ORIGINAL PAPER

Modelling and Evaluation of Policies

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ABSTRACT

Introduction: NCDs (non-communicable diseases) are considered an important social issue and a financial burden to the health care systems in the EU which can be decreased if cost-effective policies are implemented, along with proactive interventions. The CrowdHEALTH project recognizes that NCD poses a burden for the healthcare sector and society and aims at focusing on NCDs' public health policies. **Aim:** The aim of this paper is to present the concept of Public Health Policy (PHP), elaborate on the state-of-the-art of PHPs development, and propose a first approach to the modeling and evaluation of PHPs used in a toolkit that is going to support decision making, the Policy Development Toolkit (PDT). **Methods:** The policy creation module is a part of the PDT aiming to integrate the results of the rest of the health analytics and policy components. It is the module that selects, filters, and aggregates all relevant information to help policy-makers with the decision making process. The policies creation component is connected to the visualization component to provide the final users with data visualization on different PHPs, including outcomes from data-driven models, such as risk stratification, clinical pathways mining, forecasting or causal analysis models, outcomes from cost-benefit analysis, and suggestions and recommendations from the results of different measured KPIs, using data from the Holistic Health Records (HHRs). **Results:** In the context of CrowdHEALTH project, PHP can be defined as the decisions taken for actions by those responsible in the public sector that covers a set of actions or inactions that affect a group of public and private actors of the health care system. In the CrowdHEALTH project, the Policy Development Toolkit works as the main interface between the final users and the whole system in the CrowdHEALTH platform. The three components related to policy creation are: (i) the policy modeling component, (ii) the population identification component and (iii) the policy evaluation component. In policy evaluation, KPIs are used as measurable indicators to help prevent ambiguity problems in the interpretation of the model and the structure. **Conclusions:** This initial Policy creation component design might be modified during the project life circle according to the concept complexity.

Keywords: Policy Making, Public Health Policy, Policy Creation.

1. INTRODUCTION

About 36 million deaths, or 63% of the 57 million deaths that happened on a global scale in 2008, were attributed to NCDs. Cardiovascular diseases were the first cause (48% of NCDs), cancers followed with 21%, chronic respiratory diseases with 12% and diabetes with 3.5%. According to the WHO, the total annual number of deaths from NCDs will rise to 55 million by 2030 if no significant change occurs (1).NCDs also make up for the healthy life years lost based on the Disability Adjusted Life Years (DALY) (2) while NCDs are considered an important social and financial burden to the health care systems and are a barrier to development, especially related to the aging population in developed countries and the EU member states (3),(4). NCDs burden can be decreased if cost-effective policies are implemented, along with proactive interventions and regular monitoring of NCDs. Enabling health systems to respond promptly and effectively to the health-care needs of people with NCDs can reduce premature deaths. Public policies regarding risk factors such as tobacco use, unhealthy diet, physical inactivity, and the harmful use of alcohol can be implemented in several sectors (1). The CrowdHEALTH project recognizes that NCD poses a burden to the healthcare sector and society and aims at focusing on NCD's public health policies. Health policy refers to decisions, plans, and actions that are implemented to achieve specific health care goals within a society. A health policy defines a vision for the future that can be achieved by establishing targets and points of short and medium-term reference. Also, it sets priorities, outlines the expected roles of different groups, builds consensus, and raises people's awareness (5). The aim of EU public health policies is to ameliorate human health, prevent disease and support change of Europe's health systems (6). Health Policy may be difficult to define as the definition is based on the experience of who defines it. However, following the general definition of (7, 8) Public Health Policy (PHP) is the decisions taken by those responsible in the public sector that covers a set of actions or inactions that affect a group of public and private actors of the health care system to achieve specific health care goals. PHP takes into account the specific context and characteristics of the region where it has to be implemented affecting many different actors that have to be considered during its design. When a PHP is developed, a proper evaluation is mandatory to assess whether the actions or inactions are serving the defined goals. This process is monitored using Key Performance Indicators (KPIs) to evaluate whether the proposed goals are achieved and to consider the appropriateness of the selected indicators.

