

Knowledge use and Sharing into a Medical Community of Practice; the Role of Virtual Agents (Knowbots)

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Abstract: Knowledge-oriented organizations are bricks for the knowledge-based society construction. Building knowledge-based society and economy suppose challenging transition processes from the classical structure of an organization to new organizational forms that help to fill the gap between actual society and the future knowledge-based society and economy. This transition generates new issues in knowledge creation and sharing processes, related to the particularities of the new organizational forms. Therefore, in the last few years, our researches are oriented to developing and testing a number of forms of organization designed to facilitate an efficient and effective transition toward the knowledge-based society, like *communities of practice*, (*virtual networks of professionals* or *knowledge ecosystems (KE)*). Under this general frame, this paper presents the results of our research aiming to capture the necessary changes that a medical organization specialized in rehabilitation (the National Institute of Rehabilitation and Physical Medicine from Bucharest, Romania - INRMFB) has to undertake for converting its classical structure into a new knowledge-oriented one, possible and easily to being integrated into a Virtual Network for Home Health Rehabilitation of the impaired people – the meta goal of our research in recent years. Specifically, within its five sections, the paper outlines: 1. An introduction in the macro and micro-level empirical setting in which the study is carried out; 2. The methodological approach based on Social Network Analysis (SNA). Although quit often used in the medical field, as we will see in the second section of the paper, the SNA methods and models aren't used yet in the particular area of health rehabilitation; 3. The objectives of the empirical study that can be summarized as follows: *Mapping of the knowledge flows & needs in the target community of practice*. The aim of this step is to produce an accurate picture of the knowledge flows that the target community identified at the INRMFB actually enacts in the accomplishment of its organizational objectives. *Analysis & Diagnosis*: Identification of critical aspects and areas of improvements (e.g. knowledge needs, knowledge bottlenecks, structural determinants of inefficiency or of poor performance). *Design*: definition of the functional specifications for redesigning the agents, network and of the functionalities of Knowbots. 4. The survey we have designed for data collection. According with the particularities of the macro and micro-level in which our study is carried out, we have designed a survey that will help us both for diagnosing the knowledge-sharing-structure of INRMFB, and for finding adequate solutions for potential critical aspects identified in this medical facility.; 5. A set of conclusions and recommendations for the new knowledge-oriented organizational structure to be created within the INRMFB. Alongside with performing SNA in the health rehabilitation field, an important output of our study is to find answer to the following questions: *Cans the classical organizational structure of the INRMFB be transformed into a knowledge-based one, by reengineering the knowledge flows and agent's roles? If and where within the actual structure a virtual knowledge agent (knowbot) can and should be integrated?* Our paper is a consequent continuation of our work in the KE area, contributing to the completion of an integrate vision over the role of the KM techniques, human and virtual agents in the emerging of knowledge-based society. It presents a work still in progress, the final results of our study going to be presented within the ECKM2011 conference.

Keywords: community of practice, healthcare knowledge ecosystems, social network analysis, knowledge agent (Knowbot), collective learning, knowledge-based organization.

1. Macro and micro environment of our study

For achieving our research goals – discovering, developing and testing new forms of organizations that help to fill the gap between actual society and the future knowledge-based society and economy (*communities of practice (CoP)*, *networks of professionals* or *KEs.*), by collaborating with our colleagues from INRMFB (medical staff, professors, and researchers) we have designed a study that consists in:

- Analyzing the macro and micro-level empirical setting in which the study is carried out;
- Designing the main objectives of the empirical study and the methodological approach;
- Creating a personalized survey for data collection;
- Collect and process the necessary data;
- Drawing conclusions and recommendations both for the old and the new knowledge-oriented organizational structure to be created within the INRMFB.

Some of these phases were already accomplished, while others are running as we speak. Both of them are described in our paperwork.

1.1 INRMFB macro-level empirical settings

For having a complete image over the extent, links, interdependencies and influences, we start our paper by analyzing both the macro and micro environment that define the activity of INRMFB. Tacking account that the Healthcare Ecosystems are among the most complex networks (Mărăcine, Scarlat, 2008), identifying all the “agents” and the interdependencies within such a structure is crucial for a good diagnostic of the present knowledge transfer network, and especially for finding the best solutions for increasing the fluidity of the knowledge creation and sharing processes. A graphic overview of the macro-environment that includes the INRMFB is comprised by figure 1.

