relationships not identified in the previous individual studies [27].

This type of study follows a set of guidelines. The framework proposed by Harris Copper [28], is composed of seven steps:

1) Formulate the problem

In this stage it is defined what the researcher intends to study and the definitions are established for the variables involved. By defining these parameters, the scope of the analysis is outlined. Here it is also decided whether to investigate only one variable or a relationship between two or more variables.

2) Search the literature

The decision about the collection of elements to be obtained is made at this point. Defining this is a challenging task since the purpose is to cumulate the results from past studies.

3) Gather information from the studies

The selection of the type of information to be collected from each study is established in order to answer the issue of interest. It normally includes the nature of the variables, e.g. dependent and independent, the research design, implementation and statistical results. This will be the evidence that will be analyzed in subsequent steps.

4) Evaluate the quality of the studies

Evaluating the data compromises a series of critical judgments about the quality of each study, i.e., if the conclusions reached, in light of the surrounding evidence, should be considered relevant and reliable or otherwise if it should discarded or given little credibility. Example of criteria is randomization, double blinding, transparency of the methods and significant sample size.

5) Analyze and integrate the outcomes of studies

In this step, the data collected and selected is summarized and integrated to form a coherent picture. Statistical procedures are applied to separate systematic data from what can be considered “noise”. An estimation of the magnitude of a relationship or of the impact of an intervention can also be achieved.

6) Interpret the evidence

Through the interpretation of the collective evidence conclusions are obtained. These can be, for example, supporting a relationship(s) that needed to be confirmed as well as its associated reliability. Another example is concerned with the assertion of the magnitude of impact of a certain intervention.

7) Present the results

The final step includes the production of a report that presents not only the conclusions reached but also the previous steps, and the details of how they were carried out.

Albeit its clear advantages, such as the support/contestation of previous findings, the detection of possible bias in individual studies and the motivation of improvements in study

quality [29], meta-analysis is not without limitations. The decision on whether to include a study while searching the literature should be made considering that the treatments, outcomes, variables or case definitions are similar enough to be comparable [30]. Inclusion criteria should include randomization, double blinding and transparency of the methods used. In the process of gathering the studies, study diversity might be overlooked or mishandled or it might be problematic to collect an appropriate number of studies with comparable characteristics [29]. Due to the arguments presented here, this technique was reasoned not useful for the objectives of the thesis.

3.1.2. Systematic Review

A systematic review (also commonly referred as Systematic Literature Review) is a comprehensive literature search that can be replicated by others, including relevant published studies about a specific topic or area. The definition of systematic review is met with some disagreement. While some regard systematic review as an individual method, others view it as a term that also includes meta-analysis. For the purpose of this study, it will be considered as separate from the meta-analysis and as a quantitative method.

In a broad sense, literature reviews may have distinct purposes ranging from comparing and contrasting previous research, to identifying gaps in the literature, to find new research questions or to form a justification for the current work and even reinterpret and critique previous results [31].

Several guidelines exist for conducting a systematic review proposed by the PRISM statement [32] and by the Cochrane collaboration [33] and in a general way apply the following steps:

1) Defining the review question

Considered as the most important decision in formulating a systematic review. This establishes the focus by clearly framing the questions the review seeks to answer. The questions will guide several features of the review procedure, such as the eligibility criteria, search for studies, collection of evidence from each study, and presentation of the results and conclusions.

2) Develop criteria for including studies

A combination of features is considered including the topic, intervention or method addressed; and the types of studies and their quality might also be screened. This step ensures that all the collected studies have a common and sound basis.

3) Search for studies

The search is performed usually in international databases, and using English language. During this process it is normal, by analyzing the available studies, that both the research questions and eligibility criteria might suffer alterations. Results can be expanded or restricted, in an iterative process.

4) Select studies and collect data

In the selection of studies, typically three researchers are involved, where two screen the studies and make decisions independently, following the pre-established criteria, and the third one intervenes in the case of disagreement. The particular data collected from each study includes information about eligibility for inclusion in the review, methods used, the population characteristics, interventions analyzed, outcomes and results.

5) Analyze the data

At this point it is essential to methodically make inferences about the studies. In a general approach such as this one, the analysis passes through the appraisal of the concepts discussed, the methods used and the main conclusions obtained.

6) Present the results

The results are presented in the form of schemes, and in some cases where quantification is performed, in charts. Also, topics translating the main trends and ideas present in the literature are outlined.

7) Interpret the results and draw conclusions

In the interpretation of the results and conclusions, an overview of the body of literature is obtained, identifying the major topics of focus and the gaps in the literature.

The clear advantage of such a technique is that produces a literature synthesis about a specific topic or area. In this case the definition of review questions takes on greater importance, a chief limitation is related with the potential ill definition of such questions. The stipulated questions should be broad enough to encapsulate the terms and explanations needed to clarify the concepts approached but not too extensive, resulting in a lack of focus and inability to address these.

3.1.3. Scoping review

A "scoping review'' or ''scoping study'' corresponds to a method of knowledge synthesis, by comprehensively summarizing and synthesizing evidence with the intent of informing clinical practice, programs, and policy as well as defining the direction of future research [34]. In other words, this sequence of methodological steps enables us to have a sense of the "lay of the land" [35].

A recent definition recommended by Colquhoun et al. [35] after being proposed and later revised by Arksey H, O'Malley L. [34] and Daudt et al. [36]: "A scoping review or scoping study is a form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesizing existing knowledge."

The steps proposed by Arksey H, O'Malley L.'s [34] framework with enhancements by Levac et al. [37] are reviewed in Colquhoun et al.'s [35] work, and they are:

1) Identify the research question

The definition of the research question is a step that influences all later steps. Despite the broad nature of this stage, it will guide the strategy and define the scope in terms of target

population, concepts, outcomes or variables of interest. This task goes in tandem with the definition of the purpose of the review as well as the intended output (e.g., recommendations, framework)

2) Identify relevant studies

At this point, it is determined where to search, which terms to use, which sources to search, time span, and language, i.e. what is normally designated as research protocol. All the decision made must be justified, mainly concerning the restriction of the study's scope and, as a result, the potential limitations that come with it.

3) Select studies

After reading through the studies for a first time and being familiarized with the topic, exclusion criteria are developed to eliminate marginal studies. The criteria take into account the initial research question and study purpose, however it can be revised throughout the analysis of the studies according to trends that may emerge. This is an iterative process going through search, refinement of search strategy and reviewing inclusion of articles. Ideally it should be executed by multiple researchers with an initial meeting to discuss the strategy and derived criteria, followed by revision of the studies by two independent reviewers, and a third one for situations of disagreement. Also, additional meeting should be held in order to debate challenges and uncertainties.

4) Chart the data

The charting of the data can be purely descriptive, detailing what is examined as well as the applied methods, or there can be reorganization into categories, groups, parts, types or relationships. This phase is also iterative, with a continuous extraction of data an updating of the charted data. The charting should be piloted with a few sample studies to see if the charting is appropriate to answer the research question. This step may require the use of qualitative content analysis.

5) Collate, summarize and report the results

To provide an overview of the scope of the literature, a numerical analysis about the nature and extent of studies is performed. Underlying themes are presented using charts and tables.
In a subsequent phase are the discussion of the findings and their relation with the purpose of the study and the implications for future research, practice and policy.

6) Consultation

This stage offers the possibility for the stakeholder to get involved and make suggestions, critiques or insights past the literature content. It is an optional step, but when performed, it should follow guidelines that allow the clear articulation between the researchers and stakeholders and a transparent and careful elicitation, analysis and reporting of the information.

Table 3.1 – Comparison between Meta Analysis, Systematic Review and Scoping Review.

	Meta Analysis	Systematic Review	Scoping Review
Formulate/Define the problem/research question(s)	Clinical intervention or disease incidence	Research questions	Broad question or topic
Search the literature	Basis on population sample and analysis	Screening criteria for including studies	Broad criteria for including studies
Gather information from the studies	Quantitative data	Qualitative data	Qualitative data
Evaluate the quality of the studies	✓	✓	✓
Present the results /Chart the data	Statistics of quantitative results	Schemes, frameworks, qualitative analysis	Schemes, frameworks, qualitative analysis
Consultation	✗	✗	✓

This method has the clear benefit of providing a clear process of mapping areas of research; the summarized presentation enables policy makers, stakeholders and consumers to make better use of the findings, and, like in systematic literature reviews, synthetize research evidence and identify literature gaps. SR also allows for a deeper understanding of how the findings relate to each other and to the research question [38]. However, caveats such as the challenge between the breath and the depth of the analysis, the lack of guidelines for a critical appraisal of the included studies and a highly variable methodology and terminology procedure make this method hard to apply.

From the examination of the three types of literature reviews it can be conclude that, although having some points in common, they ultimately answer to different purposes. SR aims is to map the body of literature on a topic area, the goal of a SLR is to sum up the best available research on a specific question and MA aims to integrate the findings of individual studies concerning a specific intervention [39]. The initial stages of all the methods go through a definition of the problematic at hand, in other words, the questions the researchers want to answer; in this sense there is the delineation of research question(s). The literature search can entail a process of looking for studies with specific characteristics (like in meta-analysis), with specific search words (like in systematic literature reviews) or a search for studies within a scope (like in scoping reviews). In the stage of collecting the data from each study, while meta-analysis aims to collect quantitative data for future statistical analysis, the other two methods are dedicated to qualitative data for summarizing and charting purposes. For the data analysis, both SR and SLR schematize and chart the relationship between relevant concepts while in MA the results of the different studies are grouped and analyzed using statistical methods.

In a final stage, the reporting of the results and inference of conclusions is transversal to all three approaches however; SR has an additional step where there is a consultation and feedback from the stakeholders that allows for constructive criticism and improvement of present and future reviews. It is important to address the bias in the selection of studies and

in the presentation of the results. It corresponds to the systematic error in which the researcher makes untruthful inferences leading to the underestimation or overestimation of the true intervention effect. In this setting, tools have been developed to assess both the quality and the risk of bias when doing a review. They include scales where the elements of quality are rated and combined to give a global score; or checklists, in which criteria related to sampling, randomization and blinding are checked [40, 41].

Table 3.2 – Automation of literature review methods.

	Meta Analysis	Systematic Review	Scoping Review
Automation	✗	Very little	✗

In the present thesis there is no focus on a single outcome variable or intervention, which made the statistical techniques of meta-analysis inappropriate for the type of literature survey performed here. Given the exploratory nature of this literature survey, the extraction of meaningful quantitative data from studies with similar population and analysis is applicable. Conclusively, meta-analysis is not concerned with qualitative research, where there is a lot of significant data that might elucidate this work's research questions. Also, since no consultation was possible in the present work and due to the methodological uncertainties related with SR the choice was made to perform a SLR that would be valuable in answering the research questions.

All the mentioned methods do not rely or rely very little on technical tools. Some computer-assisted approaches exist to aid in the organization and categorization of tools [2]. Integrated approaches with flexibility in analyzing would provide new ways of analyzing qualitative data.

Several analyses exist to examine qualitative data. Usually literature analysis involves data comparison and contrast from two or more literature sources. Onwuegbuzie et al. [42] point out the underdevelopment of literature reviews as a result of a lack of formal and systematic analysis of the extant literature. The authors conceptualize and describe 17 qualitative data analysis techniques that can be used to analyze the most diverse sources ranging from talks, observations, drawings/photographs/videos, and documents. Twelve of them can be applied to documents. The qualitative data analysis techniques presented for research syntheses of documents are the following: constant comparison analysis, keywords-in-context, word count, classical content analysis, domain analysis, taxonomic analysis, componential analysis, theme analysis, secondary data analysis, qualitative comparative analysis, semiotics and text mining. Different classifications and definitions exist for these methods as well as significant overlap between then; this makes it imperative the clarification of what alternative techniques exist to perform a qualitative data analysis. It is valuable to use multiple qualitative data analysis techniques so that they can get more out of their research syntheses. From the information provided in Table 3.3 it is possible to conclude that a vast array of methods can be applied for the analysis of qualitative data. In this thesis, classical content analysis can be applied for the identification of dimensions and their structuration. Methods like Componential analysis, Constant comparison analysis, Keywords-in-context, Qualitative comparative

analyses and Word count can uncover possible relationships, helping in the systematic creation of sections in the literature review, determining the relevance of specific dimension and giving some insight into their relative importance.

Table 3.3 - Qualitative Analysis for research synthesis (adapted from Onwuegbuzie et al. [42]).

Type of Analysis	Short Description of Analysis	Applicability to this work	Arguments for applicability
Classical content analysis	Systematically allocating sources into codes deductively (pre-existing nodes) or inductively (nodes derived from the source data).	Yes	Multivalent analysis, provides insight at different levels
Componential analysis	Using matrices and/or tables in order to discover the disparities or similarities among coded components.	Partially	Provides some insight on relationships
Constant comparison analysis	Systematically creating codes from text data and developing themes from the codes.	Partially	Enable categorization of the sources, enhancing knowledge
Domain analysis	Examining symbols because of the belief that symbols are an essential way of communicating cultural meaning	No	Used to derive cultural meaning
Keywords-in-context	Identifying keywords and utilizing the surroundings to understand the underlying meaning in a source or across sources.	Partially	Provides some insight on relationships
Qualitative comparative analysis	Analyzing similarities and differences across sources, in a theory-building approach making connections among previously built categories, testing and to developing the categories further.	Partially	Enable categorization of the sources, enhancing knowledge
Secondary data analysis	Analyzing non-naturalistic data or artifacts that were derived from previous studies.	No	No previous conclusion for comparison purpose
Semiotics	Assuming that no meaning can be attached to a single term, text is used as a system of signs. Showing how signs are interrelated for the purpose of creating and excluding specific meanings.	No	Not the focus of the work
Taxonomic analysis	Creating a classification system that categorizes the domains, helping in the understanding of the relationships among the domains.	No	Not the focus of the work
Text mining	Analyzing naturally occurring text within various sources in order to determine semantic evidence.	No	Provides little insight, not the focus of the work
Theme analysis	Searching for relationships among domains, as well as a search for how these relationships are linked to the overall cultural context.	No	Used to derive cultural meaning
Word count	Counting the number of times a particular word is used either during a within-study or between-study analysis.	Partially	Provides some insight in identification of central issues

In the following section it will be explored a sub group of methods from PSM. This selection intends to show some of the alternatives that exist for the structuration and relation of concepts, one of the goals' of this thesis.

3.2. Problem Structuring Methods

Problem structuring approaches seek to recognize the relevance of multiple actors and their role in generating politically feasible ways of resolving real and complex problems [43]. Examples or related techniques are Cognitive Mapping, Causal Loop Diagrams, Causal Maps and System Dynamics. All these techniques intend to aid decision-making and strategy definition but they do it in different ways.

A PSM can be described as a codified approach to intervene in a problem context and to enable action in the resolution of an issue. This entails multiple actors and perspectives, uncertainties, disagreeing interests and substantial intangibles [44]. By recognizing the problem as a multidimensional and complex system, PSMs can aid in increasing the understanding about the system and study how to intervene in a sustainable and systemic way.

The points of view are gathered whether individually or in a group and subsequently discussed and explored together. The approach takes the form of a cyclical process with the findings from one deliberation providing insight for the next iteration. In the end the objective is to reach a set of developments or a strategy for problem resolution. In order to do so several modeling methods/analyses are employed to promote the development of an comprehension by participants and to, in a simplified way, represent the real world [45].

Due to the ill boundary definition of PSMs and some common characteristics, other methods such as System Dynamics can also be considered.

In this work the focus will be on methods that enable us to model/increase the knowledge of complex systems. These methods will be: Cognitive Mapping, Causal Loop Diagrams, Causal Maps and System Dynamics

3.2.1. Cognitive Mapping

Cognitive mapping is a method for problem structuring based on the view of cognition [43].

Although some divergence exists about the definition of cognitive maps, some notions are transversal across authors such as the fact that CM are a collection of nodes linked by arcs [46]. The significance of the nodes and connections has variations in the literature; for this reason, it is imperative to define in a clear way, the kind of map applied.

The links can have a semantic label, defining the nature of the relationship, can be arcs with or without direction and can also have a value associated that represents the strength of the relationship between the nodes [47].

Eden et al. [43, 48, 49] have provided an extensive literature on CM and according to them a CM corresponds to a directed graph, with the intent of qualitative understanding of a complex situation through the linkages between constructs. According to the same authors, the elements represent chunks of language used to build an argument or line of argument; these chunks are normally 10-12 words comprehending an implicit or explicit subject, active verb, and object, the connections between nodes represent an explanation or consequence. These links are not considered to be explicitly causal. The arrow out of a construct illustrates a consequence and an arrow into a construct an explanation, thus giving an explanatory meaning to one element and consequential meaning to the other.

3.2.2. Causal maps

As the name implies, the relationship established in this method is of causality, influence or implication, so naturally it is focused in establishing the effect of a given cause on a given effect [50]. A variety of formats designations are used including fishbone diagrams, impact wheels, issues trees, strategy maps, risk assessment mapping tools and cause and effect diagrams [47].

Some authors seen them as a type of CM since it is derived from the cognitive abilities of a group of decision makers. Causal maps are widely used in SODA (Strategic Options Development and Analysis) by identifying and agreeing to a set of potential alternatives [51]. Causal connections represent antecedent-consequence relationships between two nodes by connecting them with a unidirectional arrow from the antecedent (the causing agent) to the consequence (the caused agent) [47].

3.2.3. Causal Loop diagrams and System Dynamics

To further study the behavior of a complex system, System Dynamics allows to simulate its behavior, which, typically is derived from causal-loop diagram (or influence diagram). SD nodes represent variables varying over time, related with each other by positive (A has a positive influence on B if a change in A results in a change in B in the same direction) or negative relationships (A has a negative effect on B if a change in A results in a change in B in the opposite direction) [52].

CLD aim to improve insight into the underlying structure of the complex problem, display how variables coexist and relate with each other (how ‘things hang together’) and aid to identify possible and feasible intervention strategies in order to influence the system’s behavior [53].

In SD, additional structuration is done to the problem. A feedback configuration with equations or stock-and-flow diagrams is established. The presence of loops is also characteristic of this type of system, where balancing and reinforcing loops are associated to pushing the system to equilibrium or with exponential increase/decrease, respectively [44]. In a later phase, the formulation of equations and flows that relate the variables lead to a simulation-like approach that results in the assertions of upcoming trends.

All methods have the ultimate goal to support decision-making in complex issues, but they do it in various ways. CM is useful for the qualitative understanding of the problem and for revealing the structure of the problem. The downsides to this approach are related with the fact that it is associated with the belief system of the DM and is created using laborious and time consuming participatory processes. Causal maps imply a causality that in some contexts is hard to establish and support; likewise in CM the process is strenuous. CLD can be singly applied with the intent of learning about the system's behavior; for it to be applicable one has to identify somewhat quantifiable variables to be able to describe their variation throughout time, and it is only valuable if the purpose is to depict a system that has a stock and flow behavior, exponential growth or the achievement of steady states. Similarly, SD can be valuable in a more detailed modeling of the system, but with it arises difficulties related to equation definition, inability to model the whole system and data availability.

These three PSMs offer different alternatives to approach complex and multidimensional issues. Due to the diversity of information, the difficulty to establish causal pathways from the literature and the impossibility to quantify these dimensions, it was chosen the option to apply a CLD type of approach.

3.3. Content analysis

Content analysis is a research technique for making reproducible and valid inferences from qualitative data. It has been developed to ensure that all units of analysis receive equal treatment, throughout the entire analysis as well as to certify, to the extent possible, the process' objectivity, *i.e.*, that it is independent of who performs it, when and where the analysis is performed [54].
In the present thesis, it is central to unravel the evidence present in the qualitative data provided by the literature. Due to the central role of the CA, in this section it will be clarified the notions and stages of this method.

CA started as a quantitative research method with the purpose of, in a objective and systematic way, quantifiably describing the manifest content of a communication [55]. Afterwards, the quantification approach was thought to often simplify and distort the meaning and thus was proposed a qualitative approach to Content Analysis, in which meanings and insights can be obtained from the text in a more holistic manner [55]. The development of a qualitative CA led the way to a category oriented analysis, where written materials where systematically classified into selected categories of similar meaning. The interpretation of the text opens this method to the subjectivity of the coder (the researcher that methodically identifies and allocates categories in order to identify themes and patterns) [56].

This methodology typically focuses on the characteristics of language with attention to the content or contextual meaning of the text [56]. It is widely used in social sciences for

extracting themes and patterns from the sources, which can be meetings transcripts, narrative responses, open-end survey questions, interviews, printed media, emails, scientific papers, among others [56].
In the process of collecting and examining the data, there is no explicit need for the contact between the researcher and the person directly involved in the study (for example stakeholders, consumers, experts), so this method can be an unobtrusive and inexpensive procedure [55].

3.3.1. Phases of the process

CA includes a series of stages that one should go through in order to insure the validity and rigor of the process [57]. A first set of steps corresponds to the 'Preparation phase', which involves the data collection method, the sampling strategy and the selection of the unit of analysis. The second set, 'Organization phase', includes categorization and abstraction, interpretation and representativeness. The third set, 'Reporting phase' includes, the reporting of the results and of the process analysis.

Seen that there is a great variety within the approach of CA and also that this step comprises a higher degree of subjectivity, it is relevant to clarify the followed stages and different approaches.

3.3.1.1. The Preparation phase

In the 'Preparation phase' both the data collecting method and the sampling strategy can be performed using different techniques, for example classical SLR guidelines and search protocols.. The selection of a suitable unit of analysis should take into consideration the purpose of the study and the research questions. The meaning unit can correspond to a whole document (article, letter), a portion of the pages, a sentence or a word. The right unit choice balances the breadth, if it is too broad might be difficult to manage and establish a coherent meaning; and the narrowness, if it is too narrow it can result in fragmentation of the evidence [57].

3.3.1.2. The Organization phase

In the 'Organization phase' the main challenge is to deal with the diversity of the collected data. An adequate number of categories needs to be established, if there are too many classes it means that the coder has been unable to group the concepts and there is a high probability of overlapping categories; in the opposite case, a scarce number of categories indicates that the researcher is incapable of finding relevant differences and classify them as different. In these cases, the analysis must evolve in the sense of finding similarities between classes, in the first situation, or search for attributes that can distinguish them, in the second [57]. The establishment of categories is subject to some degree of interpretation when approaching a text [58]. Conformability is the criteria used in this context and it exists when

the written data is accurately represented by the interpretation of the inquirer. To ensure a conform analysis and sound interpretation of the data, the analysis should be performed by at least two researchers [59]; this criteria is also relevant in the case of intracoder reliability discussed in a subsequent section.

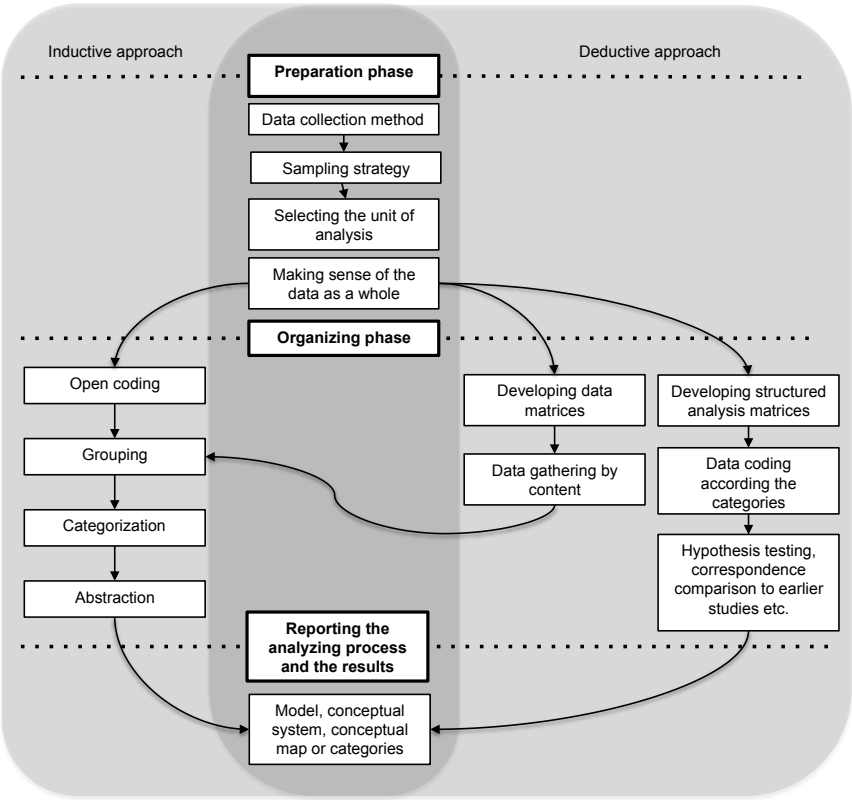


Figure 3.1 – Inductive and deductive Content Analysis approaches (adapted from Elo & Kyngäs [60]).