2. AIM

The aim of this paper is to present the concept of Public Health Policy (PHP), elaborate on the state-of-the-art of PHPs development, and propose a first approach to the modeling and evaluation of PHPs using a toolkit that is going to support decision making, the Policy Development Toolkit (PDT).

3. METHODS

The Policy Development Toolkit works as the main interface between the final users and the whole system in the CrowdHEALTH platform. The three components related to policy creation are: (i) the policy modeling component, (ii) the population identification component and (iii) the policy evaluation component. The policy creation module is a part of the PDT aiming to integrate the results of the rest of the health analytics and policy components. It is the module that selects, filters, and aggregates all relevant information to help policymakers with the decision making process. Hence, this module, as well as the whole PDT, is regarded as a decision support system for policy-makers. PDT does not only create new PHPs, but it can also be used to improve already existing PHPs. The policies creation component is connected to the visualization component to provide the final users with data visualization of different PHPs, including outcomes from data-driven models, such as risk stratification, clinical pathways mining, forecasting or causal analysis models, outcomes from cost-benefit analysis, and suggestions and recommendations from the results of different measured KPIs, using data from the Holistic Health Records (HHRs). The policy modeling component aims at providing a formal structure to a PHP. The structure is focused mainly on the key performance indicator of an existing or a new particular goal that is related to a PHP. A KPI is a clear measurable indicator with a clear definition and a mathematical formula, which helps prevent ambiguity problems in the interpretation of the model and the structure. However, since a KPI is related to specific goals of a PHP, the relation will be kept explicit in the model of the health policy. Also, particular data-driven models, specific data and sets of active and passive actors related to the PHP and the defined KPI can be made explicit in the formulation of the formal model of the PHPs, to relate possible predictions to the KPIs and hypothesize evolutions of the indicators for the improvement and development of PHPs. The policy evaluation component is devoted to the assessment of the different health policies that are under consideration in the PDT using a policy model that has to be defined in the previous component. The evaluation of the policies depends on the core concept of KPIs that defines and bases the formal policy models. Furthermore, each KPI will be associated with certain Organization for Economic Co-operation and Development (OECD) evaluation tiers (12) and the performance metrics defined, to clarify the role of each KPI inside a PHP. Besides, the policy evaluation component is responsible for obtaining the actual value of the KPI, based on its mathematical definition and the available data from the HHRs. Thus, it is very important to define clear and measurable KPIs and their associated mathematical formulas, as well as the population that is evaluated by the KPIs. The population identification component aims basically at providing a proper set of stored and available data from the HHRs that identify the proper population to measure the success of the PHP. This component can be seen as a system that applies filters to the actual data and gathers the results as an evaluation set to send it to the policy evaluation component. The population identification component is of utmost importance to clearly define the population for which the PHP is meant, before defining the different components of the PDT architecture. It is important because the policy formal model and structure depends on the understanding of health policies and its main features.

4. RESULTS

4.1. Policy modeling

Based on the definition of PHPs, the use of ontologies for policy modeling appears o be a rather complex task. The intrinsic complexity of PHPs and the extrinsic influences and dependencies on uncontrollable factors makes the design and development of PHPs rather un-

