What determines population health?

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

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A B S T R A C T

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

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. 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.

Section 2 is a brief review of the concept and methods approached in this work. Section 3 details the

multimethodology. Section 4 contains the main results, which are discussed in Section 5.

2. Review of Concepts and Methods

2.1. 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 [2]. In order to assess the health of a population, valid, comprehensive, transparent, and standardized ways of measuring and reporting on PH are needed [3], as well as PH concepts.

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 [4]. The index will be informed by evidence on the relationship between multiple determinants as well as health outcomes where this work 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 [4].

2.2. Literature Review of Methods

The purpose of synthetizing, identifying and structuring concepts and ultimately inform decision-making, can be achieved through the use of research methods in Health, Problem Structuring Methods and Content Analysis. Research methods in health allow a systematic and transparent way to summarize and consolidate the evidence on the area of Population Health.. Problem Structuring Methods 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 enables the identification and interconnection of relevant dimensions.

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. 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 quantitative data from similar population methodologies and analysis is impossible and not relevant. 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. 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.

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 [40]. 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. 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.

Content Analysis (CA) 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 [51]. 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.

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 reliability in analytical tools. To face these challenges, transparent and more automated methods are needed.

2.3. Research objectives

In this article 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.

3. Multimethodology

This section details the multimethodology. The use of a multimethodology enabled a review process that is transparent, systematic and with more reliance on automated analysis. Different methods and analytical tools were 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 in the context of PH.

The protocol consists of three stages: Preliminary Literature Review, Content Analysis, and Systems Mapping.

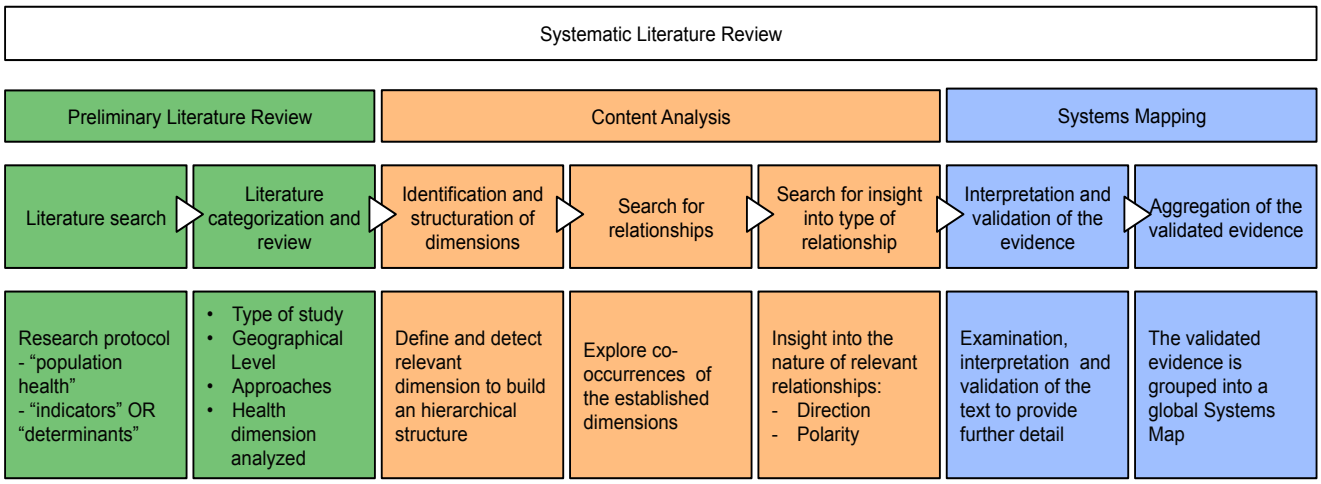

Figure 1 - Multimethodology overview.

3.1. Preliminary Literature Review

The multimethodology starts with a Preliminary Literature Review. In this analysis, a studies sample is gathered following the guidelines of a literature review, 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.

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

Population Health Policy – analyses 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 or self-collected data in order to find relationships between different dimensions and health outcomes. These can be focused on different areas such as natural environment, healthcare services, social status or cultural values.

3.2. Content Analysis

In a second part, Content Analysis is applied to construct a hierarchical structure containing all the relevant categories, using both a deductive and inductive approach, throughout the coding development. Using the concepts of deductive CA, existing indices (in the present case, GeoHealthS [69] and County Health Rankings [21]) were used as a basis for the construction of an initial structure. If it was verified that a dimension was present in the data, it was left in the structure, if not it was removed. To have an exhaustive analysis the presence of further dimensions in the text was analyzed, (inductive CA is applied).