3.3.1.3. The Reporting phase

The final stage of CA can be sometimes overlooked or underestimated but its value is considerable, only with systematic and comprehensive reporting is it possible to have a successful analysis. Depending on the final purpose of the analysis, the report can simply contain the concepts that were identified or, in addition, it can contain their hierarchy, and possible connections or relationships. Although CA does not have an explicit technique to connect concepts [61] this is achievable.

In the final remarks one should evaluate if the selected categories cover the diversity of the data (if there was an exhaustive analysis and category creation), if they are not redundant and if the relationships give valuable insight to understand the context [56].

3.3.2. Inductive and deductive approaches

Beyond being a quantitative or qualitative method, CA can also be used in two different conducts: inductive or deductive. The decision of using one of these is dependent on the purpose of the study. Inductive CA is used when there is not much previous knowledge on

the subject or if this evidence is fragmented. Deductive CA is applied when former evidence exists and it is this evidence that guides, operationalizes and structures the analysis [60, 62]. In an inductive analysis one goes from the specific to the general, the gathering of small parts leads to the formation of broad and coherent classes. The deductive process goes from a previous theory or model and searches for the detailed [60, 62].

3.3.2.1. Inductive

The inductive process involves activities like open coding, making notes and headings upon reading of the texts, free creation of categories – abstraction [58]. Next to the open coding, there is already a sense of the general message present in the text. The task that follows entails the grouping of these categories into higher order headings [63]. Category creation is based on observations that are similar, related or that can be seen as belonging to the same issue, in other words, a category is a group of content that shares a commonality; each category is labeled using content-characteristic words [54]. Ultimately when a set of categories is established, that describes a phenomenon and increases the understanding on that subject. The categories are organized in an hierarchical structure with a main, generic and sub-categories, for example in the domain of Population Health a main category might correspond to “Outcomes”, a generic category to “Mortality” and a sub-category to “Life expectancy” or “Mortality rate” (Figure 3.2). The organization of the free nodes into a hierarchical structure corresponds to the process of axial coding [64].

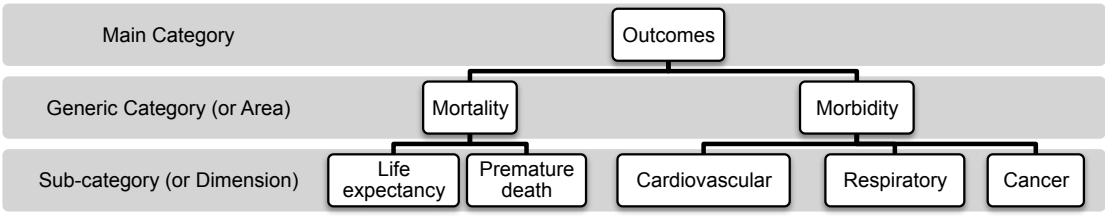


Figure 3.2 - Illustrative example of main, generic and sub-categories (adapted from [60]).

3.3.2.2. Deductive

In a deductive analysis the objective is to test the already established categories, concepts, mind maps, literature reviews or theories. It begins with a categorization matrix or similar structure and the coding is performed according to those categories [65]. The process is guided by previous work and intends to confirm or reject those findings. The matrix can be either structured, with precisely defined categories, or unconstrained, with a set of boundaries within where the categories can be created [60]. For a structured categorization there can be search for features from the data that fit the categorization framework or, instead, to select those that don’t. Thus, aspects that do not correspond to the categories frame can be grouped into new categories, using the principles of inductive content analysis [60].

In most cases, an inductive CA is applied when there is no previous findings on the subject or when knowledge is too fragmented to be conclusive. Conversely, a deductive CA is suitable if the goal is to evaluate a prior hypothesis or to compare categories in a different context [60].

3.3.3. Intracoder and intercoder reliability

The two types of reliability present in CA ensure the ability to have a systematic appraoch during the coding process (intracoder) and between different coders (intercoder).
Most authors advocate that qualitative analysis should use at least two independent coders since it will generate more robust results and reinforce the validity of the coding instrument [66]. In some cases a third partaker intervenes when there is a disagreement between the other two; normally this is only performed after the conclusion of the coding process, although there is encouragement to implement it in a pilot-testing phase and in defined intervals, to catch and correct any divergences in the coding and debate doubts that might exist.
Intracoder reliability requires that application of the same criteria throughout the whole procedure should be verified by having the same coder recode a subset of the data sample to ensure that the coder has not altered the coding decisions over time.

3.4. Concluding insights

Taking into account the methods just reviewed, some challenges are evident. The broad definitions of concepts and the high subjectivity inherent to all of the previously reviewed methods hamper their validity. The tasks performed are time consuming and laborious with a low reliance in analytical tools. To face these challenges, transparent and more automated methods are needed.

Considering this literature review, in the next section is proposed a multimethodology to structure the concept of Population Health, making use of the previously examined methods.

4. Multimethodology

This chapter presents the argument for the use of a multimethodology for the synthesis and structuration of complex and multidimensional concepts, analyzing advantages, shortcomings and challenges. The applicability to the topic of Population Health is also discussed. The selected methods designed within the multimethodology are presented and their function is clarified. The application is then applied to Population Health.

A protocol is developed, consisting of three parts: Preliminary Literature Review, Content Analysis, and Systems Mapping. In the Preliminary Literature Review the research questions and the associated strategy are presented. The inclusion criteria and the categorizations executed are also described. The Content Analysis will include the identification and structuration of the relevant dimensions, a search for co-occurrences in the same scope and an investigation to gain further insight into the nature of possible relationships. Finally, proposes a validation, structuration and aggregation procedure according to the final goal of the representation of the results in a Systems Map format. At the end of the chapter the implementation using different software as well as their integration are presented.

4.1. Why a multimethodology?

Given the objectives of this thesis, a novel multimethodology is proposed.

A multimethodology approach has been described as: “The essence of multimethodology is to utilize more than one methodology, or part thereof…within a single intervention.” [67]. Here a methodology is depicted as a set of guidelines or activities to assist in undertaking research.

The reasoning behind the use of multiple methodologies is related to the fact that real world problems are multidimensional; with it comes a richness and complexity that can be dealt with through various intervention stages [67, 68]. The process normally goes through varied platforms with different tasks and even if the distinct methods adopted perform similar operations, it can be used to bring about new insights into the problem as well as produce more reliable results [44].

Firstly: the multidimensionality of PH, which was described in previous sections, the concept entails both determinants and outcomes that have various levels of aggregation and are related to each other in non-linear fashions. Secondly, in order to define relevant dimensions and to accomplish the structuration, it is necessary to go through multiple approaches and, by doing so, complement the current understanding about the subject.

It is within this setting that a multimethodology including a Systematic Literature Review, Problem Structuring Methods and Content Analysis is proposed as a means to define, structure and identify relationships within the concept of Population Health (Figure 4.1).

Content Analysis will enable the identification and interconnection of relevant dimensions. Problem Structuring Methods will provide the tools and insight for dealing with the complexity of PH, the structuration and the relations between the multitudes of existent dimensions.

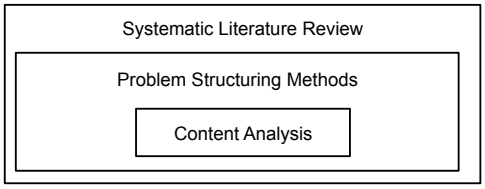


Figure 4.1 - Representation of the methods used in the multimethodology.

And finally, the aforementioned methods will contribute to the Systematic Literature Review, which provides a systematic and objective way to summarize and consolidate the evidence on the area of Population Health.

4.2. Protocol

The multimethodology consisted of 3 phases: a Preliminary Literature Review, followed by a Content Analysis and concluding in Systems Mapping. Although it is presented as a linear process (Figure 4.2 and Figure 4.3), it is carried out iteratively. In each iteration, taking into account the results obtained, adaptations and improvements can be done.

The multimethodology starts with a Preliminary Literature Review. In this analysis, a studies sample is gathered following the main guidelines of a SLR, followed by a study categorization, these categories are used to provide an overview of the PH literature, basic concepts and context, as well as to serve as basis for the subsequent Content Analysis.

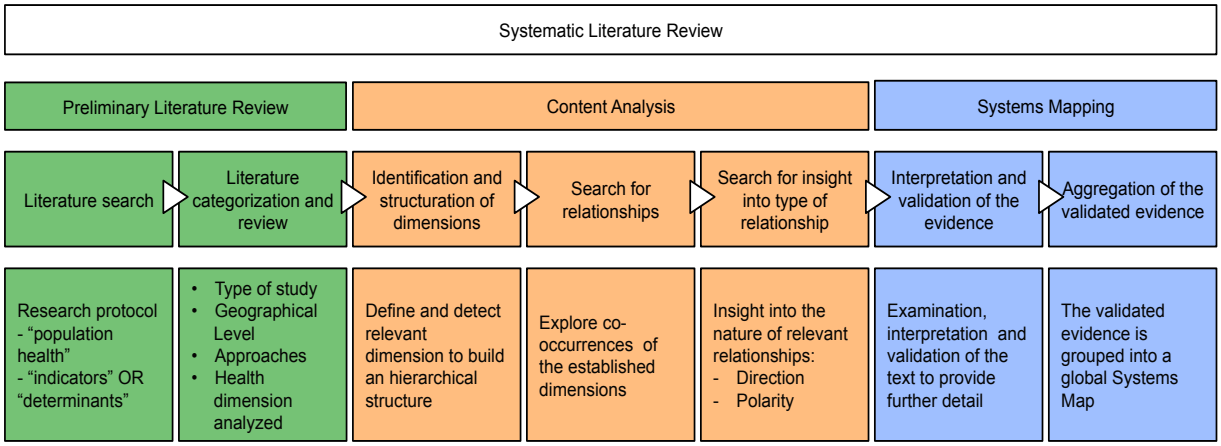


Figure 4.2 – Multimethodology overview.

In a second phase, Content Analysis is applied to construct a hierarchical structure containing all the relevant dimensions, using both a deductive and inductive approach, throughout the coding development. Afterwards, searches to find relationships are performed. The results are then presented in the form of a graph, where the nodes represented the dimension/areas. With this representation it is possible to complete a series of analysis assessing the most relevant dimensions in a holistic manner. The most relevant relationships are further examined. It is searched for insights into the nature of some of these possible relationships.

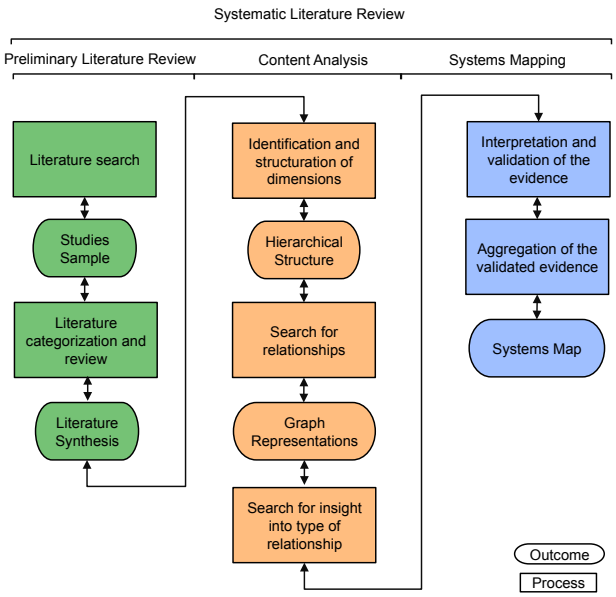


Figure 4.3 - Multimethodology outline.

Lastly, in the Systems Mapping, the relationships are examined to check that the process is able to find accurate evidence. Based on the validated relationships, the evidence is synthetized in one table for later representation of the global Systems Map. Each of the methods will now be described.

4.2.1. Preliminary Literature Review

The first stage of the multimethodology provides a studies sample upon which it will be developed a comprehensive literature synthesis and a subsequent Content Analysis.

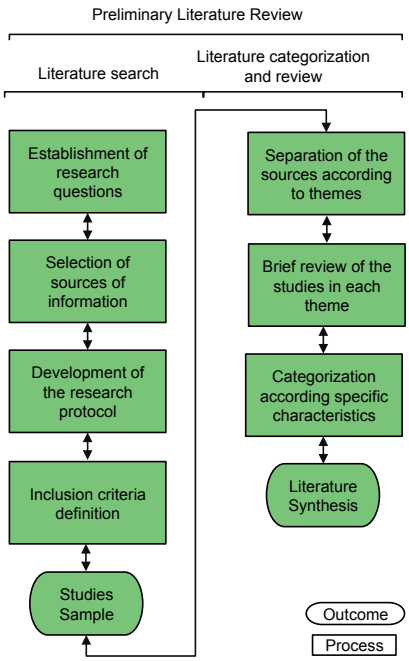


Figure 4.4 - Overview of the Preliminary Literature Review module.

4.2.1.1. Literature search

4.2.1.1.1. Research questions

The central research questions of the review are:

1) What dimensions are relevant in the context of Population Health?
2) What are the relationships between the different dimensions?
3) What is the focus of the literature in the area of Population Health?
4) What methodologically approaches are in the area of Population Health?

4.2.1.1.2. Sources of information

For this literature review, only international databases are used. The following sources are included in the review: ISI Web of Science, Science Direct and PubMed. The search was performed in February of 2015.

4.2.1.1.3. Search protocol

The purpose of the literature review is to find a comprehensive body of literature, to be broad enough as to include the wide range of approaches that exist in the Population Health field and answer to the research questions. In pilot-tested search strategies the number of results was too vast to be feasible and to restrict the number of results obtained. The term "Population Health" had to be present in the title, along with the terms "determinants" OR "indicators" in the topic, since these two last terms are sometimes used interchangeably (Table 4.2).

Table 4.1 - Exploratory searches and respective number of results.

Search Protocol	N. of results
TOPIC: ("population health")	16,613
TITLE: ("population health")	1,812
TOPIC: ("population health") AND **TOPIC**: (concept OR definition OR term)	1,392
TITLE: ("population health") AND **TOPIC**: (concept OR definition OR term)	226
TITLE: ("population health") AND **TOPIC**: (concept OR definition OR term) AND **TOPIC**: (determinant)	43
TITLE: ("population health") AND **TOPIC**: (concept OR definition OR term) AND **TOPIC**: (determinant) AND **TOPIC**: (outcome)	22
TITLE: ("population health") AND **TOPIC**: (concept OR definition OR term) AND **TOPIC**: (determinant) AND **TOPIC**: (outcome) AND **TOPIC**: (policy)	11

Exploratory searches are performed (Table 4.1) defining the final scope of the review in order to have a feasible number of results to analyze.

Table 4.2 - Search protocol.

Search Protocol
• **TITLE**: "population health" • **TOPIC**: "determinants" OR "indicators" • **Timespan:** All years • **Language:** English

4.2.1.1.4. Study selection

Given the objective of the study, the selection of studies was based on the following inclusion criteria:

- ✓ Overall assessment of the state of human health;
- ✓ Analysis at the population level;
- ✓ Includes insight into the role of determinants;
- ✓ Focus on population health.

Studies that would only focus on a particular disease or condition were excluded; the present study is concerned with the overall evaluation of health and not with specific illnesses that might affect it. The focus was only on studies that would analyze health at the level of a population; this population could be defined by an array of different criteria (by a geographical area, served by the same provider, of the same ethnicity or other common characteristic) and all the individual appraisals of individual health were excluded.

Since the role of determinants in the health of a population is considered essential, the studies included had to approach the discussion of one or more determinants.

Finally, the studies were screened on the basis of their context, only those that would fit in the Euro Healthy project context [3] *i.e.* that focus on European regions.

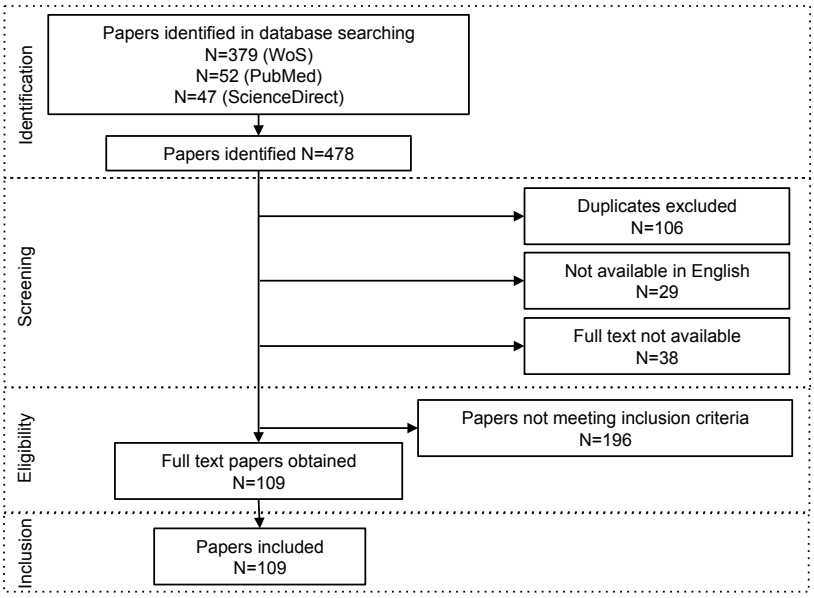


Figure 4.5 - Literature search flow

4.2.1.2. Literature categorization and review

The studies were divided into categories that were created upon reading and analyzing of the collected studies. These categories were further analyzed and synthesizing the literature in each category. The defined categories and respective descriptions are:

- Population Health Concept – discusses what Population Health should be concerned with, analyzes the general relationships between the 3 main components. Debates who should be involved in PH, its challenges, critiques and limitations.

- Population Health Policy – analyzes how to develop and choose the proper set policies, according to the necessities of a population, how to implement and communicate them, their limitations, challenges and impact;
- Population Health Approaches – proposes diverse approaches to operationalize, measure or intervene in the field of Population Health, it may include Rankings, Health Impact Assessment, Risk Management;
- Population Health Determinants and Outcomes– original or review; studies a population using publicly available or self-collected data in order to find relationships between different determinants and health outcomes. These can be focused on different areas such as natural environment, healthcare services, social status or cultural values.

In Figure 4.6, the four categories will be included in the literature synthesis and later PH Determinants and Outcomes will be used in the Content Analysis, after a categorization into three geographical levels.

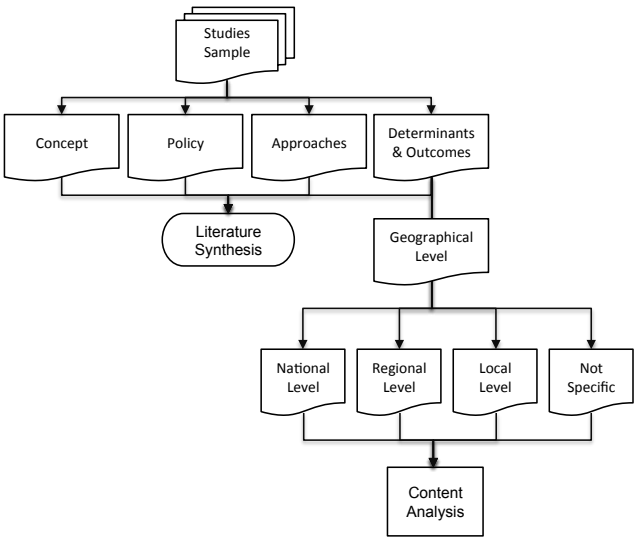


Figure 4.6 - Organization of the studies into categories.

4.2.2. Content Analysis

In the present section, the role of CA in the identification of relevant dimensions and the search for insights into their relationships is detailed. Firstly, relevant dimensions are identified and organized into a hierarchical structure, allowing the search for their co-occurrences within the same scope, which is translated into the representation of an undirected weighted graph. The analysis of the graphs enables gaining further insights into possible relationships present in the literature. Lastly, the context of the relationships that are considered the most significant is examined. This whole process is iterative; in each iteration, improvements are made to the structure, terms searched and results presented.

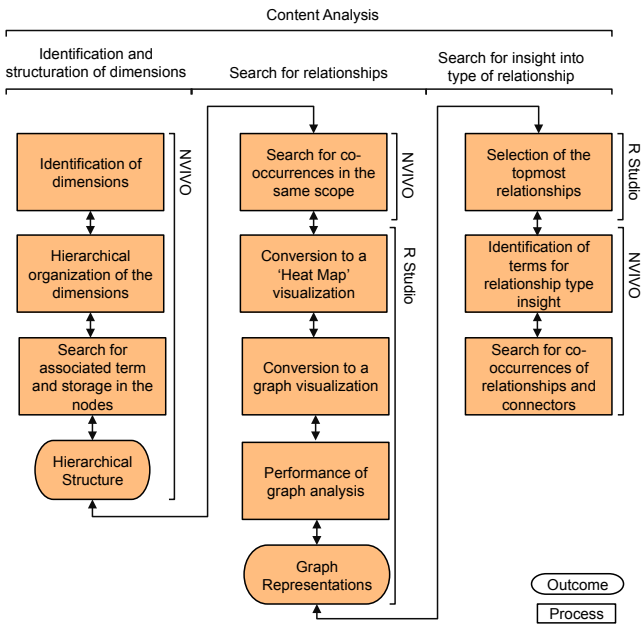


Figure 4.7 - Overview of the Content Analysis module.

4.2.2.1. Identification and structuration of dimensions

Using deductive CA, existing indices (in the present case, GeoHealthS [69] and County Health Rankings [22]) were used as a basis for the construction of an initial structure. If it was verified that a dimension was present in the literature data, it was left in the structure, if not it was removed. To have an exhaustive analysis, dimensions were further identified through the process of inductive CA. To aid this search, consecutive text searches are performed to find occurrences of those dimensions in the data.

The search uses operators that allow to capture diversity of concepts with varying terminations (Table 4.3). Initially, to develop the list of terms for each dimension, attempting to seize this diversity, exploratory searches are performed to find stemmed words or synonyms.

. Table 4.3 – Search operators and examples (adapted from [70]).

Option	Example	Comment
Wildcard ?	Role?	? represents one arbitrary character
Wildcard *	Teen* parents	* represents any number of arbitrary characters (for example, teen and teenage are found)
AND	Road AND Safety	Both words must be found
OR	Smoking OR Tobacco	Either of the words must be found
NEAR	"Air quality"~3	Air and quality are found within 3 words from each other

An example of the diverse and associated terms that can be linked to a dimension is presented in Table 4.4.

Table 4.4 - Example of the dimension and respective search words.

Dimension	Search words
Teenage Parenting	"teenage parent*"~4 OR "young parents"~4 OR "teen parents" OR "teenage pregnanc*"~4

Structural changes can happen throughout the process, which is adapted, completed or simplified, depending on the result of the previous iteration and the desire to go into further detail or simplification.

From this identification the total presence of dimensions in the data sample is analyzed.

4.2.2.2. Search for relationships

Once the structure of concepts is established, relationships between the dimensions are explored. Here it is intended to determine if two coded dimensions are present in the same scope. In this context, scope can be a set of documents, an entire document, a page of a document, a paragraph or a sentence. It is also possible to count the number of times this co-occurrence happens and store it in the form of a matrix. This analysis permits some quantitative assessment and, particularly, the possible importance of the relationship between dimensions.

In practice, every time the pair of dimensions [$Dimension_i$, $Dimension_j$] is coded within the same scope, the number in matrix cell $h_{i,j}$ is incremented by 1. Since here there is no concern with the antecedence or precedence of terms, if the position $h_{i,j}$ is incremented, the same will happen for the position $h_{j,i}$, and so the resulting matrix will be symmetrical.

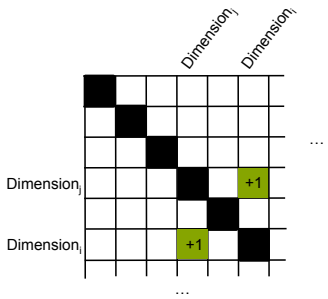


Figure 4.8 – Schematic representation of the co-occurrences storage in matrix format.

As it is argued and applied by Yearworth & White [68], the defined scope is the paragraph. The choice results from the compromise between the option between setting the scope as the whole document, which would produce unreal relationships, and the scope as the sentence which would be ideal in this context but it is not possible using the selected tools. An alternative would be word count, where the search is performed within a certain number of words away from the coded dimension. The number is established by the researcher; this would identify relationships that trespassed both sentence and paragraph boundaries. The assumption made here is that in scientific writing, one paragraph corresponds to one, and for

that reason it is valid to consider that two dimensions present in the same paragraph belong to the same line of argument.