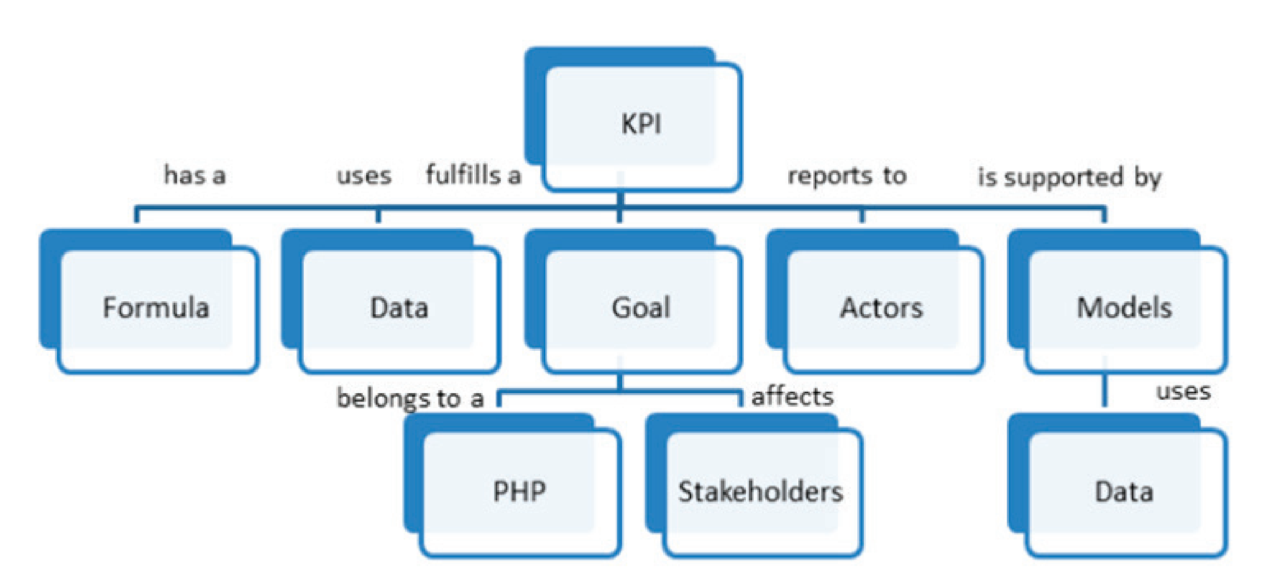

Figure 1. Conceptual structure of policy model

certain. One of the best approaches is to focus on the measurable part of a PHP: the Key Performance Indicators. The indicators of public health policies are a set of specific values that allow measuring the quality and/or success of a particular policy. As opposed to a policy, a KPI is clearly measurable using available data from the project and it may better guide the assessment of current policies and even the creation of a new policy. Hence, the proposal is to use KPIs as the core of the policy modeling structure. KPIs are measures of performance that should be based on standards and are determined through scientific evidence or the consensus of experts when evidence is unavailable. In the CrowdHEALTH project, a KPI is related to a set of data that can be used to compute their current value, and its evolution in time will be based on a mathematical formula. KPIs will be also related to a set of actors, who will be interested in measuring the success of a public health policy that will affect at the same time a group of actors, mainly citizens, but also patients, and health care professionals, among others. The KPI will measure the success of a particular PHP and its actual value will indicate whether this goal is achieved or not. Of course, the goal will be designed to affect a group of stakeholders who have a passive role. Finally, KPIs may be related to a set of data-driven models (HHR classifiers) that may yield forecasts and predictions based on available data on the Holistic Health Records. This is the basic conceptual schema of Policy Modeling centered on KPIs (Figure 1). Two examples in Table 1 and Table 2 explain the aforementioned conceptual structure of a KPI-based PHP. These two examples aim at clarifying the meanings behind each concept of the possible ontology. Firstly, the overweight and obesity Use Case is considered and a policy modeling structure filled with the corresponding information is provided. A proposal for systematically detecting overweight and obesity could be developed and modeled using the aforementioned basic structure of a PHP. Afterward, a structure is proposed for a KPI that is related to such a goal (Table 1). Regarding the Use Case on physical fitness, physical activity, and obesity which is aimed at providing direct support to school physicians and pediatricians to help them in early detection of children with increased health risks linked to poor physical fitness and obesity, the relevant policies are described in the National Program on Nutrition and Physical Activity for Health 2015-2025 (11). One of the proposed KPIs is the health-related fitness index, which is an overall evaluation of physical effectiveness in percentiles, according to age and gender. A conceptual schema based on the proposed structure could be as follows (Table 2). The two examples show that the concepts support meaningful knowledge. Hence, the designed KPI-based PHP structure allows achieving a conceptual framework for the development of a semantic model. Figure 2 shows a graphical representation of this semantic model of a PHP as a current perspective.