As we can see in figure 1, the INRMFB is part of a true Healthcare Ecosystem (Mărăcine, Scarlat, 2010). The typology of agents involved in the current process at macro level is quite wide, including hospitals (especially those having emergency rooms), medical products suppliers, Laboratories, Pharmacies, Universities, national authorities for scientific research, Romanian Healthcare Ministry, and also links with knowledge repositories accessible through the Internet. The existence of such a diversity of agents, links and knowledge flows brings many particularities in the process of knowledge creation and sharing. Also, an increasing variety of competencies – other than the medical ones – are more and more a must for the members of a medical community of practice:

- Extensive usage of the computers and dedicate software;
- Virtual communications with colleagues and medical authorities;
- Continue learning on how to use the advanced technologies embedded with the new equipments;
- Facing the new attitude of the patients that are more and more informed and educated (also by the Internet) on their medical conditions.

1.2 INRMFB micro-level empirical settings

Going deeper and looking at the micro-level, the structure of the INRMFB also involves different typologies of agents (figure 2).

The main clusters we have found here are:

a) The *Medical Community of Practice* – Medical staff. For the Rehabilitation Clinic no. 3 (the one in which we have started our study), this CoP includes 36 employees (out of all the 38 existent positions within this clinic):

- 4 doctors specialists in medical recovery, one of them is the chief of the clinic;
- 9 professional nurses – 6 of them were graduated post high school medical courses (2 years of study) and the other 3 were graduated the University of Medicine on the Bologna system;
- 10 physiotherapists – 6 of them are physiotherapist nurses and they were graduated post high school medical courses (3 years of study) and the other 4 were graduated the University of Medicine (4 or 5 years of study) and they are professional physiotherapists and kineto-therapists;
- 2 masseurs ;
- 1 psychologist also specialist in speaking deficiencies;
- 1 instructor of medical gym;
- 1 social worker – this position is vacant, in the Romanian medical educational system there are no programs that could train specialists on this domain;

- 1 occupational therapist – this position is also vacant;
- 8 nursing aids;
- 1 statistician and 1 department secretary.

