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Primary health-care network monitoring: a hierarchical resource allocation modeling approach

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SUMMARY

Management of a primary health-care network (PHCN) is a difficult task in every country. A suitable monitoring system can provide useful information for PHCN management, especially given a large quantity of health-care data that is produced daily in the network. This paper proposes a methodology for structured development of monitoring systems and a PHCN resource allocation monitoring model based on this methodology. The purpose of the monitoring model is to improve the allocation of health-care resources. The proposed methodology is based on modules that are organized into a hierarchy, where each module monitors a particular aspect of the system. This methodology was used to design a PHCN monitoring model for Slovenia. Specific aspects of the Slovenian PHCN were taken into account such as varying needs of patients from different municipalities, existence of small municipalities having less than 1000 residents, the fact that many patients visit physicians in other municipalities, and that physicians may work at more than one location or organization. The main modules in the model are focused on the overall assessment of the PHCN, monitoring of patients visits to health-care providers (HCPs), physical accessibility of health services, segment of patients in municipalities who have not selected a personal physician, assessment of the availability of HCPs for patients, physicians working on more than one location, and available human resources in the PHCN. Most of the model's components are general and can be adapted for other national health-care systems. Copyright © 2010 John Wiley & Sons, Ltd.

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INTRODUCTION

Imagine being a manager responsible for the organization of a primary health-care network (PHCN). Suppose that you get a call from a local politician who claims that

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inhabitants of his municipality are health-care deprived, and need more physicians. The problem is how to react in this situation. Will you oppose or support the politician's request, and how will you explain your answer? Do you have sufficient knowledge about the PHCN and inhabitants in that and other municipalities? Do you have sufficient – and sufficiently accurate, accessible, and well-organized – data about the local patients, their needs, and available local health-care services? Are the PHCN requirements, constraints, and management rules sufficiently well-defined? In any case, this is not an easy task.

Management of a PHCN must be based on rational decisions, supported by analyses of actual health-care data. These analyses can be provided by an appropriate monitoring and assessment system that considers a national PHCN planning strategy. This paper presents the approach that was taken to develop such a system in the Republic of Slovenia. On one hand, the approach takes into account the specific characteristics of the Slovenian PHCN, but, on the other hand, proposes a general methodology for structured development of monitoring systems. Both aspects are addressed in this paper.

The Slovenian national health-care system (HCS) is composed of different health-care providers (HCPs), and is divided into the primary, secondary, and tertiary health-care levels. The PHCN consists of four sub-systems: general practice, gynecology, pediatrics, and dentistry. According to the national health-care program (MoH, 2000), municipalities are appointed to manage PHCN on their territory according to the model that must be prescribed by the Slovenian Ministry of Health (MoH).

Recently, the MoH has initiated and financially supported the activities to develop a new, thoroughly revised PHCN monitoring model. Considering the Slovenian National Program of Health (MoH, 2000), the main strategy used in this model is focused on providing good and equal availability and physical accessibility of the PHCN for all residents of Slovenia.

In accordance with these aims, the PHCN monitoring model has to be able to assess the patients physical accessibility to the HCPs, assess the availability of physicians for patients, identify health-care deprived groups of residents, and provide other information about expected and unexpected anomalies related to the inappropriate allocation of PHCN resources. The model has to identify these anomalies as quickly and comprehensibly as possible in order to provide timely alert and prevention from unnecessary bad consequences.

Considering the characteristic of the national HCSs, this is not an easy task. Slovenia has about 2 million inhabitants, and it is divided in 210 municipalities where some of them have less than 1000 residents. Hence, many patients visit HCPs in other municipalities. Another problem is that not all physicians work full time and some of them work on two or three different locations. All these characteristics request a specific approach to the design of the monitoring model.

The developed approach can also be adapted for use in other national HCSs. Most of the modules are general in the sense that all HCSs are composed of similar elements analyzed in this model such as inhabitants living in some characteristic conditions, health-care services needed by these inhabitants, HCPs, and physicians who provide the services. Moreover, a similar approach can be useful even for the monitoring of systems as different as police or supermarket chains.

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The design of the proposed PHCN monitoring model is based on a general-purpose methodology that defines monitoring modules and organizes them into a hierarchy. Each module monitors a particular aspect of the PHCN, which is of interest for decision-makers and managers of the system. Modules include all important elements of the PHCN: patients, medical staff, and medical organizations, as well as their geographical and organizational relationships. Typical aspects about PHCN are: assessment of the PHCN considering the allocation of health-care resources, availability of the PHCN resources for patients, visit rate of patients, and the physical accessibility of the PHCN for patients. The modules use the data collected by standard procedures in HCPs, and provide on this basis a number of data analyses and visualizations. The approach is not limited to any particular data analysis methods, but rather provides means to include and combine different and possibly innovative data analysis and data presentation methods.