4.2. Population identification

The main goal of the population identification component is to provide a data set to evaluate the proposed KPI within the policy evaluation component, as well as for identifying data from the HHR population that can be used for running a data-driven predictive model. Hence, this component will serve two different but analog purposes: population identification for policy evaluation, and population identification for running predictive models. Identification of the proper population for policy evaluation must be based on a set of inclusion and exclusion criteria, which have to be included in metadata information. This metadata is data that provides information about the KPIs used to evaluate the policies and information on the predictive models, regardless of their nature, i.e. risk stratification, pathway mining, causal analysis, or forecasting. The metadata will include information for identifying the proper population through the use of filters to select the subjects under study. The data of the CrowdHEALTH project will be stored in the CrowdHEALTH data store, which in the end will be a relational data-

ITEM	Description
KPI	Rate of adults identified as obese. The pravelance of obesity in adults is known to be around 15% of the population. However, there is only around 1.5% of diagnostics of obesity reported using ICD-9 codes, which implies that obesity condition is not being taken into account when reporting and storing secondary diagnosis of the patients. The goal of this KPI would be to report an increase in the prevalence of the obesity condition in the codification of the morbidities of each patient, promoting thus a systematic detection of this condition.
FORMULA	Numerator: Number of adult population properly identified as obese (ICD9/ICD10) Denominator: Number of adult population
DATA	The data for computing this KPI and report its evolution should be obtained from the datamarts of the Health Department La Fe including primary and secondary care information about morbidity.
STAKEHOLDERS	People interested in the evolution of this KPI and who may be reported are Hospital Managers, the Head of the Endocrinology Service, and Experts on Public Health, among others.
GOAL	To sensitize healthcare professionals to boost the systematic detection of overweight and obesity in the population.
PHP	Strategy for physical activity, nutrition and prevention of obesity

ITEM	Description
ACTORS	People that may be affected by this PHP are citizens that are obese but they have not been correctly diagnosed and whose diagnosis has not been correctly stored. Also, endocrinologists may be affected as their work may be improved by this systematic detection of obesity.
MODELS	A model can be used to help detect people that are likely to be in the obesity profile. This is the risk stratification model proposed by UPV in Deliverable 5.2 based on a semi-supervised learning approach.
DATA FOR MODELS	The data to be used for the models will be determined during the development and validation of the semi-supervised model.

Table 1. Example of KPI and PHP conceptual structure

ITEM	Description
KPI	Health-related fitness index. The estimation of fitness based on motor tests 600 m run, bent arm hang, and sit ups, which gives the estimation of health-related fitness in percentiles according to age and gender.
FORMULA	Numerator: Aggregated data from the health-related fitness index Denominator: 1
DATA	The data for computing this KPI and report its evolution is gathered every April with field testing in all (about 600) primary and secondary schools in Slovenia and imported directly in SLOfit database by school administrators. The percentiles (according to sex and age) of fitness data are computed within SLOfit web application.
STAKEHOLDERS	People interested in the evolution of this KPI and who may be reported are Experts on Public Health, researchers, children's parents.
GOAL	To promote good physical activity habits and physical fitness.

ITEM	Description
PHP	Nutrition and Physical Activity for Health.
ACTORS	People that may be affected by this PHP are mainly children.
MODELS	A forecasting model can be used to help in the prediction of future evolution of health-related fitness index.
DATA FOR MODELS	The data to be used for the models will be determined during the development and validation of the forecasting model.