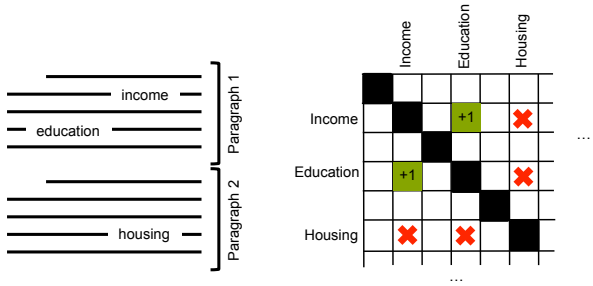


Figure 4.9 - Representation of the increment in the matrix
(according to de defined scope – the paragraph).

As a result a matrix *nxn* is obtained where *n* corresponds to the number of dimensions/areas analyzed and the entries are the number of times two dimensions appear in the same scope. The counts reveal the presence of possible relationships, but the fact that they are present in the same scope does not mean that they are necessarily related. In the case that there is a relationship this process does not establish or clarify anything about the nature of that relationship. These concerns will be explored in more detail in the next steps.

The matrices are initially visualized in the form of a 'Heat map', revealing the intensity of the possible relationships present between two dimensions, the darker the square is, the more times the two dimensions have been counted in the same scope. In the multimethodology proposed by Yearworth & White [68], the resulting matrix is used to directly build a Causal Loop Diagram, through the direct investigation and interpretation of the content. Alternatively, in this work the generation of graphs is achieved, following the suggestion by the same authors to use the matrix of counts as a binary matrix (or adjacency matrix) for subsequent visualization (Figure 4.10). An adaptation made here is related to the conservation of the counts in the matrix (translated into edges weights) that will later be used to award relative significance to the relationships. The edges' weights will also condition the spatial organization of the graph. The result is an undirected weighted graph.

	A	B	C	D	E	F
A		3	0	0	0	0
B	3		5	0	0	0
C	0	5		9	1	1
D	0	0	9		2	0
E	0	0	1	2		0
F	0	0	1	0	0	

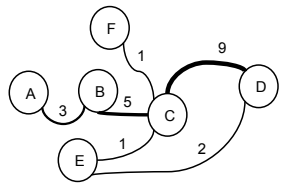


Figure 4.10 - Illustrative example with the binary matrix describing the graph
(adapted from Yearworth & White [68]).

The resulting graph has a very high density, not being able to provide any valuable insight. The reason is that the method generates a connection for any matrix entry that is non-zero. So the reasoning is the following: the higher the number of counts, the more probable it is to exist a relationship, it is valid to discard those entries that have few counts and to establish a threshold for considering a possible connection relevant. Deciding on what constitutes a

meaningful threshold, similarly to what was done before, is a heuristic developed by the coder because the alteration of this value will affect the number of potential relationships to be analyzed. To aid this decision, the number of connections obtained for a range of thresholds are plotted.

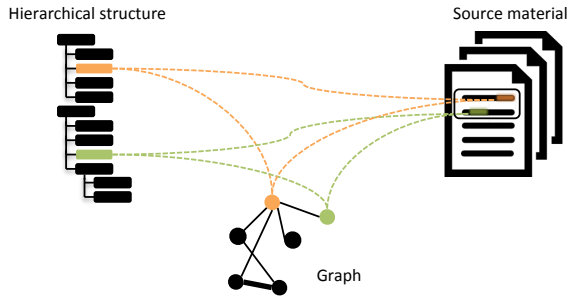


Figure 4.11 – Schematic representation of the relation between the studies, the hierarchical structure and the graphs.

After a graph is obtained (Figure 4.11), some analyses are performed and are hereafter described:

- Area analysis – In order to study only the relationship between the areas, these have the aggregated coding of the descendent nodes, i.e. all the coded text of its sub-categories.
- Area dispersion analysis – This had the intention of determining what areas are more present and to uncover if there are any area pattern present. To each dimension is associated a color linking them to their respective area.
- Node connectivity analysis – It establishes the most connected dimensions. The degree of a node corresponds to the number of connections the node is linked to. This attribute can be displayed using the relative size of the node, i.e. the size of each node is proportional to its degree. In this case there is taken into account only the number of connection and not its weight.
- Geographical level analysis – Making use of the categorization that was performed previously; it is possible to aggregate the studies into groups with different geographical levels. As it has been seen, the is a lot of diversity in the geographical scope applied and it is not always clear, for this reason, these were clustered into three different levels as it is presented in Table 4.5.

Table 4.5 - Groups of geographical levels considered for PH literature

National	Regional	Local	Not Specific
Country State	Region County Province District	Community City Neighborhood	Geographical Level is not specified

4.2.2.3. Search for insights into type of relationships

This step envisioned improving the knowledge about the possible relationships. In this sense, it is searched for connecters that would give a clue as to what was the type of relationship between the most relevant relationships previously identified.

The approach implemented was to screen the surroundings of selected relationships adopting the same scope as before. The search was performed for different types of connectors.

An exhaustive list of terms was completed to capture insights on the direction of a relationship:

1) Undirected, when the term do not indicate that there is a direction of action from a dimension to the other;
2) Directed, when a direction from one dimension to the other is implicit in the text.

The terms are presented in Table 4.6 together with the search strategy used.

Table 4.6 - Search words used to find direction evidence.

Undirected		Directed			
Association	assoc*	**Influence**	Influenc*	**Relevance**	Relevan*
Relation	relat*	**Lead to**	“lead to”	**Significance**	Significan*
		Impact	Impact*	**Causation**	Caus*
		Improvement	Improv*	**Generation**	Generat*
		Promotion	Promot*	**Motivation**	Motivat*
		Significance	Contribut*	**Increase**	Increas*
		Play a role	“play? a role”	**Decrease**	Decreas*
		Affect	Affect*	**Change**	Change*
		Effect	Effect*	**Determination**	Determ*

Following the first search, another similar search was performed but this time it was performed using terms that would indicate the polarity of the relationship.

A list of terms was completed to capture insights on the polarity of a relationship (Table 4.7):

1) Positive, A has a positive influence on B if a change in A results in a change in B in the same direction;
2) Negative, A has a negative effect on B if a change in A results in a change in B in the opposite direction.

Table 4.7 - Search words used to find polarity evidence.

Positive and Negative			
Positive	Positive	**Negative**	Negative
Increase	Increas*	**Decrease**	Decreas*

Since it is not possible to separate terms that are exclusively affected to a specific polarity (positive or negative), the search is conducted in a way to find general evidence of polarity. In subsequent steps, the establishment of positive and negative relationship will be achieved.

4.2.3. Systems Mapping

In a final examination, the analysis of specific relationships in the text is performed and the evaluation whether the identified evidence corresponds to a relationship. The validation is done in terms of direction and polarity. After, the validations are gathered in order to conclude on the polarity and direction of each relationship. Finally the collected data is translated into the form of a Systems Map. This step is essential in order to consider the validity of the methodology and suggest future improvements for the future.

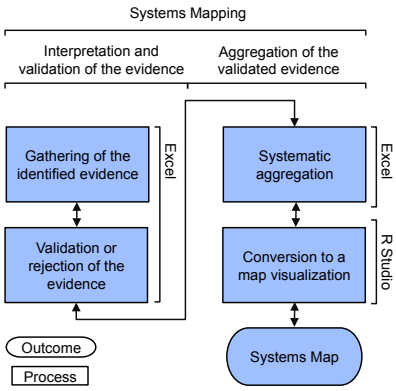


Figure 4.12 - Overview of the Systems Mapping module.

4.2.3.1. Interpretation and validation of the evidence

The evidence is gathered in the same platform and its subsequently validated or rejected. This validation in performed by the researcher for each of the distinguished attributes - polarity and direction.

4.2.3.2. Aggregation of the validated evidence

Taking into account the validations that result of each attribute, the overall evidence is assess and conditions are checked (Table 4.8). For different applications, the attributes can be adapted as well as the aggregation criteria.

Table 4.8 - Aggregation criteria.

Attributes	Aggregation Criteria
Direction	- Directed - In the case that there is any evidence of a direction between two dimensions, this evidence is preferred and displayed, - Undirected - If there is no evidence of a direction and there is of an undirected relationship, this one is displayed.
Polarity	- Positive – If the number of validated evidence of a “positive” relationship is greater than the number of “negative” relationship evidence then, the “positive” is selected, - Negative – If the number of validated evidence of a “negative” relationship is greater than the number of “positive” relationship evidence then, the “negative” is selected, - Uncertain - If the number of validated evidence of a “positive” relationship is equal to the number of “negative” or if there is no validated evidence relationship evidence then a question mark is displayed.

Geographical Level	- When there is any validated evidence that the present relationship is present in a geographical level, that evidence is displayed.

4.3. Implementation

For implementing the previously detailed multimethodology, three software were used: NVIVO, R Studio, Excel and FreeMind. NVIVO was used for the Content Analysis, allowing the organization and analysis of the documents. R Studio served for translating the analysis performed on NVIVO into different visualizations and subsequent analysis. In Excel, the final selected evidence was analyzed and the conclusions aggregated into a single format for visualization in R Studio. Freemind was used for the visualization of the hierarchical structure.

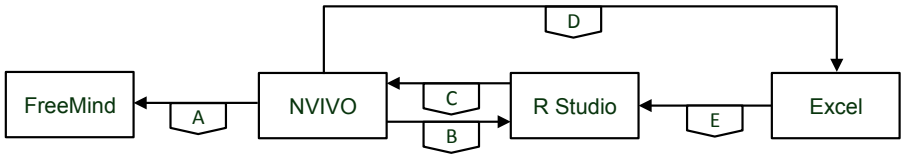


Figure 4.13 - Interconnection between the tools.

The interconnection of the three tools is represented in Figure 4.13. For visualization purposes, the structure obtained on NVIVO [11] was exported to the software FreeMind [71] (A, in Figure 4.13). NVIVO [11] is used to develop the hierarchical structure, this task is assisted by the 'Word Frequency query' of NVIVO [11] in order to identify the most frequent terms in the sample. The following step, the storage of the coded terms in the nodes, is performed using the 'Text Search query' with the search terms detailed in Annex B. For the definition of the terms, exploratory searches are performed using the software ability to find stemmed words and synonyms. NVIVO [11] also allows the organization of sources into sets; this capability is used to divide the sources into separate geographical levels (Local, Regional, National and Not specific, The Not specific although it will not be analyzed individually, it will be included in the global analysis).

Next, establishing the co-occurrences is possible through the use of the 'Matrix Coding query' with the columns and rows selected as the identified dimensions. The input included in the software are:

1. ''Search Criteria'' -> ''NEAR content''
2. ''Proximity Parameter'' -> ''In Custom Context''
3. "Specify" -> ''Surrounding paragraph''.

The 'Matrix Coding query' was applied separately to the subsets of studies, the reasons were twofold: firstly it allows obtaining separate matrices for each geographical level (permitting separate analysis) and the software did not have the capacity to analyze all of the sources at the same time. The counts matrices were exported to R Studio (B, in Figure 4.13). This enabled the handling of the matrices, allowing several visualization possibilities and thus various analyses. As a first step a 'heat map' was generated using the function *heatmap.2*,

which enables an easier appraisal of the matrix. The matrix reveals the intensity of the possible relationships present between two dimensions: the darker the cell is, the more times the two dimensions have been counted in the same scope. Using the function *graph.adjacency*, graphs are generated. For this step the matrix diagonal is deleted, seen that the algorithm used detects terms in the same paragraph, being evident that one term belongs to the same paragraph as itself, and these entries would only cause irrelevant self-loops. Due to the high density of connections present, thresholds are set (specific to each sample of studies) and all the connections with an inferior number of counts are deleted. Moreover, the coloring of each node was programmed according to the area they belong to, and the size of the nodes was defined in proportion to the number of connections they have with others, using the node functionality 'degree'. Another option is to only display the areas and observe their relations.

Once the analyses are performed from each geographical level, the top 9 strongest relationships are identified analyzing the matrices using R Studio. The selected relationships are manually inserted into NVIVO [11] (C, in Figure 4.13). In NVIVO, is performed an assessment of connectors that can provide insight into the type of relationship present. These last two tasks come together in a second 'Matrix Coding query' where the rows correspond to the relationships and the columns to the possible insight it can provide. The established scope is the same.

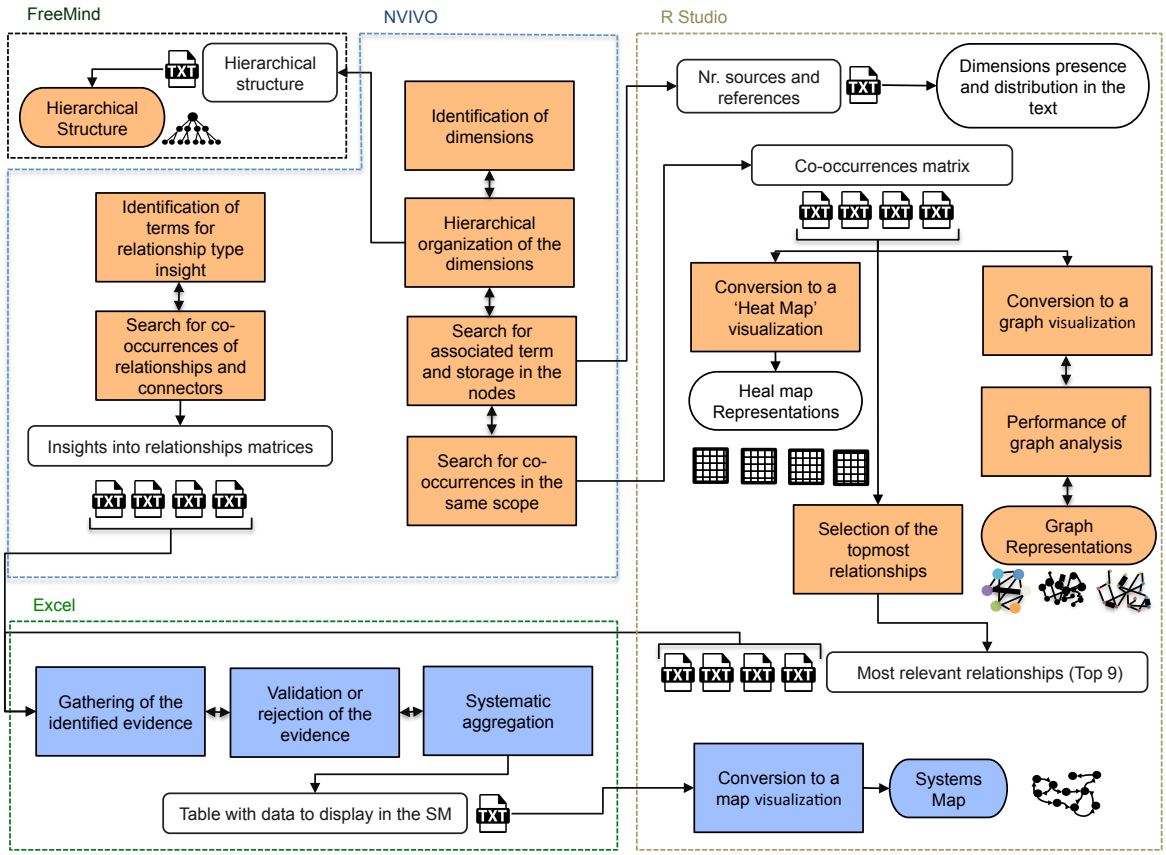


Figure 4.14 – File management between the software.

The matrices are imported to Excel in order to provide the relationships and the number of identified evidences ("import" in Figure 4.15). The evidence itself is copied from NVIVO to cell is Excel (D, in Figure 4.13). In the case that it is confirmed, the cell is colored green and in the case that is not, the cell is colored red ("validation" in Figure 4.15). All the validated evidence is gathered, according to the conditions presented in Table 4.9, and the end result is summarized in a table ("aggregation" in Figure 4.15). In this step, basic VBA functions were used to enable the import of the data from files and the counting of the colored cells.

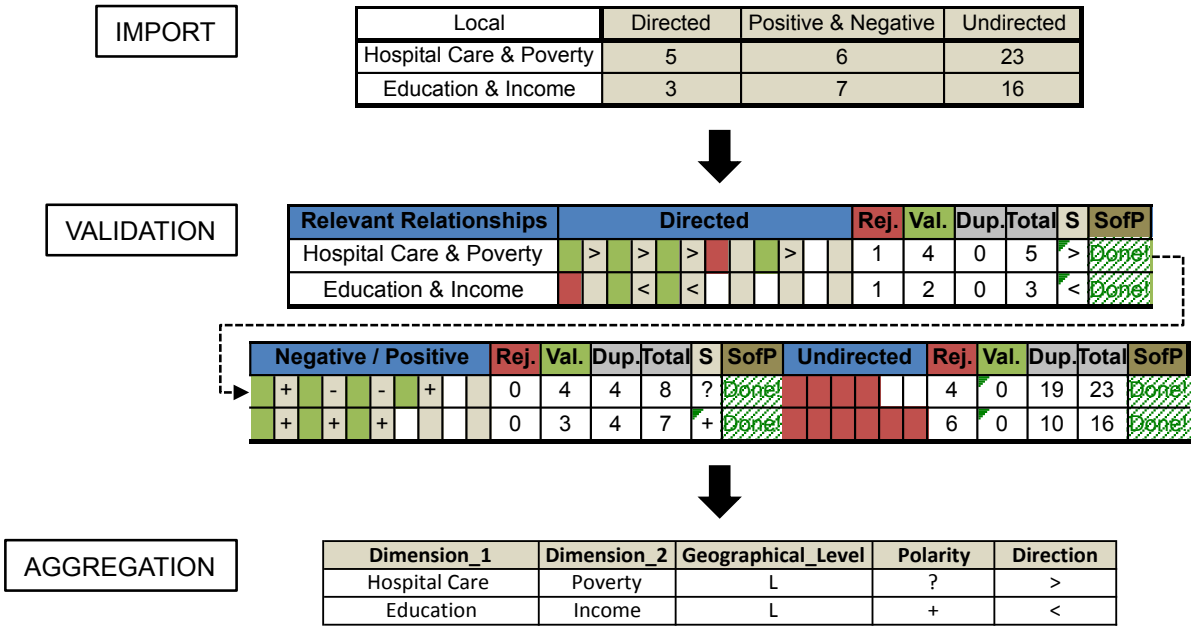


Figure 4.15 - Illustrative example of the validation and aggregation implemented in Excel.
(For illustrative purposes, the cells do not contain any written evidence)

The final table is then exported to R Studio (E, in Figure 4.13) were a function is programmed for reading the table, with all the relationship attributes, and according to that information displays it in a Systems Map structure.

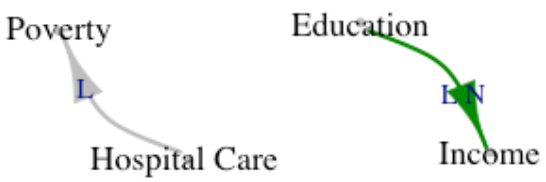


Figure 4.16 - Illustrative example derived from the information in Figure 4.15
(with the relationship between Education and Income is also present at the National Level).

In case additional evidence is found pertaining to other relationships, the collected information is set in the table format and included in the Systems Map.

.

Table 4.9 – Logical conditions evaluated for aggregation.

		Description	Logical Condition			Symbol
Direction	Directed	In the case that any evidence of a direction between two dimensions is validated, this evidence is displayed in the final map	If (nº valid "Directed") > 0	Left to Right	If the direction is believed to be from the first dimension to the second	>
				Right to Left	If the direction is believed to be from the second dimension to the first	<
	Undirected	If there is no evidence of a direction and there is of a undirected relationship, this one is displayed.	If (nº valid "Directed") = 0 & If (nº "Directed") >0			<>
	Uncertain	If there is no evidence about direction	If (nº valid "Directed") = (nº valid "Undirected") =0			?
Polarity	Positive or Negative	In the case that any evidence concerning polarity between two dimensions is validated, this evidence is displayed in the final map	If (nº valid " Sign") > 0	Positive	If the polarity is believed to be positive	+
				Negative	If the polarity is believed to be negative	-
	Uncertain	If the number of validated evidence of negative relationships is equal to the positive	If (nº valid " Sign") = 0 | If (nº " +")=(nº " -")			?
Geographical level	National	When there is evidence in the considered relationships that it is present at the National Level, Regional Level, Local Level and Not Specific Level. All the present levels are represented				N
	Regional					R
	Local					L
	Not specific					x

Given the presented methods, multimethodology and its implementation, in the next chapter it is presented the results obtained in the different stages.

5. Results

This section presents the results from applying the multimethodology as well as some interpretation. Firstly the results from the Preliminary Literature Review will be provided, covering the evaluation of the Population Health Concept, Population Health Policy, Population Health Approaches and finally Population Health Determinants and Outcomes. This overview will synthesize the different topics covered in the Population Health literature. The results from the Content Analysis it is shown the final hierarchical structure, the relative presence of the dimensions in the literature sample and the graphs representation will be presented and evaluated. In the final part, the result from the System Mapping, the Systems Map, is displayed.

5.1. Results from the Preliminary Literature Review

In this sub-section are presented the results from the Systematic Literature Review, identifying the diversity of studies developed in the field of Population Health, which include conceptual discussion, policy debate, alternative approaches and dimension examination.

5.1.1. Concept

Population Health was introduced as a complex and broad concept. What should this concept incorporate or not has been the discussion in many studies. The lack of a consensus when it comes to the definition of Population Health has given rise to the debate of "What is population health?" [14, 16, 22, 72, 73] and of related terms such as health, policy or outcomes [9]. The term 'population health' is seen as the natural evolution of the science of epidemiology and the umbrella term for 'Public health', 'Health Promotion', the determinants of health and health outcomes [72]. PH has 5 major focuses:

- ✓ Emphasis on well-being maximization
- ✓ Most equitable distribution of health outcomes
- ✓ Most favorable patterns of health determinants
- ✓ Policies as integrative action and influential in changing determinants and outcomes
- ✓ Dynamic system with non linear interaction and a network of causalities

The focus on the maximization of well being recognizes that health is dependent on more than the treatment and has given new impulse to a more comprehensive approach, moving from "avoiding disease" to "pursuing health" [16]. The determinants influence the outcomes and their distribution across the population, so the most favorable patterns are evaluated [74-76]. Policies are seen as influential on both determinants and outcomes [1]. The resulting system is dynamic with multiple non-linear relationships and a network of causalities.

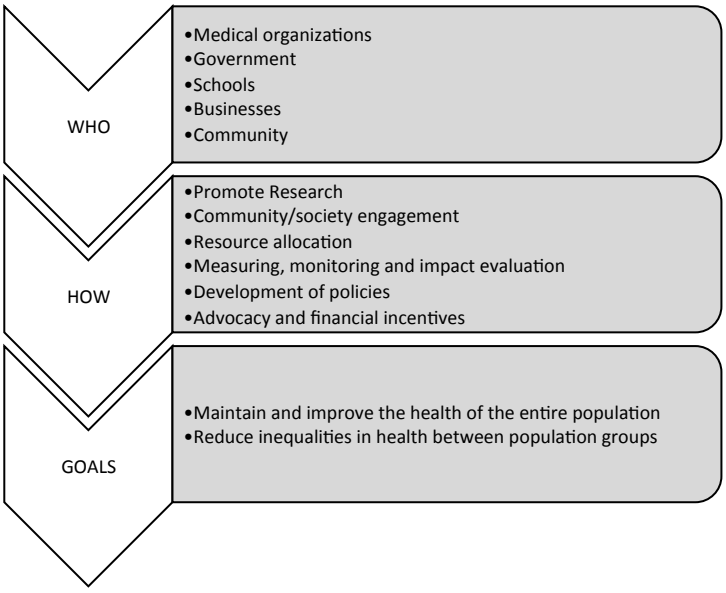


Figure 5.1 - Schematization of the stakeholders, methods and goals in Population Health

The partners involved [76-79], from medical organizations, government, schools, businesses, and community must all take action in health policy and resource allocation [77] (Figure 5.1). The support of a comprehensive population health planning is unavoidably intersectoral [76, 80]. To implement a Population Health approach it is necessary to promote action and successfully engage the different partners. In the case of research, through the development of methodologies to measure, monitor and assess the impact on PH (Figure 5.1). Other important procedures are related with community/society engagement and the establishment of financial activities.