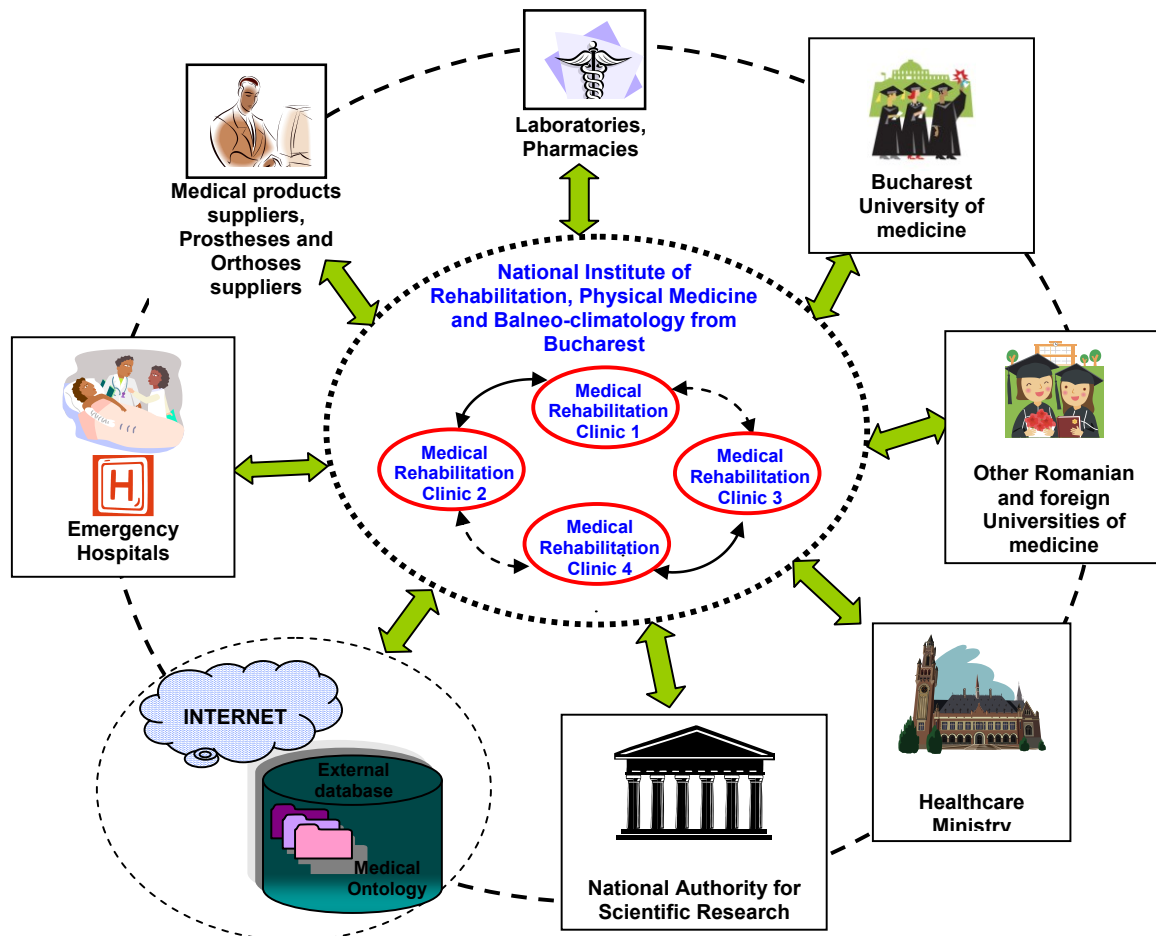


Figure 1: Health rehabilitation within the INRMFB – macro level

b) The “Patient” CoP – i.e. the disabled patient, his/her family, friends, and colleagues. Within the Rehabilitation Clinic no 3, in average there are 60 patients, usually each of them being hospitalized for 2 or 3 weeks according with the severity of the impairment.

In the present, in Romania, the demand for medical services in the rehabilitation area far exceeds the hospitals’ offer. Therefore, in order to increase the ratio offer/demand for rehabilitation services, the hospital’s management team succeeded to find some alternative solutions for the people that need specialized medical assistance, but who can be hospitalized only if they are willing (or if they can) to wait between 2.5 and 3 months. Such alternative solutions for the INRMFB consist in programs such as:

- *The “Outpatient” program* – the patient come into the hospital just to receive the treatment, without being hospitalized; and
- *The “Hospital by day patient” program* – the patient is hospitalized only during the day and is supervised to accomplish his rehabilitation program, without receiving any medication or food from the hospital.

In this way the number of assisted patients within the hospital was increased with around 30% per year.

In this moment, from the structure pictured in figure 2, within all four Rehabilitation Clinics from the INRMFB, the *Occupational therapist* and the *Social Worker* are missing agents. This is in fact one of the major lacks of the Romanian healthcare system – the professionals like social workers, occupational therapists, and psychologists.