The model was developed in accordance with the available data related to the PHCN from the following databases:

- Social Security database is the data about HCPs together with assigned patients per individual general practitioner and the patients with social security.
- The database of physicians and dentists, provided by the Slovenian Medical Chamber.
- The database of the National Institute of Public Health containing data about Slovenian health centers.
- The database of the Slovenian Statistics Bureau concerning the demographic and geographic distribution of citizens and municipalities.

This paper is structured as follows. In the next section, we describe some related approaches to assessments of HCS in other countries. The third section describes the basic methodology used in the development of the monitoring model. The fourth section presents the specific structure and modules of the developed PHCN monitoring model for Slovenia. The fifth section presents the SWOT analysis, while the sixth section provides some conclusions and directions for further work.

RELATED WORK

A national HCS is a complex system in which large quantities of data about different processes supported by information systems are produced daily (Babulak, 2006; Haux, 2006). These and other data related to HCS, such as demographic or geographic data, include useful information about health systems. Thus they are periodically or continuously analyzed in order to provide government officials, development managers, and civil society with the information for improving internal processes, planning (Williams, 1999), and resource allocation. The analyses are based on a number of carefully designed financial and non-financial indicators of HCS performance.

In order to provide an HCS assessment framework, the World Health Organisation (WHO) has defined the following goals (WHO, 2000): population health, responsiveness, and fairness in financial contribution. The population health is

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assessed by two indicators aimed at overall population health and health distribution. The responsiveness indicators address the system performance relative to non-health aspects considering population's expectations of how they should be treated by HCPs. The fairness in financial contribution of population is based on the distribution of households' financial contribution calculated by household survey data.

The Australian National Health Performance Committee (NHPC, 2001) presented another health-care assessment framework, which is adapted from the Canadian Institute for Health Information (CIHI, 1999), and aimed at the overall assessment of HCSs. This framework is implemented in Australian public sector mental health services (ISC, 2005). The indicators cover three main aspects of the HCS: health status and outcomes, determinants of health, and health system performance.

Another HCS assessment framework is the Euro Health Consumer Index (EHCI) (HCP, 2007). The EHCI is composed of 27 indicators that are focused on patient rights and information, waiting time, outcomes, generosity, and pharmaceuticals.

In comparison with the assessment frameworks described above, our PHCN monitoring model is not aimed at the overall assessment of the HCS, but at the assessment of primary health-care resource allocations considering health-care capacity and the patients' needs. Therefore, we have to develop our own indicators.

In order to avoid unmanageable proliferation of indicators, caused by attempting to cover every important aspect of a PHCN (Perera *et al*., 2007), the indicators in our model are hierarchically organized. In this way they provide both simple top-level and detailed low-level views on the PHCN.

Many frameworks for HCS assessment include indicators composed of sub-indicators. These composed indicators are usually calculated as a weighted sum of the values of sub-indicators. This is not always the best solution. For example, considering the assessment framework proposed by WHO, an HCS with a high population health, low responsiveness and bad fairness in financial contribution has the same overall assessment as the HCS with a low population health, high responsiveness and good fairness. The different HCSs have the same overall assessment. To avoid such problems, the indicators in our PHCN monitoring model are combined using multidimensional graphs, pivot tables, and techniques of multicriteria decision models.

Many indicators, such as the *responsiveness* (WHO, 2000), are based on representative households or key informant surveys using either face-to-face or postal interviews. A major concern with such survey instruments is that people from different cultures or socioeconomic backgrounds usually have different expectations. Consequently, the differences in their answers could reflect the differences in their expectations rather than the variations of HCS responsiveness. In our model, the assessments are based on data already provided by standard procedures in HCS. This makes a considerable difference in the type, quality and quantity of collected input data, affects the selection of indicators, and justifies a different methodological approach taken in our case.

In summary, to address specific characteristics of the national PHCN, available PHCN data and specific objectives of our monitoring systems, we had to design our own set of indicators and methods as described in the following two sections.

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MODEL DEVELOPMENT METHODOLOGY

Despite many frameworks related to performance and activity monitoring, such as data-driven decision support system (DSS) (Power, 2002), performance monitoring, business performance management (BPM), business activity monitoring (BAM) (Dresner, 2003), etc., there is a lack of methodologies for presenting the overall concept of the monitoring and assessment model composed of different data analysis and data presentation methods.

Our approach to the design of the PHCN monitoring model is based on hierarchically connected *modules* (Figure 1 shows an example of such a hierarchy, which is explained later in PHCN Monitoring Model Section). Each module is aimed at monitoring a particular aspect of the PHCN, which is of interest for decision-makers and managers of the system. Typical aspects about PHCN are: physical accessibility of the PHCN, the availability of the PHCN resources for patients, and visit rate of patients.