Limitations are identified at the level of the analyses where the determinants of health are examined at the macrolevel, excluding the microlevel, where conceptualization is possible and transformation probable [7]. Some argue that the definition and concept of PH is so broad that it includes everything and thus is not useful for guiding research or policy; however, a counter argument is delivered stating that a single determinant, outcome measure, or policy intervention are relevant, and may be valuable in certain situations, but must be recognized as a part of the whole of PH [1]. Butler criticizes the so called “Health Determinism” as it reflects a “deterministic way of thinking that ignores the complexity of relationships and potential adaptations” and the view of determinants as immutable [16].
It is also argued that there is a lack of context to the determinants of health (“context stripping” [8]) and leaving a reality divided up into few discrete variables and an attempt to connect them as a proxy for the real world. The argument is that reality is more layered than the simplified frameworks and knowledge is always specific to the perspective that produces it, and it is consequently always partial [7]. Others critique the utilization of the new term of PH as a false alternative of Health Promotion [81].

In this context it is also debated by some authors that the relationship between individual and population health cannot be seen as independent. They sustain that there is a dynamic and context dependent bond between both [72, 82].

5.1.2. Policy

The study and development of methodologies is fundamental to inform policy and intervention programs. Their successful communication and implementation increase their ultimate impact in the health of a population.

Table 5.1 - Populations Health Policy studies focus.

Study focus	References
Determinants of health	[83-91]
Frameworks for policy development and communication	[83, 87, 88]
Set of policy recommendations	[85, 89]
Promotion and relevance of research	[83, 86, 88, 91, 92]
Policy challenges and limitations	[86, 89, 90]
Determination of policy targets	[93]

In most studies there is a transversal concern with determinants of health [83-91] and a move away from the illness focused viewpoint. Policies mean to focus in factors that affect health in order to promote it ranging from education to the built environment.

Policies can be developed and transmitted in several ways; some studies analyze the best approach to do so [83, 87, 88]: from modeling the impact of hypothetical policies in complex systems, to analysis of different approaches [83, 87] or even how to deliver the message and raising awareness to health issues [88]; or even through message framing, narratives and visual images.

In two studies [85, 89] the outcomes were a set of recommendations and/or guidelines for future policy development. These arose from the evaluation of the necessity of specific population and the adaptation of interventions.

Research is a pillar of policy development; this fact is mentioned throughout several studies [83, 86, 88, 91, 92] where gaps in research are identified, methods advanced and the most relevant determinants of health acknowledged.

Policy development intends the creation of programs and interventions to impact population health, for that purpose it is necessary the establishment of targets for those policies [93].

5.1.3. Approaches

In the area of Population Health, numerous analyses have been proposed according to distinct research objectives. Classically, it entails the operationalization of concepts, production of theoretical models and quantitative or qualitative techniques. In the collected literature, several approaches were proposed (shown in Table 5.2)

Table 5.2 - Approaches in Population Health.

Main Methodological Approach	Reference
Population Health Ranking	[69, 94-98]
Population Health metrics	[4, 5, 99-106]
Payment system	[107, 108]
Health Geographical Information System	[109]
Health Impact Assessment	[110-115]
Bibliometric Analysis	[116]
Risk Management	[117-119]
Complexity Science	[120]
Data Analysis	[121-123]

Population Health ranking or composite index is a mathematical combination of several indicators or measures that result in a score. This score can then describe the entire set of indicators, and, as closely as possible, reality, enabling a comparative analysis between different regions or across time. In practice, the development of indices is a widely used approach due to the possibility to, in a summarized and simple way, communicate and interpret health and health related fields. Also, it is an important tool to aid in research, decision-making and resource allocation [95]. The potential lies in the aid to set agendas, promoting awareness and debate as well as in the establishment of a broad responsibility for population health and to depict the need for multisectoral collaboration to improve health. [96]. The choice of what indicators/factors to include should be done in light of the health problems, potential policies targets and overall context [95]. Another approach has been develop by Rodrigues et al. where a framework that includes notions from multicriteria value measurement and participatory methods to build a value- based population health index was proposed [69].

Besides the choice of dimensions to be measured, some studies have the concern to transmit not only the overall "score" of each one but also their distribution, variations in population health and geographical health inequalities [69, 98] The validity of such measures was also approached: "the development and validation of such measures for different purposes is a critical task for the field of Population Health research." [1]

Population Health metrics such as health indicators, dimensions and factors are very relevant to measure and continually monitor a population in order to obtain an insight into how the health of that population was, is and where it should be improved. The information contained in the data of the indicator set is to be converted into knowledge that can enable and promote population health [20]. Indicators taxonomies are essential in the development of knowledge and to support a clear communication and knowledge diffusion, others establish a conceptual framework for using indicators and reporting of population health [4, 5, 101, 106], determination of indicator categories, proposition of criteria for indicator selection [4, 105] by reviewing studies that assess the association between different dimension and health and revised related measures that could be used as indicators [99, 101, 103-105]. Indicators can also serve as goals to achieve in an incentive-based system for population health [21].

Table 5.3 - Health metrics study focus

	Aguilar-Gaxiola et al. [99]	Hancock et al. [4]	Lantz & Pritchard [100]	Lavis et al. [101]	Mathers et al. [102]	Nutbeam [103]	Parrish [104]	Chittleborough et al. [105]	McDowell et al. [106]	Etches et al. [5]
Taxonomy	✓								✓	
Conceptual framework		✓		✓					✓	✓
Set of indicators		✓	✓	✓			✓			
Indicator selection criteria		✓						✓		
Indicator attributes					✓					✓
Indicators review	✓			✓		✓	✓	✓		
Indicators use challenges					✓	✓				

There are some challenges in the implementation of an indicator based measurement system; these include data availability for the countries/cities/communities that are being compared [104], bureaucratic barriers between governmental departments and political interests in the definition of effective action on comprehensive national health targets [103], as well as the relevancy to the historical, geographical and sociocultural context in which the indicators will be used [105].

Lastly, Etches et al. [5] identify the characteristics of an ideal indicator. The development should be assured in consensus, and based on a conceptual framework in order to be reliable, sensitive and specific to the context. In terms of the data collection, it should be feasible to assess, capable to compare two different areas, and be collected in a timely fashion. For communication purposes, it should be understandable.

Table 5.4 - Characteristics of an ideal indicator
(taken from [5])

Attributes of an Ideal indicator	
Built on consensus	Reliable and sustainable
Based on a conceptual framework	Understandable
Valid	Timely
Sensitive	Comparable
Specific	Feasible

Other approaches are proposed. Payment systems were proposed with the intent to align financial incentives toward the goal of Population Health [108] such as concrete and prevention-oriented proposals for healthcare providers in the framework of emerging payment models and systems [107]. Geographical Information System are systems intended to collect, store, handle, analyze, manage, and represent all types of geographical data. In the approach suggested by Barnard [109],

Health Impact Assessment is developed in order to assess the impact of policies, plans and projects across diverse economic sectors; it provides quantitative, qualitative and participatory techniques to aid decision-makers make choices about options and improvements for health promotion [113]. This approach can help increase public awareness of the determinants of health, promote monitoring of these determinants, and foster cooperation among institutions [111]. Also, bibliometric analysis allowed to demonstrate the evolution in the field of PH, through the increase in publication rates related to the topic [116]. Risk management has surfaced as a significant area for the assessment and management of risks in health, classically related with the potential risk a single chemical or other toxic agent. Complexity Science [120] as an alternative to model PH. Outcomes can be evaluated as having "numerous dynamic non-linear interactions among its interconnected sub-systems or agents" [120] and the system having feedback mechanisms that adapt to interventions and make quick corrections. Policies for PH improvements should take into account these characteristics as well as the diversity of actors, determinants and contexts

5.1.4. Determinants and Outcomes

This subgroup of studies analyzed several Population Health dimensions and explored the relationship between them. Typically, recurring to statistical analysis, they intended to uncover possible relationships using publicly available or self collected data to perform their analysis.

The complete list of the studies is presented in Annex A. The determinants and outcomes present in these studies will be analyzed using Content Analysis. Additionally, due to the objective of find evidence at different geographical levels, the studies were categorized accordingly for subsequent analyses.

Table 5.5 - References Geographical Level.

Geographical Level	References
National	[124-144]
Regional	[145-150]
Local	[128, 151-156]
Not Specific	[144, 157-167]

5.2. Results from the Content Analysis

In this sub-section will be shown the hierarchical structure, followed by the presence of the dimensions in the literature sample and by the graphs generated. Different graph analyses will be presented.

5.2.1. Hierarchical structure

The final hierarchical structure (Figure 5.2) consisted of the two typical main categories, Determinants and Outcomes. As areas of the Outcomes it has both Mortality and Morbidity, and in the Determinants group comprises the most common such as Natural Environment, Built Environment, Health Behaviors, Healthcare, Socioeconomic. However, one area is new: Governance.

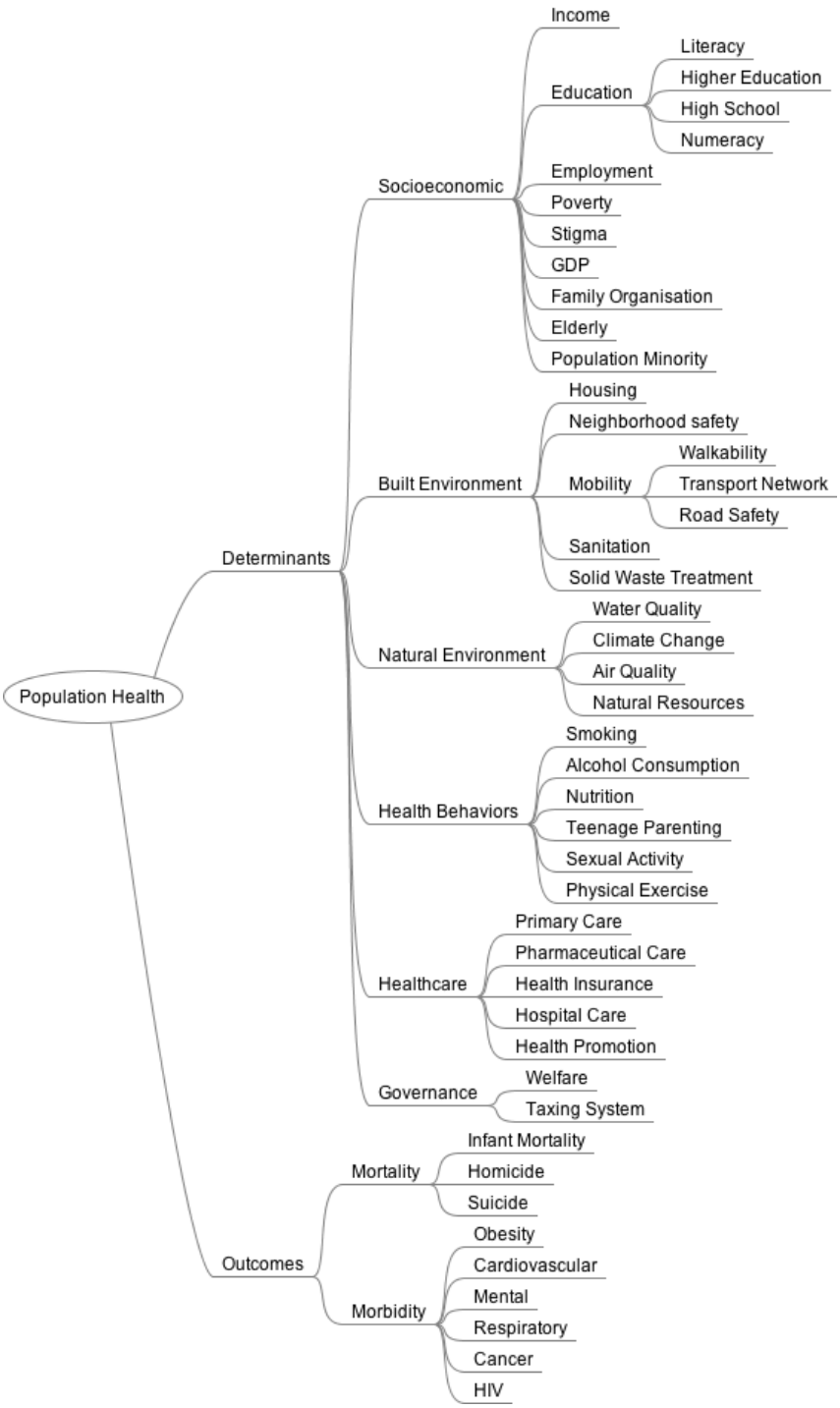


Figure 5.2 - Hierarchical structure
(using NVIVO [11] and visualization in Freemind [71]).

5.2.2. Presence and distribution of dimensions in the text

In the first analysis it is valuable to analyze the relative presence of dimensions across the gathered literature; both the total number of times the dimensions are identified as well as the number of sources where they are present is displayed in Figure 5.3 and Figure 5.4.

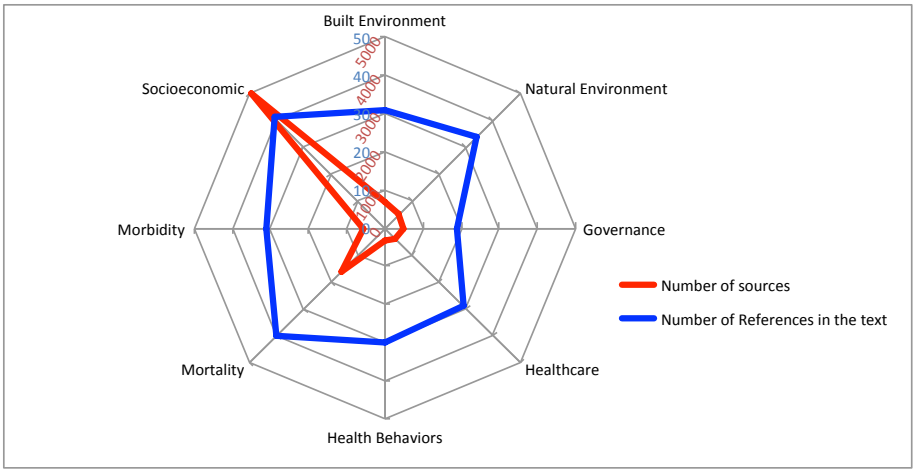


Figure 5.3 - Spider plot of the presence and distribution of the areas in the text.

Figure 5.3 presents a comparison between the presence of references in the text and presence across sources (articles) of the areas. Concerning the number of references to the Socioeconomic and Mortality dimensions, these have a superior number compared with the remaining ones, although the difference is not very relevant.

In the distribution across sources it is evident that Socioeconomic is the most represented area followed by a smaller peak from Mortality. This shows that, in most of the area, the number of references comes from a small, focused group of studies while the socioeconomic category is transversal to almost all of them.

Figure 5.4 displays the presence of references in the text and presence across sources (articles) of both dimensions and areas (Filled circle – area; Hollow circle - dimensions). Analyzing the graphic, it is possible to observe disparities between the presence of the dimensions. Due to the high dimensions density in the graphic, most of the labels were omitted, leaving only the colors that associate them to their respective area (for further analysis, the complete data is provided in Annex B).

It is evident that the more represented areas will reveal in the future more possible relationships. For example in the Socioeconomic area, namely Income will have a high probability to be related to others seen that it is very present in the studies. Conversely, Natural Environment is the least represented area, with dimensions such as Climate Change and Air Quality.

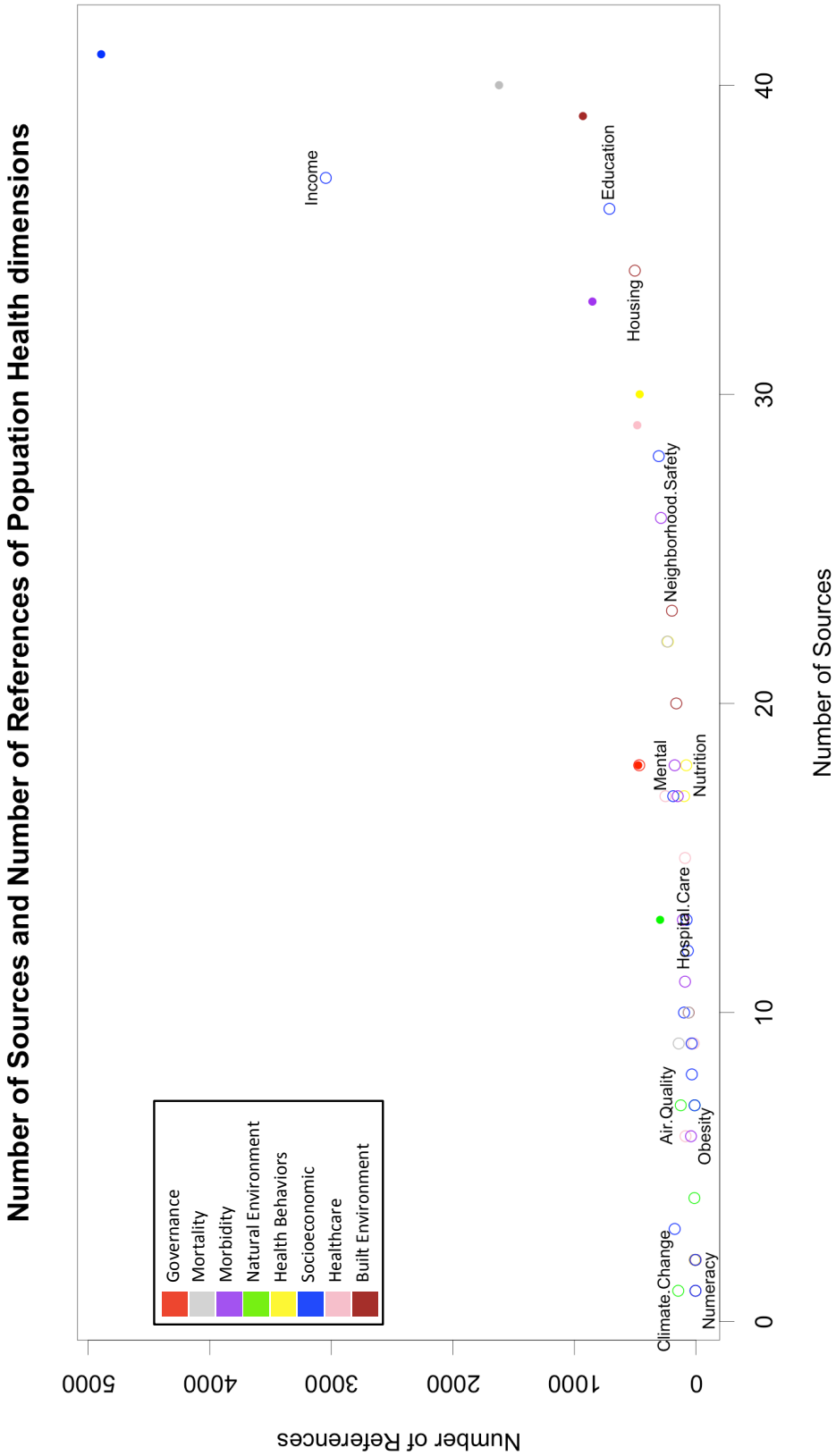


Figure 5.4 - Presence in the text and across sources of the dimensions and areas (Filled circle – area; Hollow circle - dimensions).

5.2.3. Area analysis

In Figure 5.5 all the areas are displayed, showing lines of different strengths. A differential exists in the connection between them. The link between, Socioeconomic and Mortality is the strongest; conversely, Governance and Natural Environment show a weaker connection. The size of the nodes is proportional to the number of connections it has with other nodes.

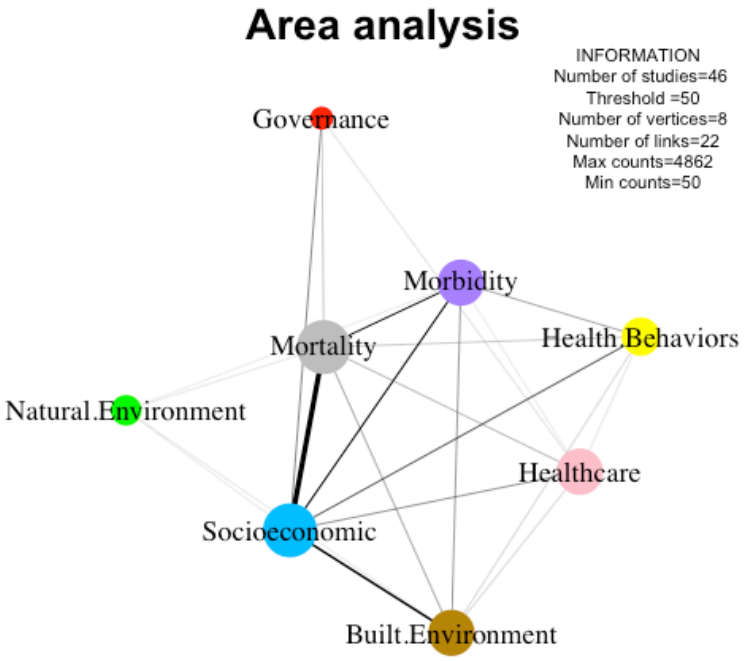


Figure 5.5 - Graph with the areas. Visualization programmed in R Studio.

These results (Figure 5.5) were partly expected by the relative presence of the categories in the sample, it was noted before (Figure 5.4) that Socioeconomic area is the most present in the studies while Natural Environment and Governance are the least present. It was also expectable that the strongest connection is between Socioeconomic and Mortality seen that Mortality is a ubiquitously used dimension to translate the health state of a population.

5.2.4. Global analysis

Following the representation of a 'heat map' (a result can be seen in Annex C), which allows the preliminary analysis, the translation into a graph representation was achieved. The distribution in space followed the criteria of connectivity: two dimensions that have a stronger connection will be place closer to each other.

From the graphic present in Figure 5.6 and some exploratory attempts, it was possible to determine a threshold for the global graph. By setting a threshold, all the links that have a lower number of co-occurrences are deleted. The selected threshold allows not only a better visualization but also removes some of the effect of random identification of dimensions within the same scope that might occur.

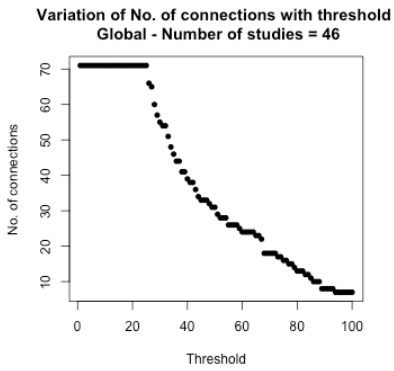


Figure 5.6 - Variation of the number of connections with threshold range from 1 to 100.

The identification of non-significant relationships can happen in situations where there is a simple enumeration of dimensions, in synthesis alike what is performed in the Abstract section or even by inaccuracy of the software in delimiting the scope; in these cases no eventual relationships are present.

5.2.5. Area dispersion analysis

As previously mentioned, the width of the edges is proportional to the number of co-occurrences counts between two dimensions. In the first representation (Figure 5.7), some central dimensions such as Income and Education and their prominent connection are observable. A distinction can be made between the dimensions that are in a more nuclear position, which are more strongly connected to each other (i.e. have appeared more times within the same scope in the text) and the set of dimensions that are more peripheral (for example Pharmaceutical Care, Air quality, Employment, Higher Education and Elderly), having weaker links.

The analysis defines the Socioeconomic area to be the most represented. This area, incorporates both of the central dimensions (Education and Income) and to a lesser extent Poverty, as well as some other peripheral ones like Literacy, Elderly, Population Minorities and Stigma. Only the Welfare dimension is represented from the Governance area, only Air Quality from the Natural Environment and two from Healthcare (Pharmaceutical Care and Health Insurance); all these dimensions are situated in the periphery feebly linked to others. In the case of the Health Behaviors (Smoking and Alcohol Consumption) they are quite close to each other contrarily to the Built Environment dimensions, Housing and Neighborhood Safety, which, albeit having a more central location, are further away from each other. Dimensions from the Morbidity and Morbidity areas are fairly distributed across the graph; they occupy a fairly central position but are not concentrated.