Table 2. Example of another KPI and PHP conceptual structure

base. Therefore, identification of the population can be performed utilizing a list of variables with their minimum and maximum thresholds that will be transformed into an SQL query. For example, if a data set from an adult population is needed to compute a KPI, a good filter may include "age" as a variable to be taken into account, along with a "minimum" attribute with a value of "18" and a "maximum" attribute with a different value. Subsequently, this filter can be transformed into a where clause within an SQL query. The metadata must also include information regarding the variables that have to be selected for each subject under study. Hence, if a KPI or a predictive model needs the "gender" of the individuals, then this could be included in the select clause within the SQL query. Hence, there is a need to design a schema that will provide all necessary information within the metadata, to identify the population, as explained in the previous paragraphs. This metadata information can be developed using an XML schema that should be able to encapsulate all the needed attributes and sub-elements to represent the necessary filters and variables in detail, its parameters, and its structure. The XML Schema Definition (XSD) for population identification contains definitions for fields that are used as filters. It specifies the types and value ranges and the valid values for filtering in a where clause within an SQL query. The XSD is shown in Table 3. There are two main types of data to be considered when filtering SQL queries: numerical data and

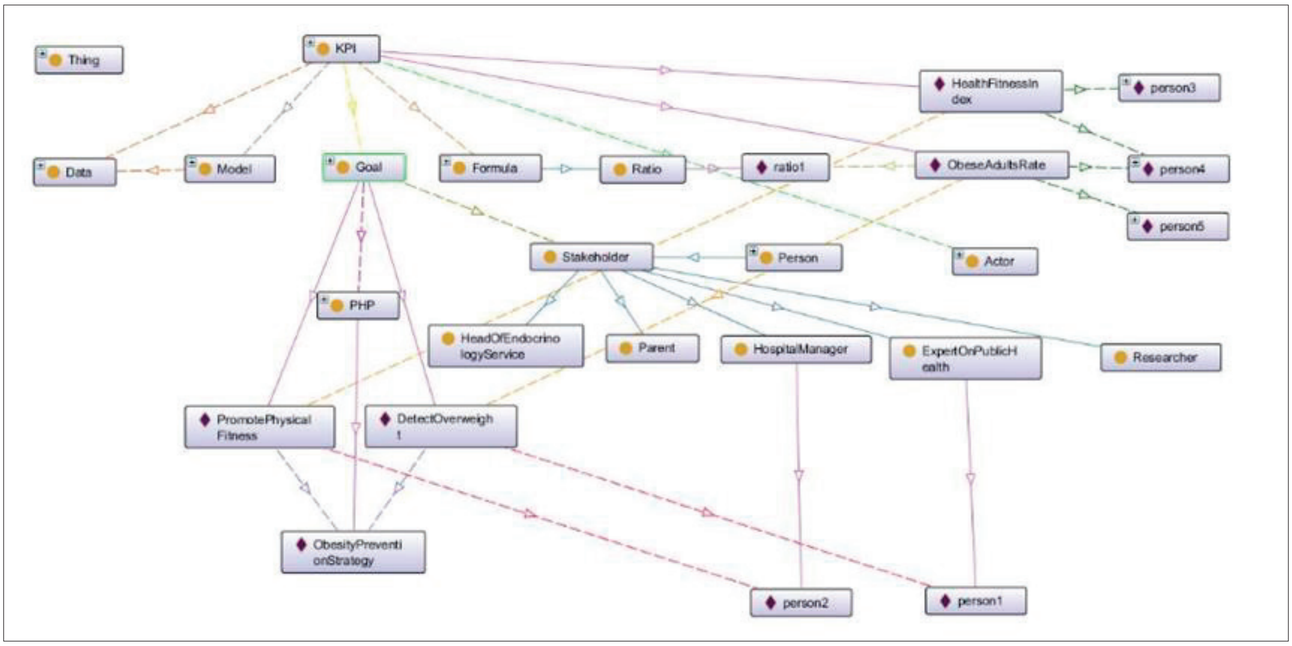

Figure 2. Graphical Depiction of a semantic model of a PHP

categorical data. Hence, there are two basic elements called NumericalDataField and CategoricalDataField that must be unique from other names in the PopulationIdentification element. Each element identifies each main type, respectively. Both elements share a set

```xml
<schema xmlns:xs="http://www.w3.org/2001/XMLSchema" project="crowdhealth" version="0.1">
<xs:element name="PopulationIdentification">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="NumericalDataField" maxOccurs="unbounded"/>
    </xs:sequence>
       <xs:sequence>
      <xs:element ref="CategoricalDataField" maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute name="numberOfFields" type="xs:nonNegativeInteger"/>
  </xs:complexType>
</xs:element>

<xs:element name="NumericalDataField">
  <xs:complexType>
    <xs:attribute name="name" type="xs:string" use="required"/>
    <xs:attribute name="displayName" type="xs:string"/>
    <xs:attribute name="vartype" type="VARTYPE" use="required"/>
    <xs:attribute name="minimum" type="xs:decimal" use="required"/>
    <xs:attribute name="maximum" type="xs:decimal" use="required"/>
  </xs:complexType>
</xs:element>

<xs:element name="CategoricalDataField">
  <xs:complexType>
    <xs:attribute name="name" type="xs:string" use="required"/>
    <xs:attribute name="displayName" type="xs:string"/>
    <xs:attribute name="vartype" type="VARTYPE" use="required"/>
    <xs:sequence>
       <xs:attribute ref="filterValue" minOccurs="1" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>