Option	Example	Comment
Wildcard ?	Role?	Represents one arbitrary character
Wildcard *	Teen* parents	Any number of arbitrary characters
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

Table 1 - Search operators and examples (adapted from [7]).

To aid this search, it is performed consecutive text searches to find occurrences of those dimensions in the data. The search is performed using operators that allow the capture of diversity with not only varying terminations (Table 1). Initially, to develop the list of terms, attempting to seize this diversity, exploratory searches are performed to find stemmed words or synonyms.
After, searches to find relationships are performed. 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 allows some quantitative assessment and, consequently, the possible importance of the relationship between dimensions.

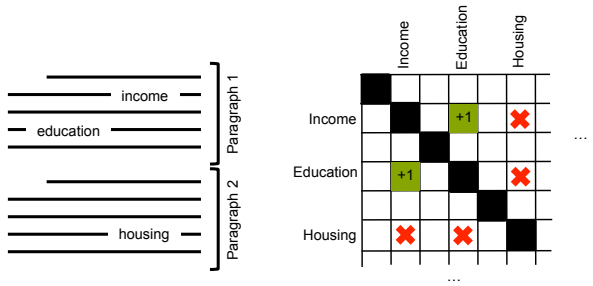

Figure 2 - Representation of the increment in the matrix according to de defined scope – the paragraph.

As it is argued and applied by Yearworth & White [8], 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. The alternative choice: 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 idea is made, and for that reason it is valid to consider that two dimension present in the same paragraph belong to the same line of argument.
The results are then presented in the form of a graph, where the nodes represented the dimension/categories. With this representation it is possible to complete a series of analysis that allowed assessing the most relevant dimensions in a holistic manner, for example how are the dimensions distributed or how many connections they have with other dimensions (Figure 3).

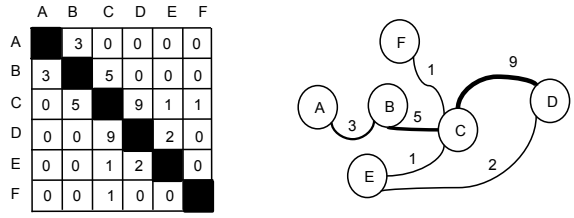

Figure 3 - Illustrative example with the binary matrix on the left describing the graph on the right (adapted from Yearworth & White [8]).

The most relevant relationships are further examined. A set of connectors is searched for in the same scope than previously established, in order to gain insight into the possible direction (directed or undirected) of the relationships. Additionally, another search includes, within the same scope, terms that indicate the polarity (positive or negative) of those same relationships.

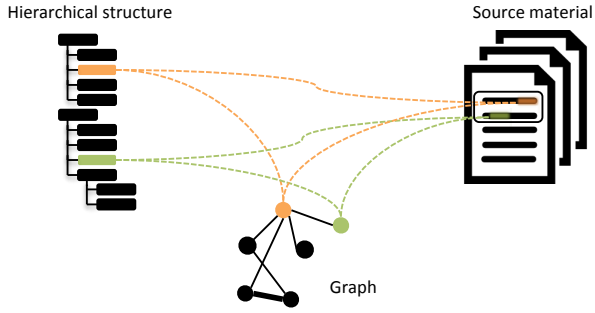

Figure 4 - Schematic representation of the relation between the studies, the hierarchical structure and the graphs.

3.3. Systems Mapping

Lastly, in the Systems Mapping, the selected relationships are examined to check that the process is able to find accurate relationships. Based on the validated relationships, their polarity and direction, the evidence in synthetized (according to the criteria present in Table 2) in one table for later representation of the global Systems Map.

3.4. Implementation

For implementing the previously detailed multimethodology, three *software* were used: NVIVO [9], R Studio, Excel and FreeMind [10]. 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

	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.

Table 2 - Aggregation criteria.

4. Main Results

In this section the main results from applying the multimethodology are presented.