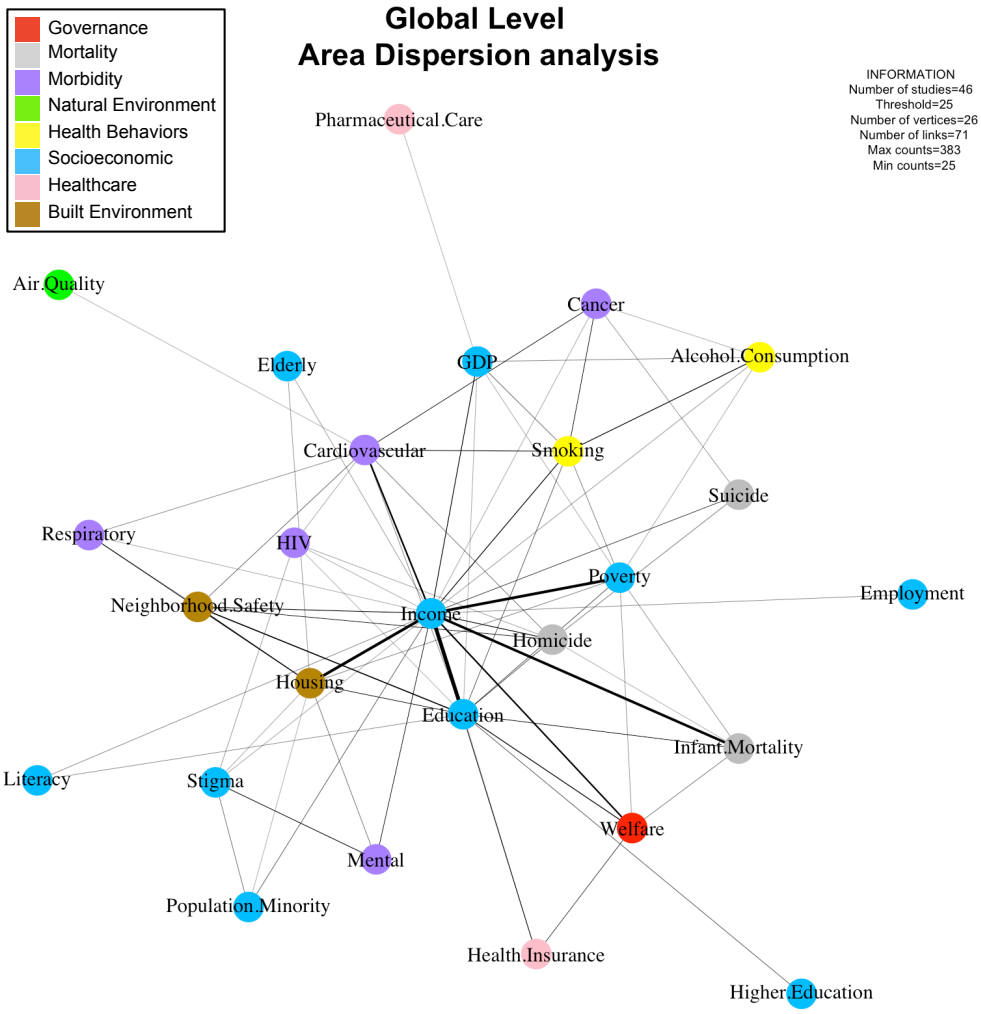


Figure 5.7 - Graph with the most relevant dimensions and their respective classification into different areas. Visualization programmed in R Studio.

5.2.6. Node connectivity analysis

The analysis of the degree of connectivity only reinforces some notions given by the previous analysis. The size of the nodes is proportional to the number of connections it has with other nodes. Intuitively, the central dimensions were connected with more dimensions and for that reason are displayed in Figure 5.8 in a greater size. It is possible to identify some dimensions that are relatively more connected: one example is Housing, where the central position already revealed some relevance; it is noticeable a greater connectivity in comparison to the others surrounding it. Another example comes from Cardiovascular; clearly it has many connections with other dimensions. As it is expected, peripheral nodes end up with a very small size as a result of their few connections.

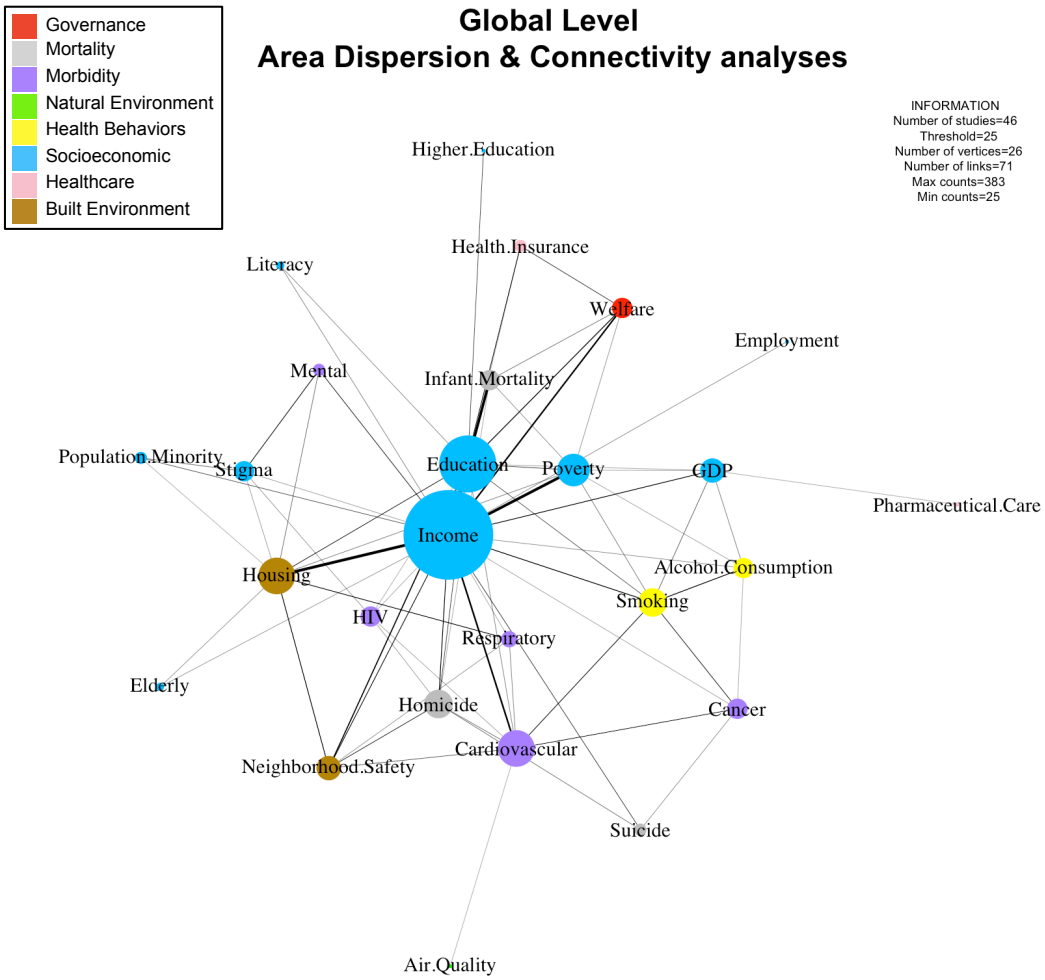


Figure 5.8 - Graph with the most relevant dimensions, their respective classification into different areas and the degree of connectivity. Visualization programmed in R Studio.

5.2.7. Geographical level analysis

In a subsequent analysis, the sample of studies was separated according to their geographical level and their graphs generated for analysis. Firstly, the variation of the total number of connections with a range of thresholds was analyzed in order to select an appropriate one (Figure 5.9). From Figure 5.9 it is possible to observe the decrease in the total number of connections with the increasing threshold. For the threshold selection, it had to be ensured the presence of a significant number of connections, however, not so high that it would prevent a proper visualization.

In all the cases with the exception of the Regional, the threshold could be set in the interval between 10 and 30, and still obtain the representation of some relationships. The Regional level had an atypically low number of connection which would result in no representation in case the threshold has set in the same order has the other, so a significantly lower threshold was selected. By establishing this threshold it is assumed that at least 10 to 30 identifications within the same scope can happen randomly and with no significance.

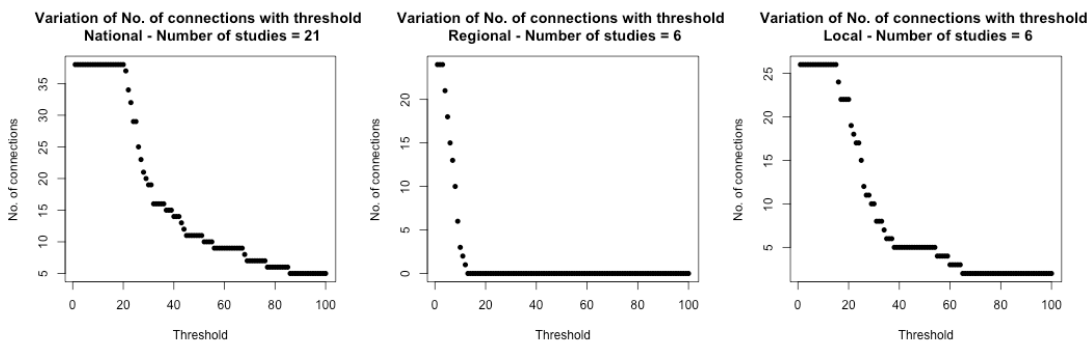


Figure 5.9 - Variation of the number of connections with threshold range from 1 to 100.

In the National level (Figure 5.10) the resulting graph has a great number of dimensions and connections in common with the Global graph, an obvious explanation is the high number of studies in the sample that are of national level (almost half). The core dimensions (Income, Education and Poverty) remain the same. Nearly all the dimensions that were represented in the global graph are also represented at the National level.

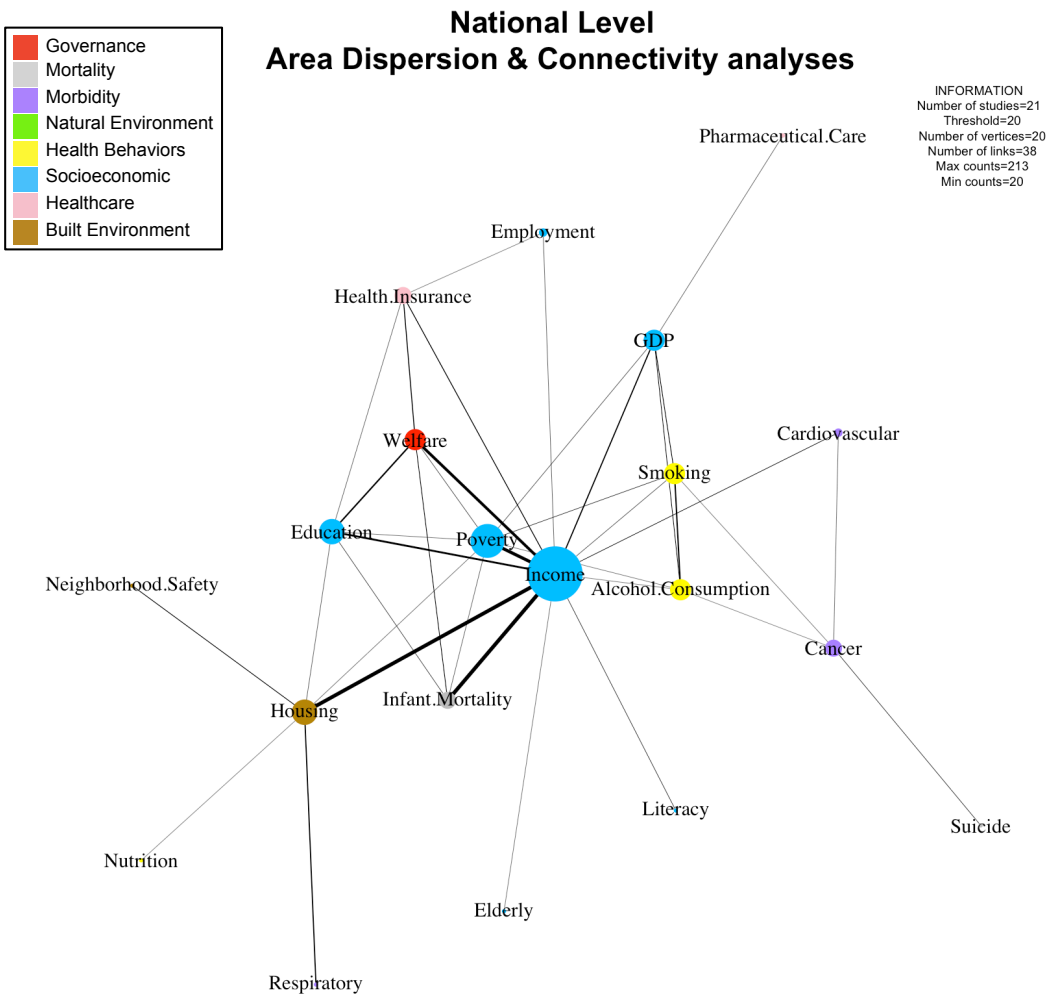


Figure 5.10 – National level graph with the most relevant dimensions, their respective classification into different areas and the degree of connectivity. Visualization programmed in R Studio.

However, Air quality, which was already feebly connected, is not present here. Another exception is Homicide that in the Global sample had a relatively high connectivity and in this analysis is not present. It can also be pointed out that Neighborhood Safety that previously had a fairly central position is presently located in the periphery. Nutrition is the only new dimension present in the National and not in the Global graph.

At the Regional level (Figure 5.11) the sample of studies is considerably low, and as a consequence the results are less reliable, this fact is only exacerbated by the fact that the number of co-occurrences is also very low. Although the valid conclusions are very limited, it can be seen that the dimensions Income and Poverty continue to have a central position and that Education is somewhat distanced.

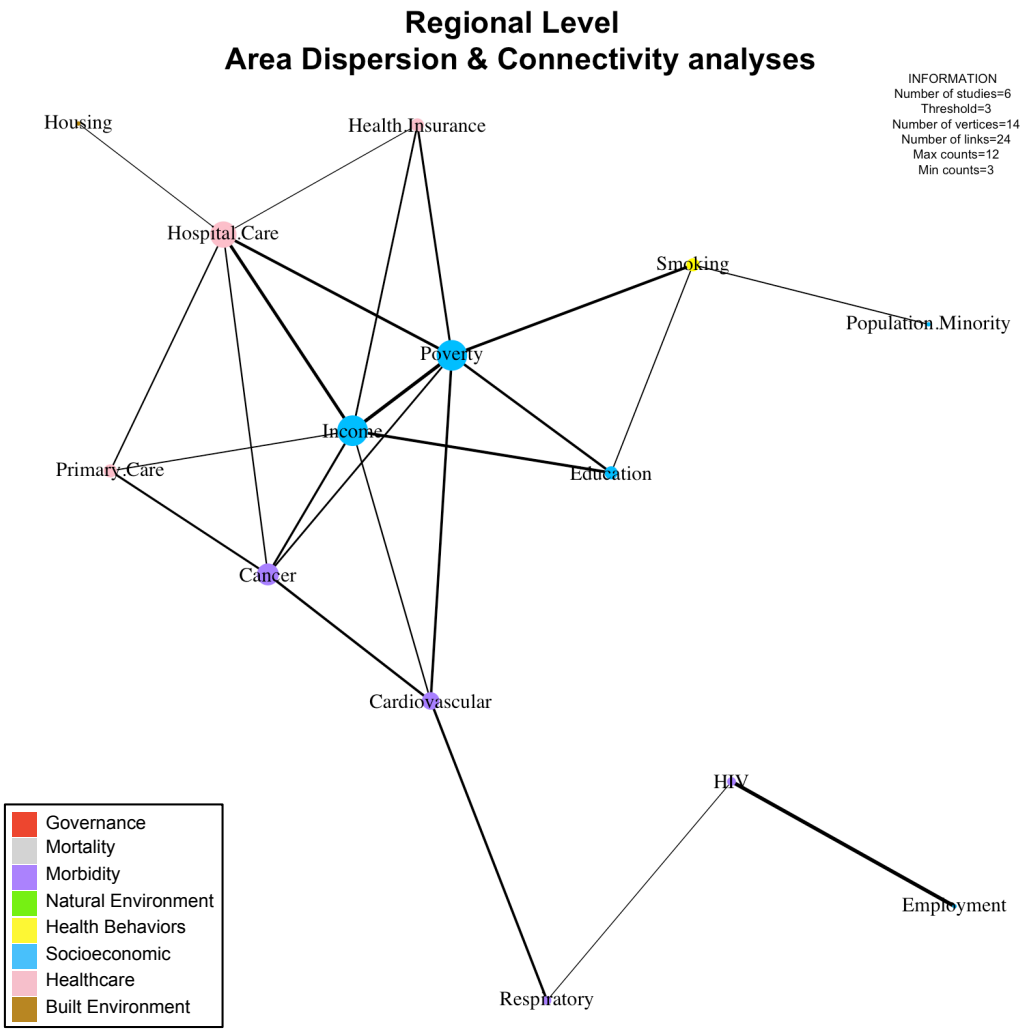


Figure 5.11 – Regional level graph with the most relevant dimensions, their respective classification into different areas and the degree of connectivity. Visualization programmed in R Studio.

Two new dimensions related to Healthcare (Hospital Care and Primary Care) appear in this context while they were absent from the previous analyses. Due to the lack of connections and the small range found (minimum number of counts is 3 and maximum is 12) it is also impossible to obtain any significant quantitative distinction between the links.

At the Local level (Figure 5.12), despite the low number of studies, the number of detected relationships is much higher than at the Regional level, which enabled the selection of a higher threshold. The two central dimensions in the graph correspond to Income and Education. However, Neighborhood Safety also stands out in the graph relatively to the remaining dimensions. Only one dimension from Health Behaviors is present (Smoking) and none from the area of Healthcare, Natural Environment and Governance.

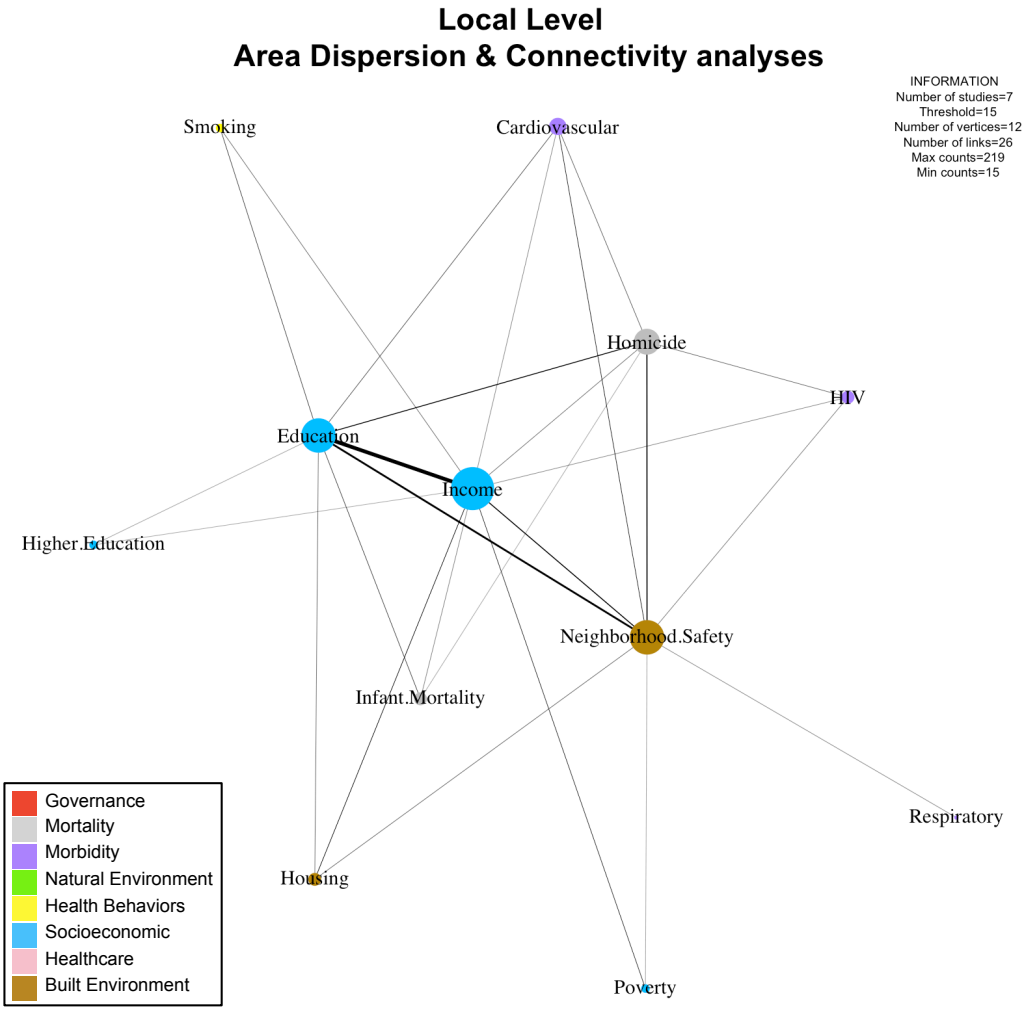


Figure 5.12 – Local level graph with the most relevant dimensions, their respective classification into different areas and the degree of connectivity. Visualization programmed in R Studio.

5.2.8. Insight into the type of relationships

Exploring the nature of the relationships revealed the presence of connectors that may indicate both the direction and the polarity of the links between two dimensions. The resulting matrices are present in Annex D.

5.3. Results from Systems Mapping

This sub-section displays the results from System Mapping (Figure 5.13). After validation or rejection of the evidence collected, its aggregation was achieved and presented in the format of a Systems Map.

In this representation, a positive relationship (green) between A and B is considered, if a change in A results in a change in B in the same direction and a negative relationship (red) B if a change in A results in a change in B in the opposite direction. In the case where no polarity was determined, the link was left grey.

In the link it is present the geographical levels in which that connection was identified. This information is not shown if the study does not specify the geographical level. When evidence for a preferred direction was provided, it was displayed; when the relationship was found to be bidirectional, this was also displayed. If no evidence was validated for either case, the link was left with no arrows. In some cases, an increase in the dimension signifies an increase to the desirable state, for example an increase in the dimension Housing means more suitable housing conditions. On the other hand, if Poverty, Stigma, Infant Mortality or any Morbidity dimension increases, this represents a more undesirable attribute.

The different geographical levels are well distributed. This fact is highly influenced by the protocol established (the selection of the top most relevant relationships from each sample). In those cases where the evidence was not validated for the relationship targeted, but it provided insight into other relationships, this evidence was collected and structured.

The resulting Systems Map provides insight into some relationships. Relationships such as Education with Income were expected a core role. The high presence of dimension from the area Morbidity was expected due to the presence of dimensions concerning this area in previous results.

The influence of the Transport Network on multiple dimensions is visible, the development of a good network has a positive impact in important factors such as Air Quality, inducing more people to use public transports and thus reducing the number of people using private cars which will also improve Road Safety; also Employment is stimulated by ensuring a connection to more job opportunities.

Two very common Health Behaviors (Smoking and Alcohol Consumption) were connect to Morbidity dimensions (Obesity and Cardiovascular); these are well known cardiovascular factor risks. Poverty was connected to several other dimensions; Nutrition was negatively impacted, poorer individuals have less access to more nutritious food, preventing them from having a balanced diet.

The path composed by Income, Housing and Respiratory is a chain leading to a morbid state by not being able to acquire appropriate housing. These dimensions will also be associated with Neighborhood Safety and in a more indirect way to Education, given that Education will be an important driver in determining future Income, and this in turn will influence the choice of future residence.

Some loops are perceptible in the central region of the Systems Map, for example, concerning the dimensions of Welfare, Education and Income and Homicide, Neighborhood Safety and Education. These can be further examined to assess some reinforcing or balancing loops. There are still many dimensions with no associated direction or polarity.