<xs:element name="filterValue">
  <xs:attribute name="validValue" type="xs:string" use="required"/>
</xs:element>

<xs:simpleType name="VARTYPE">
  <xs:restriction base="xs:string">
    <xs:enumeration value="numerical"/>
    <xs:enumeration value="categorical"/>
    <xs:enumeration value="date"/>
  </xs:restriction>
</xs:simpleType>

</schema>
```

Table 3. XML Schema Description for Population Identification

of common attributes like name, displayName, and var type. The name is a string that is used to identify the variable name. The displayName is an optional attribute that may be used by applications to refer to that field. However, the XML document only considers as significant the value of the name. If displayName is not given, then it takes the value of the name as default. The Vartype is a restricted type that allows using the following values: numerical, categorical, and dates. The NumericalData ype requires a minimum and a maximum value to be defined to provide enough information for an SQL query to be correctly defined. On the other hand, the CategoricalDataType requires a sequence of attributes with valid values for the appropriate categories.The value number of fields is the number of fields that are defined in the content of PopulationIdentification. This number can be added for consistency checks. Based on the XSD, it is possible to define an XML document that will serve as a basis for identifying a particular population for evaluating a policy through its defined KPIs. At the same time, this document can be used for identifying a population to execute the data-driven models developed for each PHP. An example of an XML document for population identification is explained next. It focuses on collecting adult citizens who have been previously diagnosed with as overweight or obese patients based on ICD-9-CM codes (Table 4). The adult population is identified through the variable "age", which is a numerical data type, with the minimum age being "18" and with a maximum value chosen to be large enough. It is clear that depending on the country, the adult age can be otherwise defined. This sort of contextual information is not considered at present but could be an improvement for future versions. The filter for including citizens who have a diagnosis of overweight or obesity

```xml
<PopulationIdentification>
   <NumericalDataField name="age" vartype="numerical" minimum="18" maximum="120" />
   <CategoricalDataField name="icd9" vartype="categorical" >
         <FilterValue validValue="278" />
         <FilterValue validValue="278.0" />
         <FilterValue validValue="278.00" />
         <FilterValue validValue="278.01" />
         <FilterValue validValue="278.02" />
         <FilterValue validValue="278.03" />
   </CategoricalDataField>
   <!-- Other Numerical or Categorical Data Fields -->
</PopulationIdentification>
```

Table 4. Example of an XML Document for Population Identification

(codified in ICD-9-CM with the following codes:278, 278.0, 278.00, 278.01, 278.02, and 278.03), can be expressed within a sequence of filter values inside the categorical data field. Further numerical or categorical data fields can be included in the XML document to represent even more filters for population identification.