Each monitoring module involves a number of *monitoring processes* (MPs), which are gathered according to a particular aspect of the PHCN. Here, the term ''monitoring process'' is used in a broad sense and denotes a periodically or continuously performed data analysis process without distinguishing between

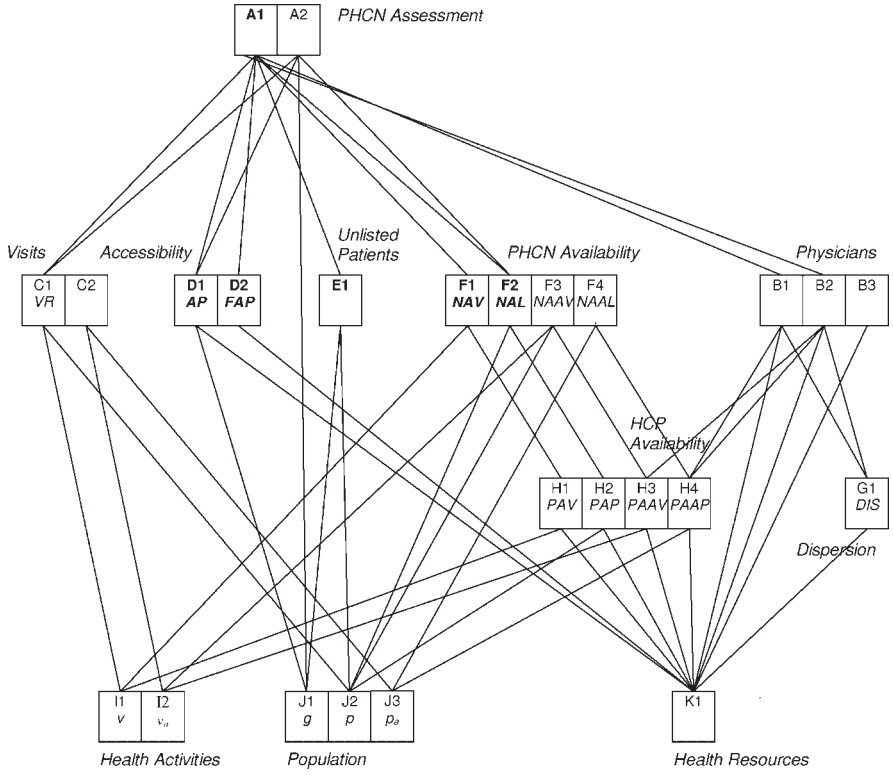

Figure 1. Hierarchical structure of modules and monitoring processes

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''monitoring,'' ''validation,'' and ''assessment.'' Notice that the term MP has a wider meaning than the term ''indicator,'' because it covers a data analysis process, which may include one or more indicators.

Each MP is characterized by the monitoring objectives, input data, data collection methods, constraints on the data, data dimensions, data analysis methods, output data, the role of output data for PHCN monitoring and planning, the output data presentation methods, target output values, the possible side effects of MPs, evidence base of the previous use of indicator, security requirements, different threats inferred from output data, and the users of these components.

Among these components, the *data analysis methods* transform the *input data* to *output data* represented by some *data presentation methods* according to the given *monitoring objectives*. Usually, the output data consist of different indicators presented by various *data presentation methods*. Again, the term ''data presentation'' is used in its broad sense and includes – mostly visual – presentations of both single data elements and more complex patterns, and it does not explicitly distinguish between ''data,'' ''information,'' ''pattern,'' and ''knowledge.''

The *target* is a level of performance that the organization aims to achieve for a particular activity. Information about *data collection* defines how and how often the data has been collected or needs to be collected. For example, data can be collected by representative surveys or by standard procedures in organizations according to some refreshment rate. The *data constraints* define the valid input and output data. The *security requirements* define the use and management of the MPs and of the data.

This approach is not limited to any particular data presentation or analysis method. In principle, any *data presentation method* can be used such as pivot tables, charts, network graphs, and maps. The same holds for *data analysis methods*, which can include Structured Query Language (SQL) procedures, On Line Analytical Process (OLAP) techniques for interactive knowledge discovery, as well as knowledge discovery in databases (KDD) and data mining methods (Han and Kamber, 2001) for discovering important but previously unknown knowledge.

The *output data* from the MPs can be classified in different ways. In accordance with their role in the decision process, they are classified into two groups. The *output data* in the first group are *formal*: they are based on standards defined by the PHCN management, and formally describe how well the organizational system is achieving its quantifiable objectives. In our model, the MPs providing information from the first group are highlighted in bold (Figure 1). The second group provides *informal* data that describe PHCN activities and performances.