Systems Map

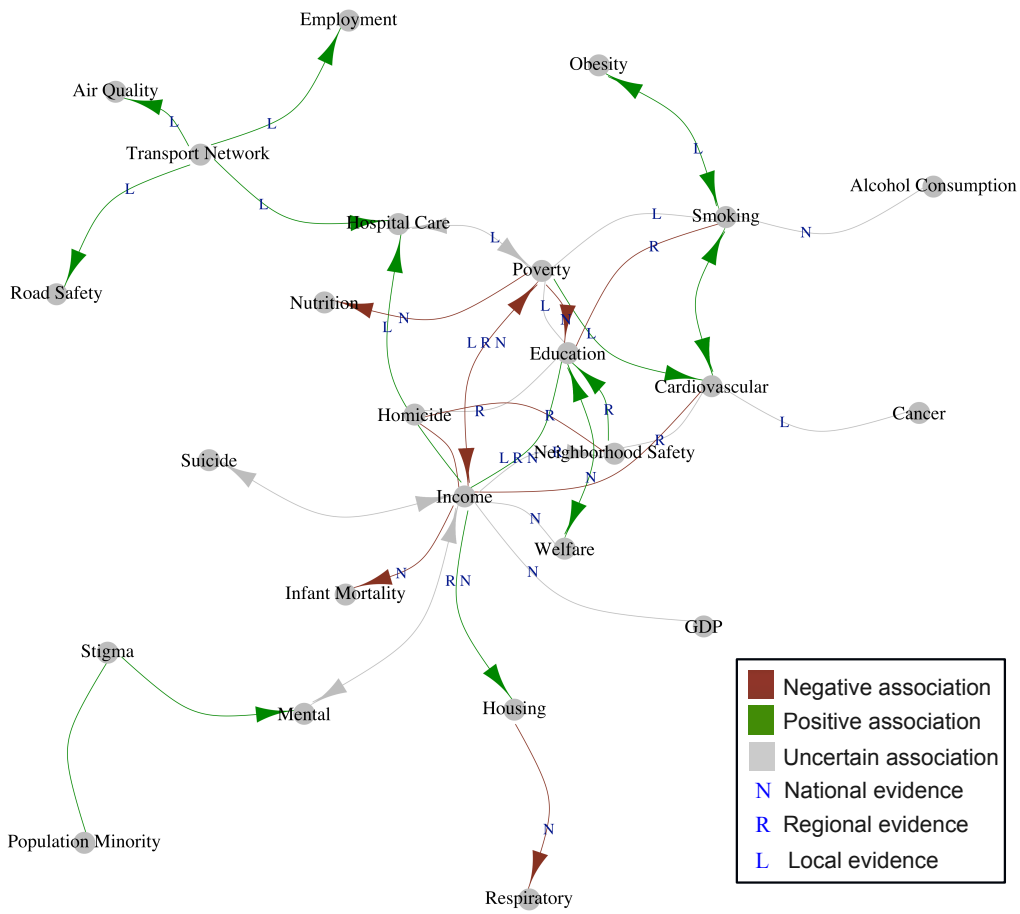


Figure 5.13 - Population Health Systems Map. Visualization programmed in R Studio.

The following chapter takes into account these results and presents a discussion about the selected methods, the proposed multimethodology and its implementation. Furthermore, the analysis of the results will be completed. Possible alternatives and improvements are also suggested.

6. Discussion

The present section discusses the methods and results developed in this thesis. The arguments presented for the use of a multimethodology will be deliberated. The proposed protocol is discussed, the choices made in each stage, the associated shortcomings, advantages and adaptations or alterations considered. The choices made for the implementation are debated as well as its implications. In a later stage the results are analyzed in terms of exhaustiveness, representativeness, validity (whether an instrument used in a study actually measures what it intentions to measure [2]) and reliability (the dependability, consistency, and/or repeatability of the data collection, interpretation, and/or analysis [2]). To finalize, the contribution of this work is acknowledged, its overall limitations, future developments and the possibility of application in other areas is considered.

6.1. Multimethodology

In Chapter 4, *Multimethodology*, both the multimethodology and its implementation were covered and detailed. The multimethodology had the intent to provide an analytical process that was systematic, comprehensive and transparent. The systematic characteristic is of crucial importance in qualitative data analysis where a bias due to subjectivity can happen; comprehensiveness and transparency should be attributes of any procedure. In this context, a multimethodology was thought to be appropriate to tackle a multidimensional and complex concept such as Population Health. The complementarity of methods was argued to offer richness to the information that would not be possible using only a single method.

In the Preliminary Literature Analysis, the research questions were established in a broad way to capture the diversity present in concept of Population Health literature. The detail present in the sample was fairly low, although for the purpose of this study it was suitable to determine more general questions and capture the diversity. The sources of information were all international databases, due to the international context in which the work is being developed - the Euro Healthy project. The final search protocol (Table 4.2) for the search and selection of studies was refined through an iterative process of exploratory searches. Lastly the inclusion criteria enabled the selection of the studies that were relevant.

The collected studies were then separated into categories, from discussion of the Population Health concept, to PH policy, PH approaches and PH determinant and outcomes. In the definition of such categories overlap is possible, meaning that a study could possibly fit into more than one category although here each one was only allocated to one. At the end of the first stage, a comprehensive review of the collected studies was obtained.

In the Content Analysis stage, a subset of the studies was selected, the PH determinant and outcomes category. The conclusions reached in this part are dependent on the focus of these studies, which can be enhanced by lowering the number of studies analyzed. The greater the number of studies examined the less biased the results.

The identification of the most relevant dimensions was initially guided by previously Population Health Indices - GeoHealthS [69] and County Health Rankings [22]. After, the search for others dimensions was performed, this step is fairly dependent on what the researcher finds relevant, although it was also guided by the relative presence of terms in the data.

The link of terms to their respective dimensions was based in the analysis of the text; this was performed in the most exhaustive way feasible. In this step, the identification of dimensions can lead to the selection of non-relevant terms – "noise". This fact can be related to the identification of words present in other text such as legends or references.

The search for dimensions within the same scope was based on the argument that the more times they appear within the same scope, the more likely it is to exist a relationship between them. Ideally, all the identified evidence using this method would be analyzed and interpreted. In this approach, further analyses were performed before an interpretation and validation, mainly due to the size of the sample. The visualization as a 'heat map' only served as an intermediate step since it was not very informative. The conversion to graph visualization permitted the holistic assessment of the most connected dimensions. Moreover, the identification of the most present areas, the identification of the most connected dimensions and differences between geographical levels was achieved.

3) In order to define the type of possible relationships, the search for connectors supplied evidence of connectors that might indicate the nature of the relationships present. A list of connectors was used (Table 4.6 and

Table 4.7) in order to capture the terms that might give some insight into these relationships.

In Systems Mapping, the researcher performs the validation of the evidence. The automation provided is in the aggregation of what is concluded for each relationship and at each geographical level. Moreover the organization of the end result into a table allows programming the automatic generation of the map according to the attributes. The conditions for concluding an attribute (direction or polarity) were the existence of any evidence that would support it. In application with a bigger or more cohesive sample, one can envisage the establishment of more stringent validation criteria such as the requirement of the validation of at least three separate pieces of evidences to determine an attribute.

The choice to use the structure Systems Map (having some similarities with a Causal Loop Diagram) was based on what it could provide: a simple representation of the different dimensions and only a set of additional information (direction, polarity and geographical level). This simplification removes some detail that could have been relevant. However, with the diverse source sample it is unfeasible to establish a common language and structure without substantial alteration of the evidence and therefore, hampering the validity of the results.

Preferably the whole process would be performed by at least three researches, this would serve for the reduction of the unavoidable subjectivity and bias and promote the discussion of some topics. Beginning with the Systematic Literature Review, followed by the Content Analysis and ending with the representation of the System Map, it would be valuable to have the data analyzed by independent researchers, later the findings should be discussed and in the case of disagreement, it should be discussed and possibly resort to a third party as a tiebreaker.

6.1.1. Implementation

After the protocol definition, it was implemented. It was argued that the ideal scope would be the sentence. This choice would enable to restrict the argument to a simple statement. Due to the impossibility of this choice, the second best option was selected – the paragraph. The assumption, in the case of scientific writing, that one paragraph transmits an idea or argument, validates the choice of the present scope. The alternative of word count (where the search is performed within a certain number of words away from the coded dimension) was discarded, although it would be possible to provide a narrower scope, due to the resulting identification of relationships that trespassed both sentence and paragraph boundaries.

The software used for the Content Analysis, NVIVO [11], presented significant limitations to deal with a fairly high number of dimensions and studies upon the performance of the Matrix query. This limitation was surpassed by separating the sample into subgroups (separation was by geographical level) and analyzing it separately. Another limitation is related to the commands that are possible to perform within the software, most of them have to be accomplished individually without the possibility to give a general command and apply it to multiple dimensions. This tool is employed usually in the domain of social sciences, where it is a valuable asset to organize and structure a small set of data, such as interviews or meeting transcripts. When dealing with a substantial sample it is necessary a considerable level of automation, to avoid time consuming tasks, which is not possible using NVIVO [11].

For the visualization, the software R Studio allowed the generation of graphs from the obtained matrices. The software allowed some adjustments to the visualization but it was not the ideal; other alternatives exist, such as Gephi [168] but lacked some flexibility in programming.

Excel was used in the aggregation of the validated data, to implement the logical conditions that were evaluated and determined the information displayed in the final Systems Map. Although further automation could be achieved, for the goals of the present thesis, the use of Excel formulas and basic VBA functions was sufficient.

6.2. Results

In Chapter 5, *Results,* the results from the different stages of the multimethodology were presented.

6.2.1. Preliminary Literature Analysis

The Preliminary Literature Analysis revealed that the concept of Population Health has been increasingly debated. Some advances have been achieved and features have been established. The most diverse approaches have been proposed to measure, monitor or alter PH. Policies in this area focus on the impact they can have on determinants with the ultimate goal of impacting the outcomes.

6.2.2. Content Analysis

In the Content Analysis Results, the reached hierarchical structure was not dissimilar to previously developed indices, GeoHealthS [69] and County Health Rankings [22], which confirmed the dimensions established in those indices. Seen that the selection of dimensions in those indices took into account the possibility to measure them, it is natural that the structure presented here will have some dimension that are non-trivial or even impossible to measure.

The organization into two main categories (Determinants and Outcomes) is also presented; in the case of the areas there are also many topics in common: Healthcare, Socioeconomic (Economic and Social in GeoHealthS [69]) and Health Behaviors (Lifestyle in GeoHealthS [69]). Both indices, contrarily to what is proposed here, join the concern of Built Environment and Natural Environment into a single area – Physical Environment. The choice to separate these two concerns, despite their inherent relationship, is that they are considered separately in terms of policy-making and the establishment of goals. The present analysis found concerns with aspects related with Governance (namely Welfare and Taxing System) and its affects on the health of a population. For that reason, a new area was established in order translate this issue. In the Outcomes the classical areas of Mortality and Morbidity were maintained. It can be argued that some of the identified dimensions were redundant, transmitting the same concern. In this work the option was made to keep the dimensions since it was meant to translate and structure what was present in the literature.

The terms associated to each dimensions were explored in order to be as exhaustive as possible. The presence and distribution of dimensions across the sources enabled the identification of differences between studies concerning the dimensions present in them; some scarcely mentioned dimensions when compared to other that were highly mentioned. This absence could be due to their real absence from the literature, or to the inability to capture the dimensions through the use of the selected terms.

The display of the resulting matrix in the form of a ‘heat map’ revealed not to be very informative. This was attributed to the higher quantity of dimensions. It only provided a small insight into singular intersections that were considerably more relevant when compared to the

rest. The translation of the matrix into a graph revealed to be very useful for the holistic visualization of the dimensions. The association of each dimension to their area allowed the determination of the most present areas. It also was possible to determine the most connected nodes and observe the differences between the geographical levels.

The selected threshold for each analysis will, to some extent, influence the result. Attempts were completed with a range of thresholds and the results did not significantly change, determining that the analysis is fairly robust.

The global graph was, evidently, the most complete result, given that it contained the information from all the studies.

It is arguable that the sample for the two lowest geographical levels – Regional and Local – is not sufficient to deliver reliable results and to acquire significant conclusions. In these cases the probability of bias is stronger, the impact that a single study has is very important and if it is very particular to a set or a single dimension it can impact greatly the end result. Even with the small sample it is conceivable to achieve some insight but the extrapolations and generalizations are difficult.

In the Global level were present dimensions from the eight areas. The relative presence of each is highly dissimilar. Socioeconomic has the greatest presence in the graph, while Welfare and Air quality are the single representatives of their respective areas. This relative presence should not be all attributed to relevance, the focus of such dimensions in studies can be related to the ease in collecting data for that dimension, for example, mortality can be easily assessed through the collection publicly available data. The concern with multiple diseases and conditions – Morbidity – had not yet been established in the literature, usually other indices would focus only in self-reported health or a couple of disorders, here it is demonstrated that these dimensions are significantly present and connected to others.

The analysis of the areas only reinforced the fact that there is a too much important focus on the areas of Mortality and Socioeconomic, possibly biased by the ease in collecting related data. Surprisingly, the Built Environment, Healthcare and Morbidity are also significantly represented in the results.

In the separate analysis of the geographical levels it was possible to establish relevant dissimilarities between them. At the National Level, the most complete results were obtained; this is naturally related to the number of studies in the sample, where is evident the similarity with the Global level.

At the Regional level, the number of studies makes it difficult to obtain valid conclusions. Albeit this shortcoming it is possible to observe the dimension of Hospital Care having a more central role and the presence of Population Minority. A surprisingly strong connection appears between HIV and Employment, this might be due to the focus of one study between these two dimensions.

At the Local level, the number of studies was also low, but the identified dimensions and relationships were greater. It still results in a somewhat scarce analysis. The central

dimensions remained the same – Education and Income. It is noteworthy the amplified relevance of Neighborhood Safety, which is only logical at this geographical level.
The results from the search for connectors were the least satisfactory. For some relationships, no presence of connector was found in the evidence, for others, many were identified although the numbers were misleading. The entries in each cell translated the number of times one of the dimensions or connectors was present and not the number of connections. This called for more refined techniques in looking for relationships and connections between words.

To analyze written data, other techniques text analyzing techniques exist such as Natural Language Processing. These algorithms are normally applied to more sophisticated tasks, such as: naive discourse analysis, identifying relationships between sentences, for instance, contrast or explanation; recognizing speech acts such as statement or even complex tasks like question answering [169]. These algorithms are beyond what is intended in this works.

6.2.3. Systems Mapping

The final Systems Map was able to provide, in a structured format, the validated evidence found in the literature. It would be desirable to obtain a more complete picture, with more dimensions and further details about the type of relationships present. The information showed some predictable results such as the intensively studied Income and Education. These dimensions have a far-reaching impact into other dimensions ranging from Mental disorder to Health Behaviors (such as smoking) or even Hospital Care. Not surprisingly, the relationship between Poverty and Income, and between Education and Income, are present in the three distinct geographical levels. The focus on the role of the Transport Network was found to be at the local level. Neighborhood Safety was expected to establish connections that were found at the local level instead of the regional level where it can be observed. This fact might be related to the fact that studies that examined this dimension did it so at this upper level.

Two other analyses were implemented in R Studio, but they were considered alternatives to the one presented here. The first one allowed the separation of the relationships into predefined intervals, for example “weak”, “moderate” and “strong”. This would allow a more direct examination of the data. A second possibility was to display, on top of the Global Level graph, in a different color, the relationships in common with each of the geographical levels.

6.3. Overall achievements and limitations

In the present work, in terms of methodology it was proposed some automation in an otherwise laborious and time-consuming task as well as the application of systematic criteria in the search for relationships. An increased systematization method was achieved with the

intent to increase the objectivity in the analysis of qualitative data. An important comprehension was provided about the Population Health literature, identification of significant dimensions was accomplished as well as the determination of relationships. The method proposed here does not replace the essential role of the researcher in ultimately evaluating and analyzing the evidence. It is necessary to evaluate whether the method is accurately performing the intended identification and the interpretation might add important details not caught through the methods.

The approach chosen has some limitations in each of the methods used; these limitations could be further reduced through further development or the choice of alternatives.
An overall limitation of the process is the sample of studies and the types of studies available in the literature. There is a major tendency to resort to statistical analysis of available data, since this data is normally available according to the easiness of collection, leading to a bias of the analysis towards these indicators. With this shift in population health it is necessary to adapt the type of analysis performed so it is in accordance with the concerns of PH.
The main option was to use the co-occurrence within the same scope as a possible clue for a relationship may be misleading; it was made clear that the fact that two dimensions are within the same scope does not necessarily ensure the presence of a relationship. It was argued, however, that the quantification of these co-occurrences could provide some indication; the more times a co-occurrence happened, the more probable a relationship might be found.
Yearworth & White [68] caution on the use of tools that implement the approaches of graph theory and network analysis functions to analyze the structure of the co-occurrences matrix; here it is argued that this task can enable a holistic visualization and description of the complex system.

Options made in the multimethodology were so far clarified; it is relevant to identify some improvements that would enhance the results obtained.
A more cohesive is needed sample in order to find more detail and consistent relationships: in the current thesis the option was to capture diversity and in this lost some richness in the detail. Another possibility was to increase the size of the sample, diminishing the possible strong bias of some studies.
The selection of the most relevant sections of the articles (results and discussion) should be performed in order to avoid the capture of terms in non-relevant sections of the studies and seen that it would be more probable to reveal relevant relationships. Other sections such as the abstract and methods can provide erroneous insight due to the summarization or methodological description not pertinent to determining dimensions and relationships.
Further analysis could be done to assess the strength of the relationship by searching for words such as “strong”, “significant” or “important”, however for this type of analysis it would be preferred a more cohesive sample.

In the validation, the defined criteria only demanded a single validated evidence for it to be accepted in the final scheme. More stringent criteria could be adopted, although in this exploratory work it would not be feasible.
It is believed that improvements throughout the proposed multimethodology would enable a greater documentation of evidence and more thorough results.

6.4. Other applications

The present multimethodology can be applied in other contexts, with special interest to areas with multiple dimensions that are interrelated and can be organized into a hierarchical structure. One example might be the evaluation of a specific industry; the procedure can go through an economic, environmental and social impact evaluation of that industry and within each section considering multiple criteria or indicators to measure the impact and how these indicators may influence each other. Another example can be the performance analysis of an institution, comprehending areas like financial, human resources management and administrative. It can be further analyzed at different levels: the institutional level, the department level and team level for example.
In these application the researcher would look for the relevant dimensions in each context and organize them in the adequate hierarchical structure. The attributes of the relationship could be adapted in changing the search terms.

The following section offers a reflection on the solutions found for encountered challenges, as well as further developments and research.

7. Concluding Remarks

This exploratory work resulted from the challenges and difficulties found in the laborious, time consuming and high level of subjectivity present in Health Research Methods such as Systematic Literature Reviews. These methods intend to synthetize the literature on a certain area or topic. The manual task such as the construction of a map that translates the fragmented evidence present in the literature is an extensive work that can profit from a more automated method. Moreover, this thesis has the purpose to answer the question "What determines population health?"; to identify dimensions, relationships and approaches in PH.

The combination of these necessities led to the development of a novel multimethodology to synthesize, identify and structure this concept.

The different stages of the multimethodology allow the comprehension of the Population Health concept, from an initial analysis of the literature to the presentation of the evidence in a structured format. The Preliminary Literature Review established a synthesis of the literature providing a basis to develop future work, the studies were separated into categories that represented the topics present in the literature and each of these categories was reviewed. The second stage, Content Analysis, allowed the systematic identification of relevant dimensions and its organization into a hierarchical structure. Next, the search for relationships was carried out with the identification of dimensions within the same scope – the paragraph. This information was used to perform a set of analyses that was crucial in providing some insight and guidance in the research process. In a final step, the search for insights into the nature of the most relevant relationships was achieved. In the third stage, Systems Mapping, the validation and aggregation of the validated data into a structured format was achieved.

The results showed that a high diversity exists in the Population Health Literature; multiple definitions, frameworks and approaches are possible. It essential to further define and reach a consensus in what the concept entails and to continue the promotion and development of research to aid policy making with the ultimate goal of maximizing the health and well being of a population.

In the Content Analysis, it was obtained the definition of relevant dimensions to distinguish nuclear dimensions from more marginal ones. Income, Education and Poverty were found to be central in this context. Differences between geographical levels were observed as well as common attributes. Nearly all the dimensions that were represented in the global graph are also represented in the National level. At the Regional Level, two new dimensions related to Healthcare (Hospital Care and Primary Care) appear while they were absent from previous analysis. At the Local Level Neighborhood Safety stands out in the analysis relatively to the remaining dimensions.

Further insight into the type of relationships present was found. The validated and aggregated data enabled to obtain a final map that intuitively translated the evidence identified by the established protocol.

The work developed here intended to identify and provide answer for challenges met in the review of methods and mapping of concepts. The multimethodology enabled a clear and comprehensive way to gather the evidence present in the literature. Some automation was provided in the identification of relationship and dimension, ultimately a review of studies less dependent on the reviewer was achieved, increasing the reliance on technical tools. Specifically, the generation of graphs, enabled a holistic appraisal of the literature, through the identification of dimensions and possible relationships. Furthermore, the aggregation of the validated data, an otherwise laborious task, was semi-automated through the assessment of logical conditions and the automatic translation into a Systems Map representation.
The work presented here provides a contribution to methods in Health Research, and their integration with complementary methods, allowing a clear way to structure knowledge is essential to inform and aid evidence-based policy-making. Specifically in the context where this work was developed, the Euro Healthy project [3].

In addition to the improvements already discussed, the present approach would benefit from a tool that would integrate all the methods proposed in this work. The available tools provide already a set of capabilities that allow some analysis of written data. It would be valuable to have more flexibility in the analysis, for instance the selection of specific parts of the documents, to have the capacity to process larger amounts of data, and to have available more detailed visualization options. Ideally, a tool would enable a more refined evaluation of the evidence, multiple analysis and final presentations. Moreover, it would be of value that several researchers would participate in the same analysis to enhance reliability.
The gaps identified here can direct future research into those topics where the necessity of uncovering these relationships has been established. Furthermore, the obtained System Map can be used in the development of a System Dynamics Models, where it would be necessary to determine equations and quantify the dimensions usually obtained through expert elicitation.

References

1. Kindig, D.A. and G.L. Stoddart, *What Is Population Health?* American Journal of Public Health, 2003. **93**(3).
2. Given, L.M., *The Sage encyclopedia of qualitative research methods.* 2008: Sage Publications.
3. Euro Healthy 2015; Available from: http://www.euro-healthy.eu/.
4. Hancock, T.L., Ron; Edwards, Rick, *Indicators that Count! Measuring Population Health at the Community Level.* Canadian Journal of Public Health, 1999. **90**(1): p. 22-26.
5. Etches, V., et al., *Measuring population health: a review of indicators.* Annu Rev Public Health, 2006. **27**: p. 29-55.
6. Cohen, D., et al., *The population health approach: A qualitative study of conceptual and operational definitions for leaders in Canadian healthcare.* SAGE Open Medicine, 2014. **2**: p. 1-11.
7. Coburn, D., et al., *Population Health in Canada: A Brief Critique.* American Journal of Public Health, 2003. **93**(3): p. 392-396.
8. Raphael, D. and T. Bryant, *The limitations of population health as a model for a new public health.* Health Promotion International, 2002. **17**(2): p. 189-199.
9. Kindig, D.A., *Understanding Population Health Terminology.* Milbank Quarterly, 2007. **85**(1): p. 139-161.
10. Szreter, S., *The Population Health Approach in Historical Perspective.* American Journal of Public Health, 2003. **93**(3): p. 421-431.
11. International, Q. *NVIVO*. 2015; Available from: http://www.qsrinternational.com/products_nvivo.aspx.
12. Public Health Agency of Canada. *What is the Population Health Approach?* . 2012; Available from: http://www.phac-aspc.gc.ca/ph-sp/approach-approche/index-eng.php.
13. Young, T.K., *Population Health: Concepts and Methods*. 1998: Oxford University Press.
14. Dunn, J.R. and M.V. Hayes, *Toward a Lexicon of Population Health.* Canadian Journal od Public Health, 1999.
15. Hacker, K. and D.K. Walker, *Achieving Population Health in Accountable Care Organizations.* American Journal of Public Health, 2013. **103**(7): p. 1163-1167.
16. Butler-Jones, D., *Applying a Population Health Approach.* Canadian Journal of Public Health, 1999. **90**(1): p. 62-64.
17. Organization, W.H., *Social determinants of health* http://www.who.int/social_determinants/en/. 2015.
18. Last, J.M., *A Dictionary of Epidemiology*. 4th ed. 2001, New York: Oxford University Press.
19. Gold, M., et al., *Cost-Effectiveness in Health and Medicine.* 1996, New York: Oxford University Press.
20. Freiler, A., et al., *Glossary for the implementation of Health in All Policies (HiAP).* J Epidemiol Community Health, 2013. **67**(12): p. 1068-72.
21. Evans, R.G. and G.L. Stoddart, *Producing, consuming health care.* Social Science & Medicine, 1990. **31**(12).
22. Kindig, D.A., *What is Population Health.* Improving Population Health - Policy. Practice. Research. http://www.improvingpopulationhealth.org, 2015.
23. *GeoHealthS.* 2015.
24. Vaz, A.S., J.; Santana, P.; Janeiro da Costa, R., *Desenvolvimento de um modelo de Avaliação de Estado de Saúde da População.* Revista Portuguesa de Saúde Pública, 1994. **12**(2): p. 5-23.
25. Porzsolt, F., et al., *Evidence-based decision making—the six step approach.* Evidence Based Medicine, 2003. **8**: p. 165-166.
26. Glass, G.V., *Primary, Secondary, and Meta-Analysis of Research.* Educational Researcher, 1976. **5**(10): p. 3-8.
27. Garg, A.X., D. Hackam, and M. Tonelli, *Systematic review and meta-analysis: when one study is just not enough.* Clin J Am Soc Nephrol, 2008. **3**(1): p. 253-60.
28. Cooper, H., *Research synthesis and meta-analysis: A step-by-step approach*. 2009: Sage Publications.