4.1. Preliminary Literature Review

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?" [11-15] and of related terms such as health, policy or outcomes [16]. The term 'population health' is seen as the natural evolution of the science of epidemiology and the umbrella term for 'Public health', 'Health Promotion', determinants of health and health outcomes [12]. PH has 5 major focuses:

- ✓ Emphasis on well-being maximization

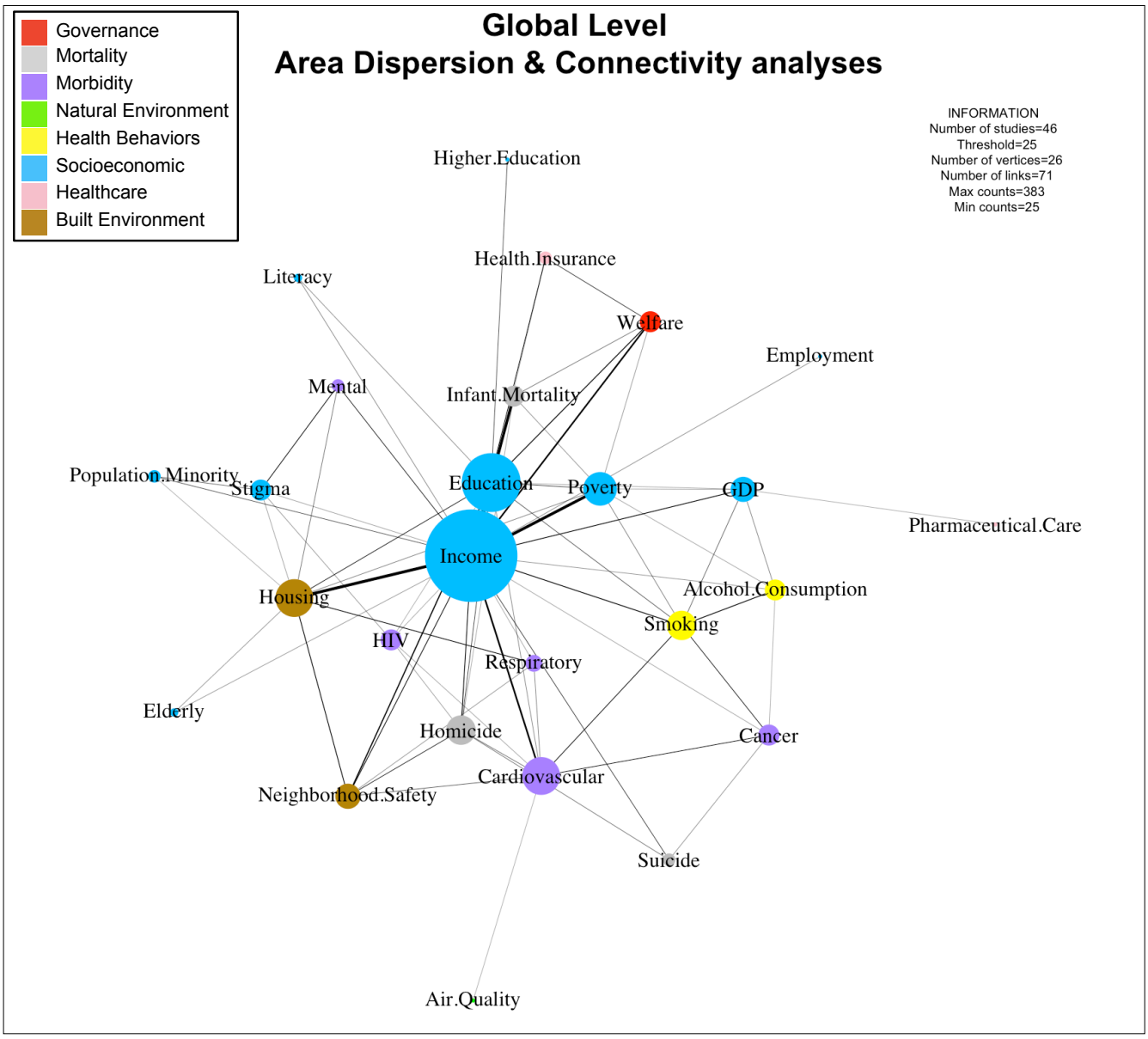

Figure 5 - Graph with the most relevant dimensions, their respective classification into different areas and the degree of connectivity. Visualization programmed in R Studio.

- ✓ 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 is on the recognition 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" [14]. The determinants influence the outcomes and its distribution, so the most favorable patterns are evaluated [17-19]. Policies are seen as influential in both determinants and outcomes [1]. The resulting system is dynamic with multiple non-linear relationships and a network of causalities.

4.2. Content Analysis

As previously mentioned, the width of the edges is proportional to the number of co-occurrences counts between the two dimensions. In the representation (Figure 5), it is already observable some central dimensions such as Income and Education and their prominent connection. A distinction can be made from the dimensions that are in a more nuclear position; these

are more strongly connected to each other (appear more times in the same scope) and a set of dimensions that are more peripheral, for example Pharmaceutical Care, Air quality, Employment, Higher Education and Elderly.