Considering the influence of managers' decisions on a certain aspect of the PHCN covered by MPs, the *output data* are also classified into two groups. The output data in the first group, such as the number of physician per population, can be changed by appropriate decisions of managers, for example, by assigning physicians' positions. The data in the second group, such as the structure of population's age and gender, cannot be directly influenced by managers' decisions. It is included in the monitoring model primarily to show the current state of PHCN.

With respect to organizational goals, the *output data* in the model are classified into *lead* and *lag* (Niven, 2003). The *lead* ones show the performances that have influence on achieving the goals, whereas the *lag* are related to the degree of

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achieving the goals. For example, the visit rate of patients to PHCN may not be considered as the goal of the PHCN so it is classified as a *lead* metric, but the equal accessibility of PHCN for all patients is usually considered as one of the main goals of this network, so the corresponding metric is classified as *lag*.

The output *data presentations methods* used in our model are classified in accordance with data organization into three categories: text only, tables, and information graphics. *Information graphics* – or ''infographics'' – are visual presentations of information, data, or knowledge such as graphs, charts, flowcharts, diagrams, and maps. The presentation methods are also divided in accordance with the used techniques into *static* and *dynamic*. Static are data presentations that could be printed on the paper without any loss of data or functionality. In contrast, dynamic presentations provide full functionality only on a computer screen. Thus a typical static graph is presented as a picture without interactive functions, and a typical dynamic graph may be combined with OLAP techniques such as drill-down, slice, and dice (Power, 2002).

The proposed PHCN monitoring model addresses also the possibility of side effects that may be induced as a reaction to the monitoring. Such an unwanted consequence is the so-called ''perverse'' learning that happens when organizations or individuals learn which aspects of performance are measured and which are not, so they use that information to manipulate their assessments (Meyer and Gupta, 1994). For example, among cardiac surgeons in New York whose individual unadjusted patient death rates have been published regularly, there has been a tendency to avoid taking on high risk cases with a subsequent increase in mortality of patients at risk for cardiac surgery (Dranove *et al*., 2002). The unintended consequences could also be caused by profoundness monitoring of individuals (physicians); the monitoring system that severely limits individual freedom could be counter-productive.

In order to improve the comprehensibility of the model, the modules are hierarchically organized. Therefore, the modules at the top level include the main MPs, which are hierarchically connected with MPs at lower levels in the hierarchy. Each *connection* represents a data channel that connects the outputs of lower-level MPs with the inputs of higher-level MPs. In principle, each connection denotes that the output data of lower-level MPs can help to explain the output data of MPs at higher levels. For example, the MP aimed at the main assessment of PHCN can be connected with the lower-level modules addressing physical accessibility of PHCN, availability of PHCN resources for patients, and the ratio between listed and unlisted patients. This functionality, which enables the users to move from data presented by higher-level MPs to appropriate data presentation of lower-level MPs or *vice versa*, can be provided by a suitable user interface.

PHCN MONITORING MODEL

The aim of the PHCN monitoring model is to improve decisions related to the appropriate allocation of health-care resources to those who need it. According to the methodology described in third section, the model consists of hierarchically connected modules. These modules are shown in Figure 1. Each module includes at

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least one MP denoted by a letter and number. The letter indicates the module that contains the MP, and the number indicates the index of the MP in the module. Some MPs provide output data in the form of named variables; in this case, abbreviated names of these variables are also shown in the corresponding MP rectangles.

PHCN assessment

The top-level module *PHCN Assessment* addresses the main aspect of the PHCN that helps to identify inequalities and other anomalies related to the allocation of health-care resources. This aspect presents general information rather than detailed explanation of anomalies; detailed explanations are provided by lower-level modules. Thus, the MPs in the *PHCN Assessment* module are based on analyses of output data from lower-level MPs. In principle, the MPs in this module must be able to process several input parameters using different methods of KDD and techniques of multicriteria decision models.

The module *PHCN Assessment* includes two MPs A1 and A2. The A1 presents the main aspects of the PHCN in the form of short clauses, such as ''more (or less) physicians (in terms of FTE, full time equivalent) is needed.'' The clauses are automatically created on the basis of input data provided by the lower-level MPs and rules that compare input data with the prescribed target values.

MP A2 is another MP in this module, and presents the main aspects of the PHCN in municipalities by a multidimensional chart (Figure 2). Each municipality is represented by a dot, which displays four dimensions:

- The dot's horizontal position shows the visit rates of listed patients from municipalities (VR, see MP C1).