4.2.1. Design of an XML document transformation into an SQL query

Since the CrowdHEALTH data store is a relational database, the common procedure to query will be through SQL queries. Thus, the XML document for population identification has to be transformed into a standard SQL query that should include all the requirements defined in the XML document. This transformation should be done using an API. These requirements will be included in the where clause of the SQL query by translating each different data field for filtering the population into a consistent and proper SQL syntax. It is worth reminding that a mandatory requirement is that the name of each data field should be the actual name of the columns in the table where the data is stored, otherwise the query will always return an error message and no results will be available. The translation of the XML Document example shown in Table 3 into an SQL query can be described as follows in Table 5. The where clause in the SQL query is based mainly on the two different types of data fields that are described in the XSD document and instantiated in the XML document. The numerical data fields for describing the filter will be transformed into two conditions for the current variable, one for the minimum attribute and another for the maximum attribute. Thus, for the example in Table 4, the minimum and maximum values of the "age" variable, which is 18 and 120, respectively, are transformed into "age >= 18

```sql
SELECT *
FROM TABLE_FROM_DATA_STORE
WHERE age >= 18
  AND age <= 120
  AND icd9 IN ('278', '278.0', '278.00', '278.01', '278.02', '278.03')
```

Table 5. Example of expected SQL query from the XML Document for population identification

AND age <= 120".Regarding the categorical data fields, the schema requires at least one valid value, but it can include more than one. Each valid value will be transformed into a list of valid values that will be part of an "IN" clause. Hence, the categorical data field for identifying the population in Table 4 is transformed into the following SQL expression "icd9 IN ('278', '278.0', '278.00', '278.01', '278.02', '278.03')" To summarize and generalize, on one hand, a numerical data field with the name "name", with a minimum value "min" and a maximum value "max" will become part of the where clause of the SQL query with the form "name >= min AND name <= max". On the other hand, a categorical data field with the name "name", and a sequence of filter valid values "value1", "value2", ... will become part of the where clause with the form "name IN ('value1', 'value2', ...)".

4.3. Policy evaluation

PHPs were described and modeled through a fundamental conceptual schema, in which the KPIs were at the core of each PHP model. KPI-centered models are expected to allow both developers and policy-makers to define, support and evaluate PHPs. The fact that KPIs are used as the core of PHPs is to facilitate the process of policy evaluation, enabling at the same time the possibility to visualize past and present results for comparison purposes, but also to forecast results (in case a forecasting model is developed for the proper KPI). Also, KPIs are invaluable tools that contribute to the process of health system performance monitoring. However, for KPIs to be effective, they need to have clear definitions to ensure that the data collected is consistent, reliable and, when possible, sharing definitions with official institutions like the WHO, OECD, EU, and other national and regional institutions. Hence, the evaluation of the PHP depends on proper definitions of the different KPIs related to that PHP. The definition of the KPI should include a well-posed formal mathematical formula without ambiguity, with proper term definitions and inclusion and exclusion criteria to ensure their validity and reliability. Valid KPIs measure what they are intended to measure, whereas reliable KPIs produce consistent results, regardless of who performs the measurement. The aim of the formal definition is to support the Population Identification component to identify the proper dataset to evaluate the KPI and then to compute the values of the PHP. The Policy Evaluation component is devoted to computing and assessing the policies through the KPIs. This component requires two inputs to compute its outcome and provide it to the Policy Creation component, where the results are being visualized and summarized. The required inputs for the computation of the KPI are: i)The mathematical formula of the KPI, which is provided by the Policy Modelling component, and ii) the dataset and the associated variables that must be used for the computation of the KPI, provided directly by the Population Identification component after querying the CrowdHEALTH database.