In this analysis it can be observed that the socioeconomic area is the most represented. To this area, it belongs 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 category 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 dimensions, Housing and Neighborhood Safety, which, albeit having a more central location, are further away from each other. Dimensions from Morbidity and Morbidity areas are fairly distributed across the graph; they occupy an approximately central position but are not concentrated. The size of the vertices is proportional to the number of connections it has with other vertices. Intuitively, the more central dimensions were more connected with further dimensions and for that reason are in found. in a greater size. For example, it is possible to identify some dimensions that are relatively to the rest are more connected. One example is Housing, its central position already revealed some relevance, nonetheless, it is noticeable a greater connectivity in comparison to the others surrounding it. Another example comes from the Cardiovascular; clearly it has more connections with other dimensions. As it is expected, peripheral nodes end up with a very small size as a result of their few connections..

4.3. Systems Map

In this representation (Figure 6) it is considered a positive relationship (green) between A and B, 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 edge was left grey.

In the edges it is present the geographical levels in which that connection was identified. This information is not showed if the study does not specify the geographical level. When evidence for a preferred direction was provided, it was displayed or when the relationship was found to be bidirectional, this was also displayed, only if no evidence was validated in either case, the edge was left with no arrows. The represented dimensions are considered to be fairly quantifiable. In some cases, an increase in the dimension signifies and increase to the desirable state, for example an increase in the dimension Housing means more suitable housing conditions on the other hand Poverty, Stigma, Infant Mortality or any Morbidity dimension, their increase represent the increase of an undesirable attribute.

The presence of the different geographical levels are well distributed, this fact is highly influenced by the protocol established (the selection of the top most from each sample). In the case that 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 provided some insight into some relationships. Some relationships were expected for example the nuclear role of dimensions such as Education and Income. The high presence of dimension from the area Morbidity was unforeseen, although this presence had already been verified in previous results.

5. Discussion

In the present section it will be discussed the methods and results developed in this work.

5.1. Results

The Preliminary Literature Analysis revealed that the concept of Population Health has been increasingly debated. Some advances have been achieved 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. Challenges have been met in the establishment of targets of policies and realistic goals. The incentive of research to aid decision-making in policy is transversal.

In the Content Analysis Results, the reached hierarchical structure was not dissimilar to previously developed indices, GeoHealthS [20] and County Health Rankings [13], this confirmed the dimensions established in those indices.

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 elevated quantity of dimensions. It only provided a small insight into singular intersections that