29. Ioannidis, J.P., & Lau, J. , *Pooling research results: benefits and limitations of meta-analysis.* The Joint Commission journal on quality improvement, 1999. **25**(9): p. 462-469.
30. Spector, T.D. and S.G. Thompson, *The potential and limitations of meta-analysis.* Journal Epidemiology Community Health, 1991. **45**: p. 89-92.
31. Jaidka, K., C.S.G. Khoo, and J.-C. Na, *Deconstructing Human Literature Reviews – A Framework for Multi-Document Summarization.* Proceedings of the 14th European Workshop on Natural Language Generation, 2013: p. 125–135.
32. Moher D, L.A., Tetzlaff J, Altman DG, , *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* Annals of internal medicine 2009. **151** (4): p. 264-269.
33. Higgins JPT, G.S. *Cochrane Handbook for Systematic Reviews of Interventions*. The Cochrane Collaboration 2008; Available from: http://www.cochrane-handbook.org. .
34. Arksey, H. and L. O'Malley, *Scoping studies: towards a methodological framework.* Internation Journal of Social Research Methodology: Theory & Practice, 2005. **8**(1): p. 19-32.
35. Colquhoun, H.L., et al., *Scoping reviews: time for clarity in definition, methods, and reporting.* J Clin Epidemiol, 2014. **67**(12): p. 1291-4.
36. Daudt, H.M., C.v. Mossel, and S.J. Scott, *Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework.* BMC Medical Research Methodology 2013. **13**(48).
37. Levac, D., H. Colquhoun, and K.K. O'Brien, *Scoping studies: advancing the methodology.* Implement Sci, 2010. **5**: p. 69.
38. Poth, C. and S. Ross, *Meta-analysis, systematic review, or scoping review? Comparing methodologies in educational research.* Unknown.
39. Pham, M.T., et al., *A scoping review of scoping reviews: advancing the approach and enhancing the consistency.* Res Synth Methods, 2014. **5**(4): p. 371-85.
40. Moher, D., et al., *Assessing the quality of randomized controlled trials: An annotated bibliography of scales and checklists.* Controlled Clinical Trials, 1995. **16**(1): p. 62-73.
41. Jüni, P., Altman, D. G., & Egger, M. (). , *Assessing the quality of controlled clinical trials.* British Medical Journal, 2001. **323**(7303): p. 42–46.
42. Onwuegbuzie, A.J., N.L. Leech, and K.M.T. Collins, *Qualitative Analysis Techniques for the Review of the Literature* The Qualitative Report 2012. **17**(56): p. 1-28.
43. Eden, C., *Cognitive mapping and problem structuring for system dynamics model building.* 1994.
44. Rosenhead, J. and J. Mingers, *Rational Analysis for a Problematic World Revisited, Problem Structuring Methods for Complexity, Uncertainty and Conflict* 2001, Chichester: Wiley.
45. De Geus, A., *Planning as learning.* Harvard Business Review, 1988. **66**(2).
46. Marchant, T., *Cognitive maps and fuzzy implications.* European Journal of Operational Research, 1999. **114**: p. 626-637.
47. Scavarda, A., et al., *A review of the Causal Mapping Practice and Research Literature*. 2004.
48. Eden, C., *Cognitive mapping.* European Journal of Operational Research, 1988. **36**: p. 1-13.
49. Eden, C. and F. Ackermann, *The analysis of cause maps.* Journal of management studies, 1992. **29**(3).
50. Axelrod, R., *Structure of decision: The cognitive maps of political elites.* 1976: Princeton university press.
51. Montibeller, G. and V. Belton, *Causal maps and the evaluation of decision options—a review.* Journal of the Operational Research Society, 2006. **57**(7): p. 779-791.
52. Richardson, G.P., *Problems with causal-loop diagrams.* System Dynamics Review, 1986. **2**: p. 158-170.
53. Butland, B., et al. , *Foresight. Tackling obesities: future choices. Project report.* 2007.
54. Krippendorff, K., *Content Analysis: an introduction to its methodology.* 1980.
55. Cho, J.Y. and E.-H. Lee, *Reducing Confusion about Grounded Theory and Qualitative Content Analysis: Similarities and Differences.* The Qualitative Report, 2014. **19**(64): p. 1-20.
56. Hsieh, H.F. and S.E. Shannon, *Three approaches to qualitative content analysis.* Qual Health Res, 2005. **15**(9): p. 1277-88.

57. Elo, S., et al., *Qualitative Content Analysis: A Focus on Trustworthiness.* SAGE Open, 2014. **4**(1).
58. Graneheim, U.H. and B. Lundman, *Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness.* Nurse Educ Today, 2004. **24**(2): p. 105-12.
59. Burla, L., et al., *From Text to Codings.* Nursing Research, 2008. **57**(2): p. 113-117.
60. Elo, S. and H. Kyngäs, *The qualitative content analysis process.* Journal of Advanced Nursing, 2008. **62**(1): p. 107-115.
61. Harwood, T.G. and T. Garry, *An overview of content analysis.* The Marketing Review, 2003. **3**(4): p. 479-498.
62. Thayer, A., et al., *Content Analysis as a Best Practice in Technical Communication Research.* Journal of Technical Writing and Communication, 2007. **37**(3): p. 267-279.
63. Burnard, P., *A method of analysing interview transcripts in qualitative research.* Nurse Education Today, 1991. **11**: p. 461-466.
64. Strauss, A.L., Corbin, J.,, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. 1998, Thousand Oaks, London, New Delhi.: Sage.
65. Moretti, F., et al., *A standardized approach to qualitative content analysis of focus group discussions from different countries.* Patient Education and Counseling, 2011. **82**(3): p. 420-428.
66. Kondracki, N.L., N.S. Wellman, and D.R. Amundson, *Content Analysis: Review of Methods and Their Applications in Nutrition Education.* Journal of Nutrition Education and Behavior, 2002. **34**(4): p. 224-230.
67. Mingers, J. and J. Brocklesby, *Multimethodology: Towards a Framework for Mixing Methodologies.* Omega International, 1997. **25**(5): p. 489-509.
68. Yearworth, M. and L. White, *The uses of qualitative data in multimethodology: Developing causal loop diagrams during the coding process.* European Journal of Operational Research, 2013. **231**(1): p. 151-161.
69. Rodrigues, T.C., et al., *The MACBETH approach to health value measurement: a multicriteria model for building a value-based population health index*. 2014.
70. Edhlund, B. and A. McDougall, *NVivo 10 essentials.* 2013: Lulu.com.
71. *FreeMind.*
72. Batchelor, P., *What do we mean by population health?* Community Dent Oral Epidemiol, 2012. **40 Suppl 2**: p. 12-5.
73. Hayes, M.V., *Population Health Promotion: Responsible Sharing of Future Directions.* Canadian Journal of Public Health, 1999. **90**.
74. Poland, B., et al., *Wealth, equity and health care: a critique of a "population health" perspective on the determinants of health.* Social Science & Medicine, 1998. **46**(7): p. 785-798.
75. Harvey, P.W., *Social determinants of health — why we continue to ignore them in the search for improved population health outcomes!* Australian Health Review, 2006. **30**(4): p. 419-423.
76. Keleher, H., *Population health planning for health equity.* Aust J Prim Health, 2011. **17**(4): p. 327-33.
77. Kindig, D.A. and G. Isham, *Population Health Improvement: A Community Health Business Model That Engages Partners in All Sectors.* Frontiers of health services management, 2014. **30**(4).
78. Warnecke, R.B., et al., *Approaching health disparities from a population perspective: the National Institutes of Health Centers for Population Health and Health Disparities.* Am J Public Health, 2008. **98**(9): p. 1608-15.
79. Raphael, D. and T. Bryant, *The state's role in promoting population health: public health concerns in Canada, USA, UK, and Sweden.* Health Policy, 2006. **78**(1): p. 39-55.
80. McMichael, A.J. and C.D. Butler, *Emerging health issues: The widening challenge for population health promotion*, in *The 6th Global Conference on Health Promotion*. 2005.
81. Robertson, A., *Shifting discourses on health in Canada: from health promotion to population health.* Health Promotion International, 1998. **13**(2): p. 155-166.
82. Arah, O.A., *On the relationship between individual and population health.* Med Health Care Philos, 2009. **12**(3): p. 235-44.

83. Tarlov, A.R., *Public Policy Frameworks for Improving Population Health.* Annals New York Academy of Sciences, 1999. **896**(1): p. 281-293.
84. Cabieses, B., *At the edge of individual cognitive-behavioural policies: how to walk the public health path to effectively improve population health?* salud pública de méxico, 2013. **55**(4): p. 421-426.
85. Davis, E., et al., *Population health and wellbeing: Identifying priority areas for Victorian children.* Australia and New Zealand Health Policy, 2005. **2**(16).
86. Fox, D.M., *The determinants of policy for population health.* Health Econ Policy Law, 2006. **1**(Pt 4): p. 395-407.
87. Hall, P.A., R.C. Taylor, and L. Barnes, *A capabilities approach to population health and public policy-making.* Rev Epidemiol Sante Publique, 2013. **61 Suppl 3**: p. S177-83.
88. Niederdeppe, J., et al., *Message Design Strategies to Raise Public Awareness of Social Determinants of Health and Population Health Disparities.* Milbank Quarterly, 2008. **86**(3): p. 481-513.
89. Raphael, D., *Public policies and the problematic USA population health profile.* Health Policy, 2007. **84**(1): p. 101-11.
90. Raphael, D., *Shaping Public Policy and Population Health in the United States: Why is the Public Health Community Missing in Action?* International Journal of Health Services, 2008. **38**(1): p. 63-94.
91. Teutsch, S.M. and J.E. Fielding, *Applying comparative effectiveness research to public and population health initiatives.* Health Aff (Millwood), 2011. **30**(2): p. 349-55.
92. Frohlich, K.L., et al., *Advancing the Population Health Agenda.* Canadian Journal of Public Health, 2004. **95**(5): p. 392-395.
93. Hertzman, C. and M. Wiens, *Child development and long-term outcomes: a population health prespective and summary of successful interventions.* Social Science & Medicine, 1996. **43**(7): p. 1083-1095.
94. Athens, J.K., et al., *Using empirical Bayes methods to rank counties on population health measures.* Preventing Chronic Disease, 2013. **10**: p. E129.
95. Crimmins, E., *Health expectancies: what can we expect from summary indicators of population health?*, in *Summary Measures of Population Health*. 2002. p. 213-219.
96. Olivier, T.R., *Population Health Rankings as Policy Indicators and Performance Measures.* Public Health Research, Practice and Policy, 2010. **7**(5): p. A101.
97. Peppard, P.E., et al., *An initial attempt at ranking population health outcomes and determinants.* Wisconsin Medical Journal, 2004. **103**(3): p. 52-56.
98. Reidpath, D.D., *Population health. More than the sum of the parts?* J Epidemiol Community Health, 2005. **59**(10): p. 877-80.
99. Aguilar-Gaxiola, S., et al., *Towards a unified taxonomy of health indicators: academic health centers and communities working together to improve population health.* Acad Med, 2014. **89**(4): p. 564-72.
100. Lantz, P.M. and A. Pritchard, *Socioeconomic Indicators That Matter for Population Health.* Public Health Research, Practice and Policy, 2010. **7**(4).
101. Lavis, J.N.M., Cameron A.; Payne, Jennifer I.; Farrant, Mark S. R., *Work-Related Population Health Indicators.* Canadian Journal of Public Health, 2001. **92**(1): p. 72-78.
102. Mathers, C.D., et al., *Population health metrics: crucial inputs to the development of evidence for health policy.* 2003.
103. Nutbeam, D., *Achieving Population Health Goals: Perspectives on Measurement and Implementation from Australia.* Canadian Journal of Public Health, 1999. **90**(1): p. 43-46.
104. Parrish, R.G., *Measuring Population Health Outcomes.* Public Health Research, Practice and Policy, 2010. **7**(4): p. A71.
105. Chittleborough, C.R., et al., *A life-course approach to measuring socioeconomic position in population health surveillance systems.* J Epidemiol Community Health, 2006. **60**(11): p. 981-92.
106. McDowell, I., R.A. Spasoff, and B. Kristjansson, *On the Classification of Population Health Measurements.* American Journal of Public Health, 2004. **94**(3): p. 388–393.
107. Auerbach, J., *Creating incentives to move upstream: developing a diversified portfolio of population health measures within payment and health care reform.* Am J Public Health, 2015. **105**(3): p. 427-31.

108. Kindig, D.A., *Purchasing Population Health: Aligning Financial Incentives to Improve Health Outcomes.* Health Services Research, 1998. **33**(2).
109. Barnard, D.K. and W. Hu, *The Population Health Approach: health GIS as a bridge from theory to practice.* Int J Health Geogr, 2005. **4**: p. 23.
110. Eyles, J.D., *Health, Environmental Assessments and Population Health: Tools for a Complex Process.* Canadian Journal of Public Health, 1999. **90**.
111. Bhatia, R. and J. Corburn, *Lessons from San Francisco: health impact assessments have advanced political conditions for improving population health.* Health Aff (Millwood), 2011. **30**(12): p. 2410-8.
112. Frankish, C.J., et al., *Health impact assessment as a tool for population health promotion and public policy.* A Report to the Health Promotion Development Division of Health Canada, 1996.
113. Gulis, G. and Y. Fujino, *Epidemiology, population health, and health impact assessment.* J Epidemiol, 2015. **25**(3): p. 179-80.
114. Wise, M., et al., *The role of Health Impact Assessment in promoting population health and health equity.* Health Promotion Journal of Australia, 2009. **20**(3): p. 172-179.
115. Ebi, K.L., *Healthy people 2100: modeling population health impacts of climate change.* Climatic Change, 2007. **88**(1): p. 5-19.
116. Tricco, A.C., et al., *Shifts in the Use of PopulationHealth, Health Promotion, and Public Health.* Canadian Journal of Public Health, 2008. **99**(6): p. 466-471.
117. Krewski, D., et al., *An Integrated Framework for Risk Management and Population Health.* Human and Ecological Risk Assessment: An International Journal, 2007. **13**(6): p. 1288-1312.
118. Krewski, D., et al., *Public perception of population health risks in Canada: Risk perception beliefs.* Health, Risk & Society, 2008. **10**(2): p. 167-179.
119. Krewski, D., et al., *Expert vs. public perception of population health risks in Canada.* Journal of Risk Research, 2012. **15**(6): p. 601-625.
120. Jayasinghe, S., *Conceptualising population health: from mechanistic thinking to complexity science.* Emerg Themes Epidemiol, 2011. **8**(1): p. 2.
121. Studnicki, J., et al., *A Minimum Data Set and Empirical Model for Population Health Status Assessment.* American Journal of Preventive Medicine, 2001. **20**(1): p. 40-49.
122. Garmon Bibb, S.C., *Issues associated with secondary analysis of population health data.* Appl Nurs Res, 2007. **20**(2): p. 94-9.
123. Carmignani, F., et al., *Identifying covariates of population health using extreme bound analysis.* Eur J Health Econ, 2014. **15**(5): p. 515-31.
124. Babones, S.J., *Income inequality and population health: correlation and causality.* Soc Sci Med, 2008. **66**(7): p. 1614-26.
125. Bradbear, C. and S. Friel, *Integrating climate change, food prices and population health.* Food Policy, 2013. **43**: p. 56-66.
126. Brennenstuhl, S., A. Quesnel-Vallee, and P. McDonough, *Welfare regimes, population health and health inequalities: a research synthesis.* J Epidemiol Community Health, 2012. **66**(5): p. 397-409.
127. Cantarero *, D., M. Pascual, and J. María Sarabia, *Effects of income inequality on population health: new evidence from the european community household panel.* Applied Economics, 2007. **37**(1): p. 87-91.
128. Dunn, J.R., P. Schaub, and N. Ross, *Unpacking Income Inequality and Population Health.* Canadian Journal of Public Health, 2007. **98**.
129. Folland, S., *Does "community social capital" contribute to population health?* Soc Sci Med, 2007. **64**(11): p. 2342-54.
130. Gulliford, M.C., *Availability of primary care doctors and population health in England: is there an association?* Journal of Public Health Medicine, 2002. **24**(4): p. 252-254.
131. Hájek, O.i., et al., *Czech republic vs. eu-27: economic level, health care and population health.* Central European journal of public health, 2012. **20**(3): p. 167–173.
132. Jacobs, D.E., et al., *The relationship of housing and population health: a 30-year retrospective analysis.* Environ Health Perspect, 2009. **117**(4): p. 597-604.
133. Judge, K., J.-A. Mulligan, and M. Benzeval, *Income inequality and population health.* Social Science & Medicine, 1998. **97**.
134. Kim, A.-S. and E.T. Jennings Jr., *Effects of U.S. States' Social Welfare Systems on Population Health.* Policy Studies Organization, 2009. **37**(4): p. 745-767.

135. Mackenbach, J.P., *Cultural values and population health: a quantitative analysis of variations in cultural values, health behaviours and health outcomes among 42 European countries.* Health Place, 2014. **28**: p. 116-32.
136. Mellor, J.M. and J. Milyo, *Is Exposure to Income Inequality a Public Health Concern? Lagged Effects of Income Inequality on Individual and Population Health.* Health Services Research, 2003. **38**(1): p. 137-151.
137. Nelson, K. and J. Fritzell, *Welfare states and population health: the role of minimum income benefits for mortality.* Soc Sci Med, 2014. **112**: p. 63-71.
138. Ram, R., *Further examination of the cross-country association between income inequality and population health.* Soc Sci Med, 2006. **62**(3): p. 779-91.
139. Sanders, A.E., S. Lim, and W. Sohn, *Resilience to urban poverty: theoretical and empirical considerations for population health.* Am J Public Health, 2008. **98**(6): p. 1101-6.
140. Siddiqi, A. and C. Hertzman, *Towards an epidemiological understanding of the effects of long-term institutional changes on population health: a case study of Canada versus the USA.* Soc Sci Med, 2007. **64**(3): p. 589-603.
141. Thornton, J.A. and J.L. Rice, *Does Extending Health Insurance Coverage to the Uninsured Improve Population Health Outcomes?* Appl Health Econ Health Policy, 2008. **6**(4): p. 217-230.
142. Torre, R. and M. Myrskyla, *Income inequality and population health: an analysis of panel data for 21 developed countries, 1975-2006.* Popul Stud (Camb), 2014. **68**(1): p. 1-13.
143. Liu, L., et al., *Pharmaceutical expenditures as a correlate of population health in industrialized nations.* Ann Pharmacother, 2008. **42**(3): p. 368-74.
144. Hatzenbuehler, M.L., J.C. Phelan, and B.G. Link, *Stigma as a Fundamental Cause of Population Health Inequalities.* American Journal of Public Health, 2013.
145. Bockerman, P., et al., *Economic inequality and population health: looking beyond aggregate indicators.* Sociol Health Illn, 2009. **31**(3): p. 422-40.
146. Costich, J.F. and D.J. Patton, *Local legal infrastructure and population health.* Am J Public Health, 2012. **102**(10): p. 1936-41.
147. Hartley, D., *Rural Health Disparities, Population Health, and Rural Culture.* American Journal of Public Health, 2004. **94**(10).
148. Mustard, C.A., et al., *Assessing ecologic proxies for household income: a comparison of household and neighbourhood level income measures in the study of population health status.* Health & Place, 1999. **5**: p. 157-171.
149. Studnicki, J., et al., *Special healthcare taxing districts: association with population health status.* Am J Prev Med, 2007. **32**(2): p. 116-23.
150. Young, F.W. and E. Rodriguez, *Types of provincial structure and population health.* Soc Sci Med, 2005. **60**(1): p. 87-95.
151. Wan, T.T.H. and J.H. Broida, *Indicators for planning of health services: assessing impacts of social and health care factors on population health.* Socio-Economic Planning Sciences, 1983. **17**(4): p. 225-234.
152. Rainham, D., R. Cantwell, and T. Jason, *Nature appropriation and associations with population health in Canada's largest cities.* Int J Environ Res Public Health, 2013. **10**(4): p. 1268-83.
153. Hou, F. and J. Myles, *Neighbourhood inequality, neighbourhood affluence and population health.* Soc Sci Med, 2005. **60**(7): p. 1557-69.
154. Galea, S., N. Freudenberg, and D. Vlahov, *Cities and population health.* Soc Sci Med, 2005. **60**(5): p. 1017-33.
155. Galea, S., J. Ahern, and A. Karpati, *A model of underlying socioeconomic vulnerability in human populations: evidence from variability in population health and implications for public health.* Soc Sci Med, 2005. **60**(11): p. 2417-30.
156. Galea, S. and J. Ahern, *Distribution of education and population health: an ecological analysis of New York City neighborhoods.* Am J Public Health, 2005. **95**(12): p. 2198-205.
157. Zimmerman, F.J., *Habit, custom, and power: a multi-level theory of population health.* Soc Sci Med, 2013. **80**: p. 47-56.
158. Wilkinson, R.G. and K.E. Pickett, *Income inequality and population health: a review and explanation of the evidence.* Soc Sci Med, 2006. **62**(7): p. 1768-84.

159. Thomas, B., *Health and health care disparities: the effect of social and environmental factors on individual and population health.* Int J Environ Res Public Health, 2014. **11**(7): p. 7492-507.
160. McMichael, A.J., C.D. Butler, and J. Dixon, *Climate change, food systems and population health risks in their eco-social context.* Public Health, 2015.
161. MacPherson, D.W. and B.D. Gushulak, *Human Mobility and Population Health: New Approaches in a Globalizing World.* Perspectives in Biology and Medicine, 2001. **44**(3): p. 390-401.
162. Lynch, J., et al., *Is Income Inequality a Determinant of Population Health? Part 2. U.S. National and Regional Trends in Income Inequality and Age- and Cause-Specific Mortality.* Milbank Quarterly, 2004. **82**(2).
163. Lynch, J., et al., *Is income Inequality a Determinant of Population Health? Part 1. A Systematic Review.* Milbank Quarterly, 2004. **82**(1).
164. Krewski, D. and D. Rainham, *Ambient air pollution and population health: overview.* J Toxicol Environ Health A, 2007. **70**(3-4): p. 275-83.
165. Garin, N., et al., *Built Environment and Elderly Population Health: A Comprehensive Literature Review.* Clinical Practice & Epidemiology in Mental Health, 2014. **10**: p. 103-115.
166. Baker, D.P., et al., *The education effect on population health: a reassessment.* Popul Dev Rev, 2011. **37**(2): p. 307-32.
167. Moreno-Serra, R. and P.C. Smith, *Does progress towards universal health coverage improve population health?* The Lancet, 2012. **380**(9845): p. 917-923.
168. Bastian, M., S. Heymann, and M. Jacomy, *Gephi: an open source software for exploring and manipulating networks.*, in *International AAAI Conference on Weblogs and Social Media.* 2009.
169. Chowdhury, G., *Natural language processing.* Annual Review of Information Science and Technology, 2003. **37**: p. 51-59.
170. Dunn, J.R. and M.V. Hayes, *Social inequality, population health, and housing: a study of two Vancouver neighborhoods.* Social Science & Medicine, 2000. **51**: p. 563-587.
171. Muntaner, C., et al., *Politics, welfare regimes, and population health: controversies and evidence.* Sociol Health Illn, 2011. **33**(6): p. 946-64.
172. The Free Dictionary. 2015; Available from: http://www.thefreedictionary.com/.
173. Thesaurus Dictionary. 2015; Available from: http://www.thesaurus.com/.
174. World Health Oganization. 2015; Available from: http://www.who.int/topics/en/.
175. Encyclopaedia Brittanica. 2015; Available from: http://www.britannica.com/.
176. Unicef. 2015; Available from: http://www.unicef.org/.
177. Merriam Webster Dictionary. 2015; Available from: http://www.merriam-webster.com/.
178. Organisation Co-development Economic Countries. 2015; Available from: http://www.oecd.org/health/.
179. Oxford Dictionnaries. 2015; Available from: http://www.oxforddictionaries.com/.
180. Center for Disease Control. 2015; Available from: http://www.cdc.gov/.