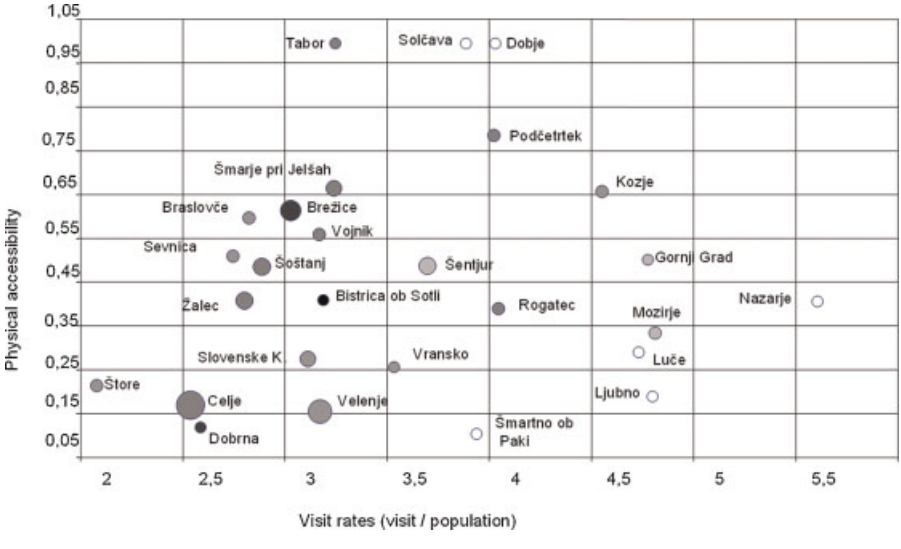

Figure 2. The overall view on the PHCN sub-segment of the general practice for the Celje region (year 2003)

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- The vertical coordinate corresponds to the physical accessibility of patients to providers (AP, see MP D1).
- The dot color intensity represents the network availability for visits (NAV, see MP F1).
- The dot diameter is proportional to the number of inhabitants in the municipality (*g*, see MP J1).

In this way, municipalities that have average values of VR and AP appear in the middle of the chart. The outliers represent more or less unusual municipalities with respect to particular aspects of PHCN. A more detailed and accurate explanation of reasons for such municipalities' positions in the chart is provided by lower-level modules B–F (see Figure 1).

Physicians

The module *Physicians* covers the human resources included in the PHCN. This important aspect is covered by MPs B1, B2, and B3 (see Figure 1). A PHCN manager has to know where more (or less) physicians or nurses are needed now or in the future, particularly because the health studies take many years to complete. This information is provided by OLAP based on the MP B1 that presents the aspects of physicians characterized by their specialization, age, gender, workload, location where they work, and *dispersion* (see Figure 1). On the other hand, MP B2 is aimed at discovering interesting relations in physicians' data by an association rules discovery method (Srikant and Agrawal, 1996). In this model these rules show characteristics of physicians in some municipalities.

The managers of the PHCN also needs to know the education level and obtained licenses of physicians, because in the past some employed physicians were discovered not to have a formal qualification for their job. Thus, MP B3 is aimed at the monitoring of physicians' and dentists' qualification for the job they actually performs. The main performance indicator is the physician's specialization degree, granted by the Slovenian Medical Chamber, which must be verified every 7 years. This specialization degree is a prerequisite for getting a license for employment in an area of medicine. To monitor the suitability of physicians for the job they perform we have used a network visualization technique (Batagelj and Mrvar, 2006).

Visits

The module *Visits* addresses the frequency of patient visits to HCPs. Thus, MP C1 shows an average visit rate (VR) of listed patients from a municipality. VR is a ratio between the number of visits of listed patients from municipality and the number of listed patients in that municipality.

MP C1 is further improved by MP C2 that is focused on the ratio between the actual visit rate and the expected visit rate of the same listed patients over the same period of time. For example, in the chart in Figure 3, the vertical axis shows the ratio between actual visit rates and the expected rates. The chart clearly reveals unusually high visit rates of population under 20 to the general practice in some municipalities,

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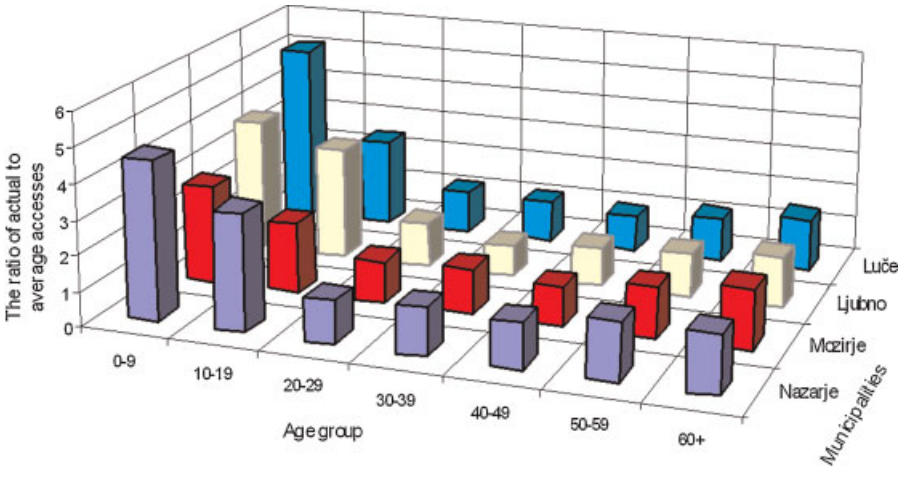