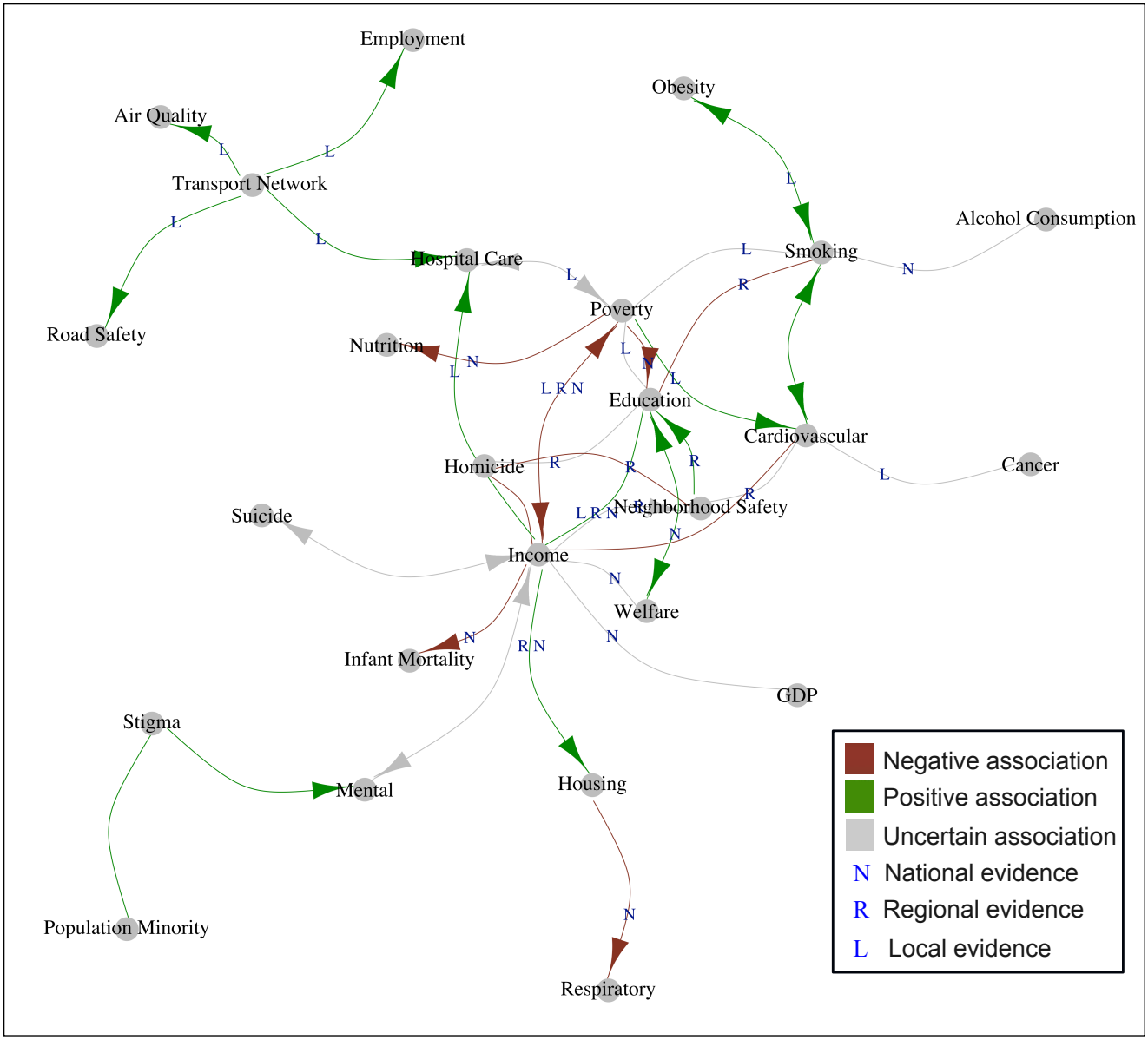

Figure 6 - Population Health Systems Map. Visualization programmed in R Studio.

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 allowed to identify differences between studies, some scarcely mentioned dimensions when compared to other that were highly mentioned. This absence could be due to its real lack of presence in the literature or to the inability to capture the dimensions through the use of the

were considerably higher 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, also it 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 seen that it contained the information from all the studies.

In the Global level it was achieved the presence of 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, income can be easily assessed through the collection publicly available data on average income. The concern with multiple diseases and conditions – Morbidity – had not yet been established, 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.

In the separate analysis of the geographical levels it was possible to establish relevant dissimilarities between them.

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 relationship present. The information showed some predictable results such as the intensively studied Income and Education. These dimensions have a far-reaching impact into other dimension 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 as it can be observed. This fact might be related to the studies that examined this dimension did it so at this superior level. This is a shortcoming of associating the geographical level of a relationship to the one stated in the study.

5.2. Overall limitations and achievements

The approach chosen has some limitations in each of the methods used; these limitations could be further decreased through further development or the choice of alternatives.

An overall limitation of the process is the studies sample 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, the bias of the analysis is to this 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 to use the co-occurrence in the same scope as a possible clue for a relationship could be misleading; it was made clear that the fact that two dimensions are in the same scope it does not necessarily ensure the presence of a relationship. It was argued that the quantification of these co-occurrences could provide some indication, the more times a co-occurrence happened, the more probable it was it would be found a relationship.

Yearworth & White [8] caution the use of tools that implement the approaches of graph theory and network analysis functions to analyze the structure of the matrix generated by the NVIVO[9] matrix query for potential loops of relationships; here it is argued that a analogous task can enable a holistic visualization and description of the complex system.

Additionally, since the results obtained were still very high, a refinement was made. The search for connectors that enabled the definition of the type of relationship was achieved.

The options along the multimethodology were so far clarified; it is also relevant to identify some improvements that would enhance the obtained results.

A more cohesive sample in order to find more detail and consistent relationships, in this context it was intended to also capture diversity and in this it was 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.

5.3. Other applications

The present multimethodology can be applied in other contexts, with special interest to areas with multiple dimensions that can be organized and structured into a hierarchical structure and that are interrelated, One example might be the evaluation of a specific industry, the procedure can pass by an economic, environmental and social impact of that industry and within each section multiple criteria or indicators to measure that impact and these indicators may influence each other. Another example can be the performance analysis of an institution, compromising 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 that context and organize them in the adequate hierarchical structure. The attributes of the relationship could be adapted in changing the search terms.

6. Concluding Remarks

In the present work, it was proposed methods that allowed alternative analysis to 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 qualitative data. An important comprehension was provided about the Population Health literature, identification of significant dimensions was accomplish as well as the determination of relationships.

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