Annexes

Annex A – Determinants & Outcomes Geographical Categorization

Authors	Title	Year	Geographical level
Babones[124]	Income inequality and population health: Correlation and causality	2008	Country
Baker et al.[166]	The Education Effect on Population Health: A Reassessment	2011	Not Specific
Bockerman et al.[145]	Economic inequality and population health: looking beyond aggregate indicators	2009	Region
Bradbear & Friel[125]	Integrating climate change, food prices and population health	2013	Country
Brennenstuhl et al.[126]	Welfare regimes, population health and health inequalities: a research synthesis	2012	Country
Cantarero et al.[127]	Effects of income inequality on population health: new evidence from the European Community Household Panel	2005	Country
Costich & Patton[146]	Local Legal Infrastructure and Population Health	2012	County
Dunn et al.[128]	Unpacking income inequality and population health - The peculiar absence of geography	2007	Country
Dunn & Hayes[170]	Social inequality, population health, and housing: a study of two Vancouver neighborhoods	2000	Neighborhood
Folland[129]	Does "community social capital" contribute to population health?	2007	State
Galea & Ahern[156]	Distribution of education and population health: An ecological analysis of New York City neighborhoods	2005	Neighborhood
Galea et al.[155]	A model of underlying socioeconomic vulnerability in human populations: evidence from variability in population health and implications for public health	2005	Neighborhood
Galea et al.[154]	Cities and population health	2005	City
Garin et al.[165]	Built environment and elderly population health: a comprehensive literature review.	2014	Not Specific
Gulliford[130]	Availability of primary care doctors and population health in England: is there an association?	2002	Country
Hajek et al.[131]	Czech Republic vs. EU-27: economic level, health care and population health	2012	Country
Hartley[147]	Rural health disparities, population health, and rural culture	2004	Region
Hatzenbuehler et al.[144]	Stigma as a Fundamental Cause of Population Health Inequalities	2013	Not Specific
Hou & Myles[153]	Neighbourhood inequality, neighbourhood affluence and population health	2005	Neighborhood
Jacobs et al.[132]	The Relationship of Housing and Population Health: A 30-Year Retrospective Analysis	2009	Country
Judge et al.[133]	Income inequality and population health	1998	Country
Kim & Jennings[134]	Effects of US States' Social Welfare Systems on Population Health	2009	State
Krewski & Rainham[164]	Ambient air pollution and population health: Overview	2007	Not Specific

Liu et al. [143]	Pharmaceutical expenditures as a correlate of population health in industrialized nations	2008	Country
Lynch et al.[162]	Is income inequality a determinant of population health? Part 2. US national and regional trends in income inequality and age- and cause-specific mortality	2004	Not Specific
Lynch et al.[163]	Is income inequality a determinant of population health? Part 1. A systematic review	2004	Not Specific
Mackenbach[135]	Cultural values and population health: a quantitative analysis of variations in cultural values, health behaviours and health outcomes among 42 European countries	2014	Country
MacPherson & Gushulak[161]	Human mobility and population health - new approaches in a globalizing world	2001	Not Specific
McMichae et al.[160]	Climate change, food systems and population health risks in their eco-social context	2015	Not Specific
Mellor & Milyo[136]	Is exposure to income inequality a public health concern? Lagged effects of income inequality on individual and population health	2003	State
Moreno-Serra & Smith[167]	Does progress towards universal health coverage improve population health?	2012	Not Specific
Muntaner et al.[171]	Review article: Politics, welfare regimes, and population health: controversies and evidence	2011	Cou2ntry
Mustard et al.[148]	Assessing ecologic proxies for household income: a comparison of household and neighbourhood level income measures in the study of population health status	1999	Province
Nelson & Fritzell[137]	Welfare states and population health: The role of minimum income benefits for mortality	2014	Country
Rainham et al.[152]	Nature Appropriation and Associations with Population Health in Canada's Largest Cities	2013	City
Ram[138]	Further examination of the cross-country association between income inequality and population health	2006	Country
Sanders[139]	Resilience to Urban Poverty: Theoretical and Empirical Considerations for Population Health	2008	State
Siddiqi & Hertzman[140]	Towards an epidemiological understanding of the effects of long-term institutional changes on population health: A case study of Canada versus the USA	2007	Country
Studnicki et al.[149]	Special healthcare taxing distracts - Association with population health status	2007	District
Thomas[159]	Health and Health Care Disparities: The Effect of Social and Environmental Factors on Individual and Population Health	2014	Not Specific
Thornton & Rice[141]	Does extending health insurance coverage to the uninsured improve population health outcomes?	2008	State
Torre & Myrskylae[142]	Income inequality and population health: An analysis of panel data for 21 developed countries, 1975-2006	2014	Country
Wan[151]	Indicators for planning of health services: assessing impacts of social and health care factors on population health	1983	Community
Wilkinson & Pickett[158]	Income inequality and population health: A review and explanation of the evidence	2006	Not Specific
Young & Rodriguez[150]	Types of provincial structure and population health	2005	Province
Zimmerman[157]	Habit, custom, and power: A multi-level theory of population health	2013	Not Specific

Annex B – Glossary, search terms, number of sources and references

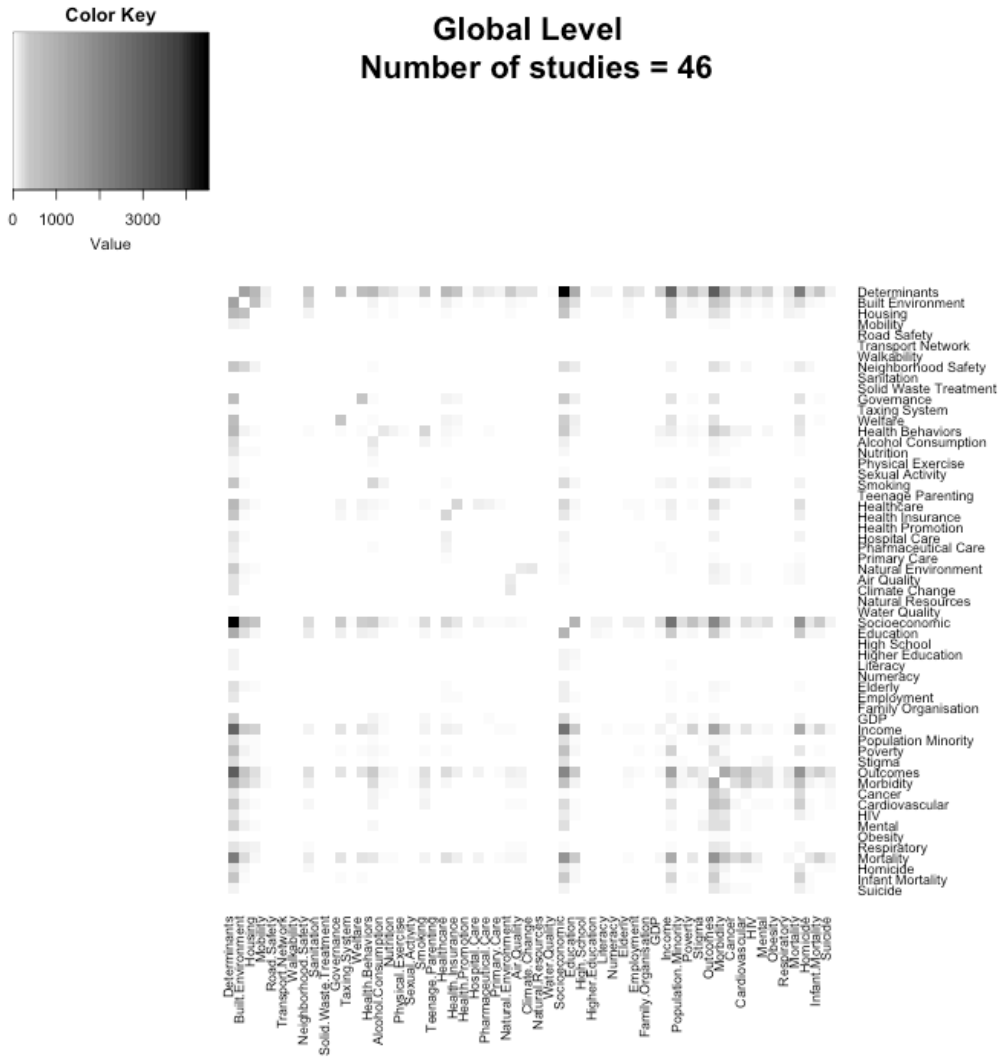
Dimension	Description	Search Terms	Sources	Refs.
Determinants			41	7539
Built Environment			39	930
Housing	Any shelter, lodging, or dwelling place, the providing of houses for a group or community. [172]	hous* OR home? OR shelter OR dwelling OR habitation? OR residence? OR lodg*	34	503
Mobility	The movement of people in a population, as from place to place, from job to job, or from one social class or level to another. [173]	mobility	10	60
Road Safety	Prevention of road traffic injury(a fatal or non-fatal injury incurred as a result of a collision on a public road involving at least one moving vehicle). [174]	"road safety"~4 OR "road accident"~3	1	4
Transport Network	Network of public tranports.	"transport network" OR "public transport" OR "public transports"	1	1
Walkability	Capability of traveling, crossing, or covering an area by walking, suitability to or adapted for walking. [173]	walkability	2	10
Neighborhood Safety	The feeling of sadety felt by the people living on that neighborgood, related with crime rates and violence.	"neighborhood safety"~6	23	198
Sanitation	Development and application of sanitary measures for the sake of cleanliness and protecting health. [173]	sanitation OR sewage	2	4
Solid Waste Treatment	The collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful. [175]	"solid waste" OR "waste treatment"	2	3
Governance			18	475
Taxing System	System by which governments finance their expenditure by imposing charges on citizens and corporate entities. [173]	"tax system"~3 OR "taxing system"~3	2	8
Welfare	Financial or other assistance to an individual or family from a city, state, or national government. [173]	welfare	18	467
Health Behaviors			30	463
Alcohol Consumption	The drinking of alcoholic beverages has is a common feature of social gatherings. [174]	alcohol*	17	98
Nutrition	Nutrition is the intake of food, considered in relation to the body's dietary needs. [174]	"balanced diet" OR nutrition OR eating	18	80
Physical Exercise	Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure. [174]	"physical exercise" OR "physical activity"~3 OR "physical activities"~3 OR sport?*	8	29
Sexual Activity	Activities associated with sexual intercourse; Sexual Transmited diseases or infections, sexual behaviour and orientation. [172]	"sexual transmited disease?" OR "sexual transmited infection?" OR "sexual behaviour" OR "sexual activity"	2	16

Smoking	The act of smoking tobacco. [173]	smok* OR tobacco	22	231
Teenage Parenting	When a teenage girl, usually within the ages of 13-19, become pregnant and delivers the child. [176]	"teenage parent*"~4 OR "young parents"~4 OR "teen parents" OR "teenage pregnanc*"~4	2	9
Healthcare			29	483
Health Insurance	Insurance against loss through illness of the insured; especially : insurance providing compensation for medical expenses. [177]	"health insurance"~3 OR medicaid OR medicare	17	251
Health Promotion	Health promotion is the process of enabling people to increase control over, and to improve, their health. It moves beyond a focus on individual behaviour towards a wide range of social and environmental interventions and initiatives. [174]	"health promotion"~3	9	19
Hospital Care	Utilization and acess to the hospital services like the urgences, admissions and discharges. [173]	hospital OR urgences OR discharge?	15	90
Pharmaceutical Care	Pharmaceutical care focuses the attitudes, behaviours, commitments, concerns, ethics, functions, knowledge, responsibilities and skills of the pharmacist on the provision of drug therapy with the goal of achieving definite therapeutic outcomes toward patient health and quality of life. [174]	pharma*	6	86
Primary Care	Medical care from the doctor who sees a patient first and provides basic treatment or decides that the patient should see another doctor. [177]	"primary care"	9	37
Natural Environment			13	295
Air Quality	Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. [174]	"air quality"~3 OR "air pollution"~3	7	125
Climate Change	A long-term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature. [173]	"climate change"~3	1	146
Natural Resources	Natural Resources are all that exists without the actions of humankind. On earth we include sunlight, atmosphere, water, land (includes all minerals) along with all vegetation and animal life that naturally subsists upon or within the heretofore identified characteristics and substances. [174]	"natural resource"~3 OR "natural resources"~3	4	13
Water Quality	Water quality is essential for drinking-water supply, food production and recreational water use. Water quality can be compromised by the presence of infectious agents, toxic chemicals, and radiological hazards. [174]	"water quality"~3 OR "water pollution"~3 OR "water treatment"~3 OR "drinking water"~3 OR "potable water" OR "clean water"	7	11
Socioeconomic			41	4893
Education			36	712

High School	A school attended after elementary school or junior high school and usually consisting of grades 9 or 10 through 12. [173]	"high school" OR schooling	2	5
Higher Education	Education beyond high school, specifically that provided by colleges and graduate schools, and professional schools. [173]	university OR college OR "higher education"	8	34
Literacy	The ability to read and write. [173]	literacy	9	35
Numeracy	The ability to use or understand numerical techniques of mathematics. [173]	numeracy	1	4
Elderly	Senior citizens, people of advanced age. [173]	elderly	13	77
Employment	An occupation by which a person earns a living; work; business. [173]	employment OR job	12	67
Family Organisation	The relationships, ties or arragements, support given by their members, also includes dynamics, size and composition of the family unit. [173]	"family support"~3 OR "family relations"~3 OR "family ties"~3 OR "family dynamics"~3 OR "family size"~3	7	11
GDP	Gross Domestic Product (GDP) is a measure of the size of an economy. It is an aggregate measure of production translated by the sum of the gross values added of all resident, institutional units engaged in production. [178]	gdp OR "gross domestic product" OR "domestic product"	17	187
Income	Monetary payment received for goods or services, or from other sources, as rents or investments. [173]	income OR wage	37	3045
Population Minority	Group in society distinguished from, and less dominant than, the more numerous majority. [173]	"population minority" OR "population minorities"	10	98
Poverty	The state or condition of having little or no money, goods, or means of support; condition of being poor. [173]	poverty	28	306
Stigma	A mark of disgrace or infamy; a stain or reproach, as on one's reputation. [173]	stigma	3	175
Outcomes			41	2332
Morbidity			33	712
Cancer	Cancer is the uncontrolled growth and spread of cells. It can affect almost any part of the body. The growths often invade surrounding tissue and can metastasize to distant sites. Many cancers can be prevented by avoiding exposure to common risk factors, such as tobacco smoke. [175, 179]	cancer OR tumor OR tumors	17	150
Cardiovascular	Cardiovascular disease is caused by disorders of the heart and blood vessels, and includes coronary heart disease (heart attacks), cerebrovascular disease (stroke), raised blood pressure (hypertension), peripheral artery disease, rheumatic heart disease, congenital heart disease and heart failure. [174]	cardiovascular OR "heart disease" OR "heart attack" OR stroke OR hypertension	26	288
HIV	The human immunodeficiency virus (HIV) is a retrovirus that infects cells of the immune system, destroying or impairing their function. As the infection progresses, the immune system becomes weaker, and the person becomes more susceptible to infections. The most advanced stage of HIV infection is acquired immunodeficiency syndrome (AIDS). [174]	hiv OR aids	13	108
Mental	Mental disorders comprise a broad range of problems, with different symptoms. However, they are generally characterized by some combination of abnormal thoughts, emotions, behaviour and relationships with others. [174]	"mental illness*"~3 OR "mental disease?"~3 OR "mental health" OR depression	18	175

		OR "mental disorder?"~3 OR anxiety		
Obesity	Overweight and obesity are defined as abnormal or excessive fat accumulation that presents a risk to health. A crude population measure of obesity is the body mass index (BMI). [174]	obes* OR overweight* OR BMI or "body mass index"	6	41
Respiratory	Respiratory tract diseases are diseases that affect the air passages, including the nasal passages, the bronchi and the lungs. They range from acute infections, such as pneumonia and bronchitis, to chronic conditions such as asthma and chronic obstructive pulmonary disease. [174]	"respiratory disease?"~4 OR "respiratory illness*"~4 OR pneumonia OR bronchitis OR asthma	11	90
Mortality			40	1620
Homicide	The killing of one human being by another. [173]	homicide?	9	142
Infant mortality	The death of a baby before his or her first birthday is called infant mortality. [180]	"infant mortality"	22	236
Suicide	Suicide is the act of deliberately killing oneself. [174]	suicide?	10	63

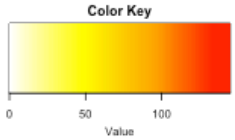
Annex C – Global dimensions co-occurrences matrix



Annex D – Matrices of insight into relationships

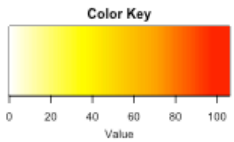
Relevant Relationships
Direction & Polarity
National

Directed	Polarity	Undirected	
0	0	0	Education & Income
8	54	98	Housing & Income
3	72	228	Income & Infant Mortality
0	40	132	Income & Poverty
20	79	73	Income & Welfare
0	10	24	Alcohol Consumption & Smoking
0	34	40	Education & Welfare
0	15	55	GDP & Income
53	38	41	Housing & Respiratory



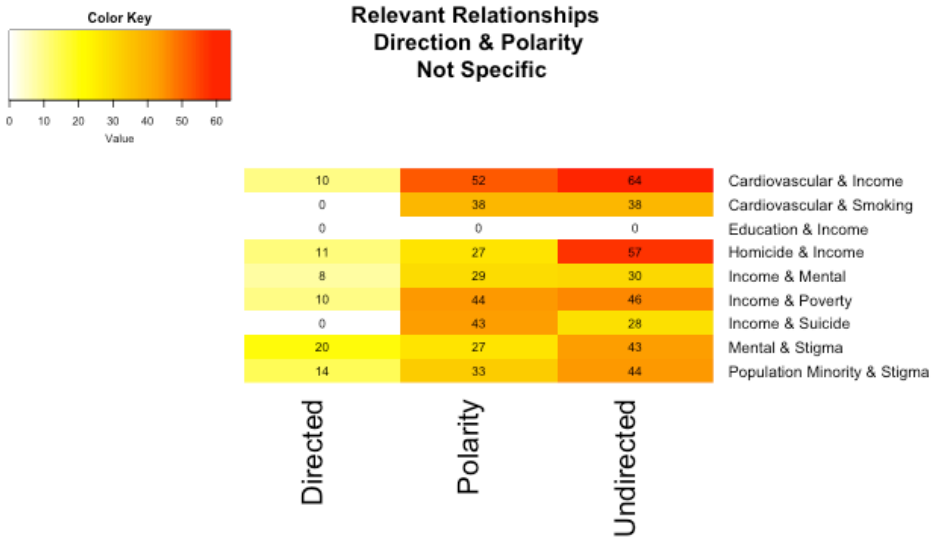
Relevant Relationships
Direction & Polarity
Regional

Directed	Polarity	Undirected	
3	13	26	Cancer & Cardiovascular
3	7	8	Cardiovascular & Poverty
0	0	0	Education & Income
0	7	9	Education & Poverty
0	16	13	Employment & HIV
0	0	10	Hospital Care & Income
0	0	8	Hospital Care & Poverty
0	46	145	Income & Poverty
3	5	11	Poverty & Smoking



Relevant Relationships
Direction & Polarity
Local

Directed	Polarity	Undirected	
0	5	23	Cardiovascular & Neighborhood Safety
0	5	63	Education & Homicide
0	5	63	Education & Income
7	36	106	Education & Neighborhood Safety
0	25	44	Education & Smoking
0	9	63	Homicide & Neighborhood Safety
8	29	31	Housing & Income
8	25	32	Income & Neighborhood Safety
3	28	20	Income & Poverty



Annex E – Main R Studio code

```
# GENERATION OF THE GLOBAL HEAT MAP
png(filename = "~/Dropbox/M/TESE/Matrizes/Output/Global 'Heatmap'.png", width = 700, height = 700,
units = "px", pointsize = 14,bg = "white",  res = NA)
my_palette1 <- colorRampPalette(c("white", "gray80", "gray75", "gray70", "gray65", "gray60", "gray55",
"gray50", "gray45","gray40","gray35","gray30","gray25","gray10","gray0"))(n=200)
test22t_heatmap<-heatmap.2 (test22t_matrix,
  main = "Global Level \n Number of studies = 46", # heat map title
  density.info="none",  # turns off density plot inside color legend
  trace="none",         # turns off trace lines inside the heat map
  margins =c(8,8),      # widens margins around plot
  col=my_palette1,       # use on color palette defined earlier
  dendrogram="none",     # removes dendrogram
  Rowv=FALSE,            # turn off row clustering
   sepwidth=c(0.05,0.05),     #  separation lines width
  Colv="NA")           # turn off column clustering
dev.off()

# GENERATION OF THE GLOBAL GRAPH
thresh_global <- 25                        #the defined threshold
test22t_matrix[test22t_matrix < thresh_global] <- 0 # eliminates all connections inferior to the threshold

png(filename = "~/Dropbox/M/TESE/Matrizes/Output/Global Graph (areas+degree).png", width = 1700,
height = 1900, units = "px", pointsize = 45,bg = "white",  res = 70)

graph22 <- graph.adjacency(test22t_matrix/max(test22t_matrix), mode="undirected",
weighted=TRUE,diag=FALSE)                  # translates the matrix into a graph
E(graph22)$width <- E(graph22)$weight  * 10            #establishes the width of the edges according to
the number of counts
a=read.table("areas.txt",header=T, sep="\t")
V(graph22)$Area=as.character(a$Area[match(V(graph22)$name,a$Node)]) # creates a node attribute
called "Area" by extracting the value of the column "Area" in the attributes file when the Node number
matches the node name.
graph22 <- delete.vertices(graph22, V(graph22)[ degree(graph22)==0 ])  #deletes the isolated nodes
par(mar=c(2.1,2.1,2.1,2.1))
V(graph22)$color=ifelse(V(graph22)$Area=="Built.Environment", "brown",
                    (ifelse(V(graph22)$Area=="Health.Behaviors", "yellow",
                          (ifelse(V(graph22)$Area=="Natural.Environment", "green",
```

```
                                (ifelse(V(graph22)$Area=="Socioeconomic", "blue",
                                      (ifelse(V(graph22)$Area=="Morbidity", "purple",
                                            (ifelse(V(graph22)$Area=="Healthcare", "pink",
                                                  (ifelse(V(graph22)$Area=="Governance", "red",
                                                        (ifelse(V(graph22)$Area=="Mortality", "grey",
"orange")))))))))))))))                                 #colors the node according to its area

V(graph22)$size=degree(graph22)  # sets the size of the node according to the degree
 graph_print <- plot.igraph(graph22,
layout=layout.lgl,              # spreads the nodes in space
 vertex.label.cex=1,                    # size of the node label
  vertex.label.color="black",                   # color of the node label
 vertex.label.font= 1,                          # font of the node label
 vertex.frame.color="NA",               # color of the node label frame
 main = "Global \n Area Dispersion & Connectivity Degree",      # graph title
 axes=FALSE,                                    #removes axis
 vertex.shape="circle",                 # node shape
 frame=FALSE)
 text(1,1, paste0("INFORMATION \n Number of studies = 46  \n Threshold=", thresh_global, "\n Number
of vertices=", vcount(graph22), "\n Number of links=",ecount(graph22) ,"\n Max
counts=",max(test22t_matrix),"\n Min counts=",min(E(graph22)$weight)*max(test22t_matrix)), cex=0.5 )
                                        # print information about the generated graph
dev.off()

# GENERATION OF THE SYSTEMS MAP
png(filename = "~/Dropbox/M/TESE/Matrizes/Output/Systems Map.png", width = 5000, height = 6000,
units = "px", pointsize = 150,bg = "white",  res = NA)

SM=read.table("Workbook5.txt",header=T, sep="\t")
graph_map <- graph.data.frame(SM, directed=TRUE, vertices=NULL)
E(graph_map)$label=E(graph_map)$Geographical_Level
E(graph_map)$arrow.mode=ifelse(E(graph_map)$Directionality =="?", 0,
                        (ifelse(E(graph_map)$Directionality =="<", 1,
                                (ifelse(E(graph_map)$Directionality ==">", 2,
                                (ifelse(E(graph_map)$Directionality =="<>", 3,0)))))))
E(graph_map)$color=ifelse(E(graph_map)$Polarity=="+", "green4",
                        (ifelse(E(graph_map)$Polarity=="-", "tomato4",
                                (ifelse(E(graph_map)$Polarity=="?", "gray","" )))))
par(mar=c(1,1,1,1))
graph_map_print <- plot.igraph(graph_map,
layout=layout.lgl,
   vertex.label.cex=.6,
 edge.label.cex=.5,
 vertex.frame.color="NA",
  vertex.label.color="black",
 vertex.label.font= 1,
 edge.width=5,
edge.arrow.size=1,
edge.arrow.width=0.7,
 main = "Systems Map",
 vertex.color="grey",
 axes=FALSE,
 vertex.size=5,
 vertex.shape="circle",
 frame=FALSE,
  edge.curved=TRUE)
dev.off()
```