Figure 3. The ratio between actual and expected visits of patients to general practice HCPs (year 2003)

especially in Luče and Nazarje, compared to other municipalities (not shown in this figure, due to space constraints).

In general, the increased visit rate of patients to the HCPs can indicate unhealthy living environments or unhealthy habits of some population groups. Consequently, in addition to PHCN planning, the visit rates are also important for monitoring the health level of population. The MPs in this module are only informal indicators because the patient's visit rates are reflected in results of MPs F1 and F3.

Accessibility

The *Accessibility* module is aimed at monitoring the physical accessibility of patients to HCPs. The module includes two MPs aimed at monitoring the physical accessibility of patients to HCPs. MP D1 (see Figure 1) measures the accessibility for patients (AP) that shows the proportion of the population that needs excessive time to get to the nearest HCP than it is the maximal acceptable travel time, considering the length and the category of roads. Because this proportion depends on the maximal acceptable travel time for the patients to the nearest HCP, these values have to be chosen carefully. In our case, the maximal acceptable travel time was set statistically as one standard deviation above the national average. Generally this time must be prescribed by the responsible authority.

The second MP, D2, provides full accessibility for patients (FAP). It assesses the proportion of population that need more time than the prescribed time to get to the nearest HCP open 24 h daily. The access time computation takes into the account the road length and the road category. The difference between FAP and AP is that first one considers only the HCPs working for 24 h, and the second one considers all the public HCPs. In the model the results are presented similarly by a table and a map (data not shown). Because the accessibility of HCPs is important for patients, the

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MPs D1 and D2 are used as formal indicators which affect the decisions related to health-care resource allocation.

Unlisted patients

The module *Unlisted Patients* monitors the proportion of unlisted residents in municipalities. The unlisted residents are those without their own physicians. The proportions of unlisted population, provided by MP E1, is calculated as the ratio between the number of unlisted patients and all the population in a municipality. At a primary level the residents are usually assigned to their physicians. This module could show some health-care deprived areas where residents rarely visits the HCPs for different reasons, and usually individuals do not have their own physicians. Because MP E1 provides important information about the residents in municipalities, it is used as a formal indicator.

PHCN availability for patients

The module *PHCN Availability for Patients* is focused on the assessment of the availability of the PHCN for listed patients considering the health-care capacity and needs of the patients. Again, the listed patients are those who have their own physicians. This assessment shows how the PHCN capacity is adapted for the patient needs. The providers in the PHCN with insufficient capacity are overloaded, and their patients are health-care deprived. On the other hand, the providers with excess capacity increase the costs of the PHCN. In general, the assessment of the availability is based on the ratio of the PHCN capacity available for patients to the demand for this capacity from the same patients. Because many patients access HCPs in the neighboring or even more distant municipalities, some municipalities do not have their own HCPs, and some physicians do no work full time, the assessment of PHCN availability for patients in these municipalities is not proportional to the simple ratio between the number of physicians and the number of inhabitants. Thus we have to develop new indicators. This aspect of the PHCN is covered by the next four MPs:

- MP F1 (see Figure 1) provides NAV that is aimed at the assessment of the PHCN availability considering the visits of the listed patients and the PHCN working time. The PHCN working time is the time when the physicians of HCPs included in the network are available for their patients. The NAV is proportional to the average PHCN working time that could be spent for the visits of patients from the municipality.
- MP F3 (see Figure 1) provides network availability for adjusted visits (NAAV). Because the NAV indicator does not consider that different patient treatments require different working time, this assessment is improved by MP F3 that gives NAAV, which is proportional to the ratio between the PHCN adjusted working time spent for visits from the municipality and adjusted visits from the same municipality.
- MP F2 indicator provides the network availability for listed patients (NAL) aimed at measuring the availability of the PHCN for listed patients from a certain area.

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The NAL patients indicator is defined as the ratio of the PHCN working time available for listed patients from the municipality in a certain period (usually 1 year) and the number of the same listed patients.