4.4. Information stream between the components

Figure 3 shows the information flow between the three components and the Policies creation component that centralizes data flow. The Policies modeling component defines the structure of each KPI for each policy. The KPI encloses a mathematical formula and data requirements specification, which have to be sent through the Policies creation component to the Policy evaluation component and the Population identification component, respectively. The latter one gets the data requirements, as an XML specification, and is transformed into an SQL query (or SPARQL, alternatively) to extract the corresponding dataset, taking into account the variables to be used in the mathematical formula and the inclusion/exclusion criteria. The variables may be aggregated if required by the KPI to be calculated. The dataset is used then in the Policy evaluation component, where the variables are used for computing the value of the KPI based on its formula. Finally, both the KPI and the policy modeling KPI are sent to the policy creation component from the Policy evaluation component to support the Policy Development Toolkit and visualization of the data. The mathematical formula of KPIs often needs aggregated data that are used as numerators and denominators of a quotient. For instance, all the indicators of the Spanish strategy on physical activity, nutrition, and prevention of obesity follow the aforementioned formulation (10). As a first approach, each factor of the KPI formula will be transformed manually into an SQL query to collect the corresponding information. Later versions may provide a more flexible approach to enable a semi-automatic interpretation of the numerator and denominator of the indicators. For instance, the KPI of the example tries to estimate the rate of the adult population that has been identified as obese. This is translated into a mathematical formula in Figure 4. To compute this formula, both factors need to be calculated as aggregated information from the CrowdHEALTH data store. The first factor, the numerator, may be gathered using an SQL expression such as:

Whereas the denominator may be gathered using:

The final result may be compared later with the result of the expectations from public health surveys, and also with the results of data sources from different regions in Europe. For example, the current results from HULAFE datasets are that less than 3% of the capita of the Health Department is correctly diagnosed as obese. This can be compared with the expected result of the

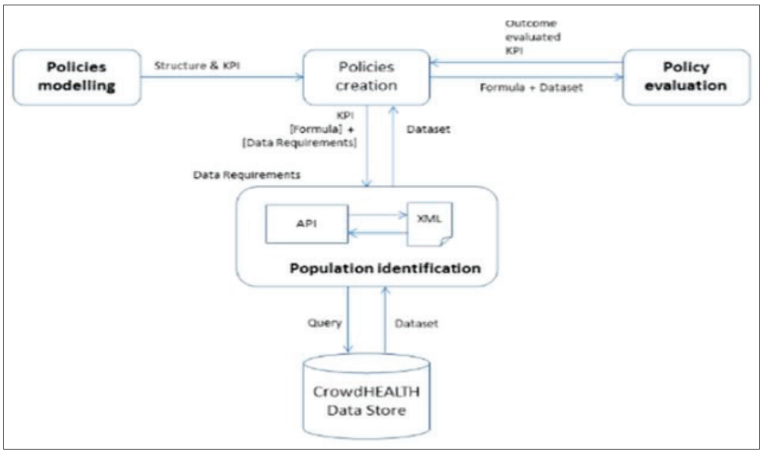

Figure 3. Information stream between the components

public health surveys that state that the obese adult population represents around 14% of the population. This result would indicate a failure in the goal of promoting a systematic detection of obesity in the adult population. A closer value of the indicator to the expectations would point out a better outcome of public health policies regarding systematic detection of obesity. Thus, this KPI would be able to assess if the systematic detection of obesity is successful or not.

5. CONCLUSION

The present work defines what a Public Health Policy (PHP) is in the context of the CrowdHEALTH project (12-17). It also proposes state-of-the-art best practices of PHPs in general and in NCDs particularly. The paper also presents the technologies and methodologies based on ontologies and semantic reasoning that can be used for modeling PHPs providing examples for further understanding. A structure for policy modeling based on Key Performance Indicators as the core of the structure is proposed since KPIs enable direct measurement of parts of the PHP. Finally, methodologies that can be developed for the three different components communication: policy modeling, policy evaluation and population identification within the policy creation component are presented. This is an initial design that might be modified during the project life circle according to the conceptual complexity and the available information managed by the platform.

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