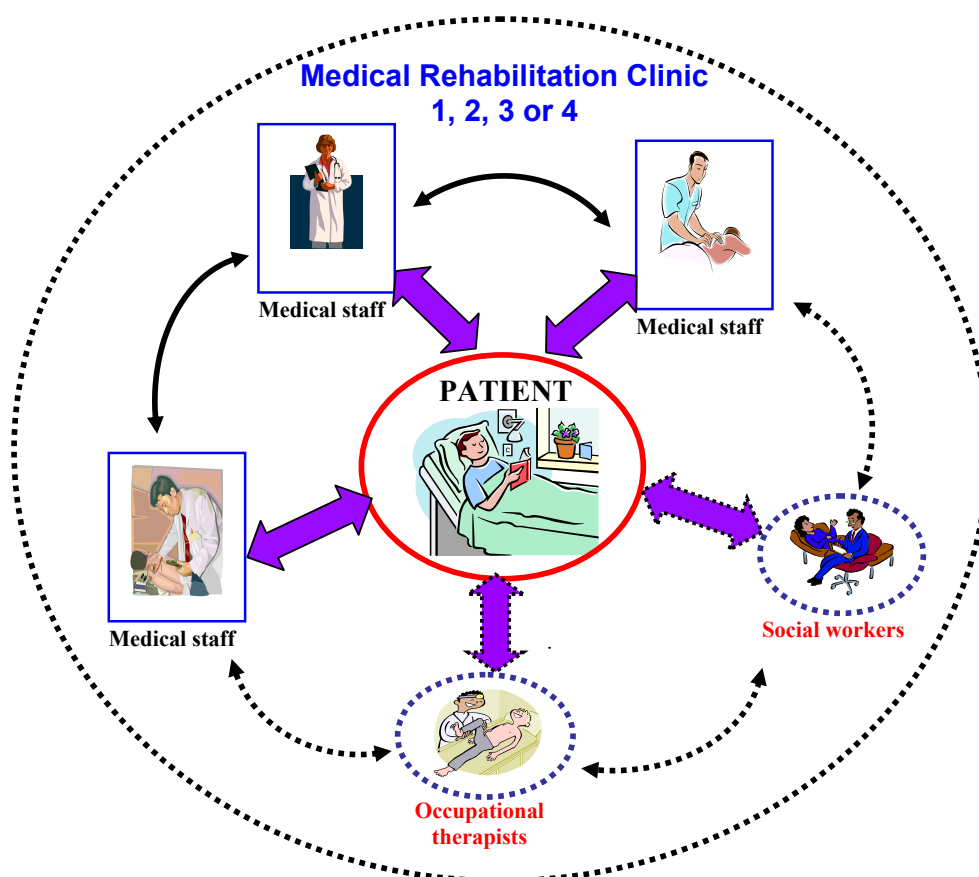


Figure 2: The actual classic structure of a rehabilitation clinic of the INRMFB

In the future, by extending the study to the “Patient” CoP we intent to find out how their recovery process is affected by the missing of the *Occupational therapists, Social Workers and Knowbots*.

2. Objectives of the study and the methodological approach

The objectives we intent to achieve through our study can be summarized as follows:

- Mapping of the knowledge flows & needs in the target medical community of practice at the INRMFB;
- Analysis & Diagnosis: Identification of critical aspects and areas of improvements (e.g. knowledge needs, knowledge bottlenecks, structural determinants of inefficiency or of poor performance);
- Design: definition of the functional specifications for redesigning the agents, network and of the functionalities of Knowbots.

These objectives will be achieved using the Social Network Analysis (SNA) specific methodology. That is way we start this section of the paper with a brief of the SNA methods and tools, and we continue it with the detailed analysis of each of the objectives of our study above outlined.

2.1 SNA – specific methods, tools, software and applications

2.1.1 SNA – the concept, models and methods

As we all know, a social network is a very complex social structure made of *nodes* (individuals – human or virtual – or organizations) that are *tied* by one or more specific types of interdependency (values, ideas, financial exchange, information and knowledge, friendship, kinship, conflict or trade). SNA views social reality in terms of nodes – individual agents within the networks –, and *ties* – the relationships between the agents. The social networks operate on many levels, from families up to the level of nations or group of nations, and play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

SNA is an analytic approach, with its own theoretical statements, methods, models, software, researchers and applications. SNA produces a lot of models and methods, where the attributes of individuals are less important than their relationships and ties with other actors within the network. Social networks models (especially the dynamic models of networks) have also been used to examine how organizations interact with each other, characterizing the many informal connections that link executives together, as well as the evolution of associations and connections between individual employees at different organizations. SNA methods also play a key role in hiring, in business success, and in job performance.

The models and methods used in SNA are based on a set of networks metrics such as:

- *Betweenness* – degree an individual lies between other individuals in the network; it's the number of people who a person is connecting indirectly through their direct links;
- *Closeness* – the degree an individual is near all other individuals in a network (directly or indirectly). It is the inverse of the sum of the shortest distances between each individual and every other person in the network;
- *Centrality* – the count of the number of ties to other actors in the network;
- *Flow betweenness centrality* – the degree that a node contributes to sum of maximum flow between all pairs of nodes (not that node);
- *Eigenvector centrality* – a measure of the importance of a node in a network. It assigns relative scores to all nodes in the network based on the principle that connections to nodes having a high score contribute more to the score of the node in question.
- *Centralization* – the difference between the number of links for each node divided by maximum possible sum of differences;
- *Clustering coefficient* – a measure of the likelihood that two associates of a node are also associates themselves. A higher clustering coefficient indicates a greater “cliquishness”;
- *Cohesion* – the degree to which actors are connected directly to each other by cohesive bonds;
- *Radiality* – degree an individual's network reaches out into the network and provides novel information and influence;
- *Reach* – the degree any member of a network can reach other members of the network.
- *Structural cohesion* – the minimum number of members who, if removed from a group, would disconnect the group;
- *Structural equivalence* – the extent to which actors have a common set of linkages to other actors in the system. The actors don't need to have any ties to each other to be structurally equivalent.