- MP F4 considers that different age–gender groups of listed patients spend different amounts of physician's working time for treatments. The output of this MP is called network availability for adjusted listed patients (NAAL), which is proportional to the ratio between available working time of PHCN for listed patients from a municipality and anticipated working time considering age and gender of patients from the same municipality.

The MPs based on patients' visits, such as F1, F3, H1, and H3 (see Figure 1), show the availability of the PHCN in the past. In contrast, the MPs based on the number of listed patients, such as F2, F4, H2, and H4, provide an anticipated availability of the PHCN. This anticipation considers characteristics of listed patients such as gender and age. In general, the assessment of workload for the past shows the anomalies in the PHCN that have already happened, on the other side the anticipated assessment of workload provides the information that could prevent future anomalies in the PHCN, but they are usually less accurate. In the model the output data from these MPs are presented by tables and charts based on OLAP techniques, and maps based on Geographic Information System (GIS) techniques.

Dispersion

The module *Dispersion* addresses the problem that some physicians work on more than one location. Depending on the requirements, a physician may work on more than one location, but this dispersion usually means additional workload for physicians and their lower availability for patients at one of the locations. The dispersion is provided by MP G1.

HCPs availability

The module *HCPs Availability* is focused on the assessment of the HCPs and physicians availability for their patients. This assessment shows how the capacity of each HCPs is adapted for the patient needs. The HCPs with insufficient capacity are overloaded, and their patients are health-care deprived. On the contrary, the excess capacity increases costs of providers. Generally, this assessment is based on the ratio between the capacity of HCP and the needs of patients listed on this provider. The main difference between the MPs in this module and processes in the module *PHCN Availability* (see Figure 1) is that the former processes are aimed at the assessment of the availability of HCPs for patients listed on the provider, and processes in the latter module are aimed at the assessment of the availability of the PHCN for patients from a certain region. The perspective provided by this module is covered by the next MPs:

- MP H1 is aimed at the assessment of the HCP availability considering the patient's visits to HCP and HCP working time. An indicator providers availability for visits

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(PAV) calculated by this MP is proportional to the average HCP working time that can be spent for a patient's visit.

- MP H3 gives provider's availability for adjusted visits (PAAV) aimed at the availability of an HCP for its patients considering the visits adjusted in accordance with the expected physician's working time needed for treatments. The PAAV is defined as the ratio of the available working time of the HCP for their patients in a certain period to adjusted visits in the same period.
- MP H2 provides the assessment of the providers availability for patients (PAP), which is proportional to the average HCP working time that can be spent for listed patients in a certain time period (usually 1 year). It is defined as the ratio of the HCP working time to number of patients listed to the provider.
- MP H4 consider that different age–gender groups of listed patients require different HCPs workload, where listed patients are adjusted in accordance with the expected physician's working time spent for their treatments. We call this assessment providers' availability for adjusted patients (PAAP), and it is proportional to the ratio between the working time of HCP and expected working time needed for listed patients. The estimation of expected working time is based on the age–gender structure of the listed patients.

The monitoring of physicians' and HCP's availability for patients based on PAP and PAAV may induce unwanted side effects. For example, to improve these indicators, physicians or HCPs may arrange more visits to their patients than necessary in order to show their lower availability for patients and higher workload. This manipulation could be prevented by using additional indicators (PAP and PAAP) that are based on the number of listed patients and not on the number of their visits.

Health activities

The *Activities* module provides the basic data about health activities done by HCPs, which are aimed at improving the health of patients. The actions analyzed are the patient's visits to HCPs. The data about these visits, such as time, HCPs, and diagnosis, are provided by MP H1. MP H2 provides the visits adjusted according with the expected time for health treatment. In H2, the visits are grouped in accordance with the expected time. Each group is weighted considering the physician's working time used for the treatment. Thus the values of adjusted visits is proportional to the physician's time spent for health treatment. The output data from this MPs can be combined with other data or presented by different methods.

Population

The module *Population* is focused on data about the population serviced by the HCPs included in the PHCN. The first MP, J1, provides different data about the population aggregated across municipalities where they live. Most of this data was obtained by the Statistical Office of the Republic of Slovenia. The second MP, J2, provides data about listed patients such as gender, age, and municipalities where they live. Most of

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this data was obtained from the Institute of Public Health of the Republic of Slovenia. This module also includes MP J3 that provides the expected working time of physicians spent for a listed patient. The listed patients are grouped according to their age and gender, and each group is weighted in accordance with the expected working time spend for all treatments in a certain period. Usually this period of time is 1 year.

Health resources

The module *Health Resources* provides the basic data about physicians and HCPs. This is done by MP I1 that provides the different data about physicians such as age, gender, HCP where they work, FTE, and education. The main sources of this data are the National Institute of Public Health, Health Care Institute Celje, Slovenian Social Security Database, and Slovenian Medical Chamber.