Most of these metrics are of our interest in analyzing the dynamics of the CoPs within the INRMFB's rehabilitation clinics.

2.1.2 SNA software

Due to the extraordinary dynamics of the economic and social areas where SNA methods are used today, a wide range of SNA software was developed, like for example:

- Detica NetReveal – Social Network Analysis for insurance or banking fraud, crime detection, intelligence, tax evasion, border control and network risk based targeting (<http://www.deticanetreveal.com/>);
- Indiro SNA Plus – Highly scalable Social Network Analysis for Telecoms (<http://www.idiro.com/>);
- Keyplayer - a very good program for identifying nodes whose elimination can disrupt a network (<http://www.analytictech.com/keyplayer.htm>);
- MetaSight – Email/communication network visualization and analysis (<http://www.morphix.com/index.htm>);
- NodeXL – Network Overview, Discovery and Exploration for Excel (<http://nodexl.codeplex.com/>);
- ORA – Social Network Analysis, Network Visualization, Meta-Network Analysis, Trail Analysis, Geospatial Network Analysis, Network Generation (<http://www.casos.cs.cmu.edu/projects/ora/index.html>);

- StOCNET – open software system for the statistical analysis of social networks using advanced statistical methods based on explicit probability models for dynamic networks (<http://stat.gamma.rug.nl/stocnet/>);
- UCINET 6 – excellent for general SNA, having good help menus (<http://www.analytictech.com/ucinet.htm>).

Of interest for our study is Microsoft's *NodeXL* – an open-source template for using with Excel that goes further than other SNA tools and provides instant graphical representation of relationships of complex networked data. NodeXL was developed by a multidisciplinary team of experts and it is of interest also to researchers and students studying visual and network analytics and their application in the real world. Networks can be imported from and exported to a variety of file formats, and built-in connections for getting networks from Twitter, Facebook, YouTube, and a local email are provided.

2.1.3 SNA medical applications

As applications, until now, SNA and network modelling approaches have been used in *epidemiology* to help understand how patterns of human contact aid or inhibit the spread of diseases such as HIV in a population. The evolution of *health care networks* can sometimes be modelled by the use of agent based models, providing insight into the interplay between communication rules, physicians' opinions and medical infra-structure.

Diffusion of innovations theory (innovative networks) explores health care networks and their role in influencing the spread of new medical ideas and practices. *Change agents* and *opinion leaders* often play major roles in spurring the adoption of innovations, although factors inherent to the innovations also play a role.

SNA has enjoyed extensive application in public health, particularly adolescent risk behaviours oriented toward substance use. According with Valente (2010), applications of SNA to public health and medical issues can be divided today into following areas:

- Social support and its influence on mortality and morbidity - represent the largest area of application (Knowlton, 2003);
- AIDS/STDs and family planning research - have benefited from network theory and modelling (Aral et al., 1999);
- Community health projects - have used network analysis to improve message dissemination and program implementation (Stoebenau and Valente, 2003);
- Inter-organizational collaboration, cooperation, and exchange studies - have been conducted to improve understanding of health service provision (Harris et al., 2008);
- Understanding and improving health care provider performance (Soumerai et al., 1998).

Until now, none of the studies were dedicated to the particular field of health rehabilitation, leaving an important research gap that could be filled by researches like the one we conduct at the INRMFB.

2.2 Mapping of the knowledge flows in the target community of practice

This step of our study aims to produce an accurate picture of the knowledge flows that the target community identified in the medical area of rehabilitation process actually enacts in the accomplishment of its organizational objectives. The output of the mapping step will be: (a) the *identifications of all the typologies and number of agents* involved in the current process; (b) the *mapping of the relationships among the subjects* with a focus on the exchanges of information and knowledge taking place in the network.