SWOT ANALYSIS

The presented PHCN monitoring model provides the main aspects and detailed information about the network from the patient's point of view. The strength of the model is based on hierarchically connected modules. Each module, composed of at least one MP, is aimed at a particular aspect of the PHCN (Figure 1). The MPs in the top-level module provide the main picture of the PHCN considering the allocation of health-care resources, and the MPs in lower-level modules provide the detailed information abut particular aspects of the network. This hierarchically structured model is appropriate for top-down monitoring.

For example, top level MP A1 (Figure 1) indicates that patients in municipality Nazarje have low value of NAV (see MP F1). The multidimensional chart (Figure 2) provided by MP A2 implies that high visit rate (VR) (see MP C2) in Nazarje is the reason for a low value of NAV in Nazarje. The three-dimensional bar chart (Figure 3) provided by MP C2 shows detailed information about the VR in Nazarje. This chart shows that patients under 20 from Nazarje have more than three times higher VR than expected, considering the average VR for these age groups in the Celje region. This example, based on real data, shows how the model indicates the anomalies in the PHCN. The model is also able to reveal possible reasons for these anomalies (increased visit rates) and detailed information about these reasons (increased visit rates of patients under 20). Considering the information provided by the model, the decisions related to the PHCN can be justified by logical arguments based on the available data.

Another strong point is that the model utilizes different data presentations and analysis methods. For example, data is analyzed by a broad collection of methods, including SQL procedures, OLAP techniques (see MP C1), GIS techniques (MPs D1 and D2), rule-based models (MP A1), and data mining methods such as association rules discovery (MP C2). The results are presented by automatically generated text (MP A1), different charts (MPs A2, B1, and C1), visualization of association rules (MP C2), network graphs (MP B3), and maps (MPs D1, G1, and F1).

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The size of districts monitored by the PHCN monitoring model is not limited. The model can provide useful information about municipalities with less than 1000 residents and even those without HCPs. This is possible because the methods for PHCN assessments (see the module *PHCN Availability*) consider the migration of patients from and into other municipalities.

The weaknesses of our approach to PHCN monitoring are manifested in potentially misleading information provided by the model and unintended consequences of the monitoring. Despite many interesting methods used in our PHCN, the threat that misleading data can lead to wrong decisions, and consequently to negative impacts on the PHCN, cannot be completely avoided. The main reasons for the misleading information are deficient and wrong input data, incorrectly selected methods of data analysis, and inappropriate interpretation of the results. We also have to consider the unintended consequences of the PHCN monitoring such as ''perverse'' learning (Meyer and Gupta, 1994) and those caused by too profound monitoring of individuals (physicians).

The opportunities provided by the chosen model design lies in the fact that various aspects of the PHCN provided by the model could reduce some unintended consequences of monitoring. For example, the NAV indicator (see MP F1) shows the availability of the PHCN for patient's visits. If the HCPs availability or workload were assessed only from this viewpoint, it could create a ''perverse'' motivation to increase the number of illness treatments rather to work on their prevention. This can be alleviated by the inclusion of several indicators that, when used together, can indicate such anomalies. In our case, we thus assess HCPs availability using a second indicator, *availability for the listed patients* (see MP F2). Further opportunities are indicated in the Conclusions Section.

CONCLUSIONS AND FURTHER WORK

A large amount of available electronic data from different fields, and many methods for their analysis used by efficient software and hardware, present an opportunity to improve efficiency of monitoring systems. In order to utilize these opportunities, it is important that the monitoring model is not limited to any particular form of input data, data analysis, and data presentation method.

The same approach that we used to design the PHCN monitoring model can be used in other fields. For example, in another project we use this approach to describe a model for monitoring and assessment of employees' activities in order to improve information security in a public organization. In this case, the top level module shows unusual and potentially suspicions associations between employees and other persons or objects. The middle-level modules are aimed at detailed aspects of these associations, and the lowest modules describe the basic data provided by different log files and documents.

In principle, the basic approach of the presented PHCN monitoring model can be used for the monitoring of systems as different as police or supermarket chains. For example, police systems are composed of similar elements, such as inhabitants that need security services and police units that provide these services, as those in the

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PHCN consisting of patients and HCPs. Each police station is responsible for the security in its region, like the HCP is responsible for the health of patients in its region. By such analogy, different organizations can be actually monitored by similarly designed models.

In further work, we plan to adapt the proposed method to other systems (e.g., a police network). Moreover, our present work in the monitoring of the Slovenian PHCN is not concluded. The proposed model and the presented indicators will become even more important once we start addressing the PHCN quality and the actual populations health level, which is planned in future work.

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