The above actions are performed by SNA through the following steps (Cross et al., 2002):

- *Identification of the target group*: a number of four rehabilitation teams (clinics) with their patients were identified at the INRMFB – a unique rehabilitation hospital in Romania. In general it is recommended to pick up groups that cross physical, functional and even organizational boundaries; from this perspective, the INRMFB meet all these requirements.
- *Design the survey*: in general different surveys may be designed to identify different kind of networks, such as (i) *Information network*, (ii) *Advice network*, (iii) *Learning networks*, etc. The

survey that we have designed particularly for the INRMFB is used to reconstruct the existing relational systems (see section 3 for of the paper).

- *Collect the data:* the survey was distributed through the members of the CoP from the Rehabilitation Clinic no. 3 and 4 within the INRMFB. It is important to secure a very high response rate in the unit (between 80% and 100%) to not miss key individuals in the mapping.

The following set of attributes is considered in the survey to characterize a node to node link (N2N):

- *The object of exchange: which is the nature of exchanged information;*
- *The frequency of exchange: how often interaction happens;*
- *The medium of exchange: how exchange takes place? F2F conversations, telephone, email, formal communication (e.g. standard letter, forms, bulletins ...). A medium continuum has been defined by Daft and Langel (1986) in which medium changes according to equivocality of information. The less equivocal is the nature of information that has to be exchanged, the more standardize and impersonal the communication medium is.*

The development of the survey has taken into consideration *variables operationalization* and *survey structures* already developed in the SNA literature.

2.3 Analysis: Identification of critical aspects and areas of improvements

The surveys content will be used to produce sociograms that will be analyzed by using SNA software (NodeXL and UCINET). The software will produce graphical representations of the network structures and compute relevant structural indicators. These outputs will allow us to identify network roles and possible problems.

Roles are identified in the literature in various ways. For example:

a) Cross et al. (2002) base their definitions on the structural properties and they have found:

- Connectors;
- Boundary spanners;
- Information brokers;
- Peripheral specialists.

b) Gould et al. (1989), in terms of brokerage capability and function, identify:

- Coordinator;
- Gatekeeper;
- Representative;
- Itinerant brokers.

c) Rogers (2003) in terms of the function played by an individual in knowledge diffusion processes:

- Innovators;
- Opinion leaders.

d) While Gladwell (2000) reports about:

- Connectors;
- Salesmen;
- Mavens.

▪

Usually, typical organizations' structural problems regard:

- Presence of bottlenecks in the information/knowledge flows (e.g. individuals that are too central and suffer from work or information overload);
- Lack of boundary spanners, i.e. individuals providing effective connection among diverse groups;
- Presence of marginalized individuals whose more intense involvement in the process could be instead desirable;

- Lower than needed connection density;
- Lack of knowledge hubs;
- Network fragmentation (presence of disconnected clusters).

By analyzing the actual structure of the four clinics from the INRMFB, one or more of these problems we expect to face. Given the particularities of this hospital, other structural issues also could be found.

2.4 Definition of the functional specifications for redesigning the agents, network and the functionalities of Knowbots

Once the critical aspects have been identified we will start the redesign of the network with the aim of developing an augmented socio-technical system both by increasing / reorienting / intensifying / introducing new knowledge flows, and through the introduction of intelligent agents as nodes whose role will be to provide knowledge and/or to solve structural problems in the existing organizational networks. For instance, we may find out that we need better communication among specialists in the different phases of the process for the purposes of a better traceability of the therapeutic process. Or we may discover that doctors need helps in some step of the diagnosis. Or that better patient-doctors communication has to be provided to support home care. Given the set of needs, we will define a set of priorities and focus. Then we will identify functional requirements for the design of intelligent agents (knowbots) starting from the general description and architecture developed in our previous researches. In fact, the Knowbot design will be an instantiation of the general knowbot model introduced in Mărăcine and Scarlat (2010).

The augmented network will be represented in an agent-based model to simulate its behaviour and perform what-if analysis to check if the proposed technological solutions and the redesign of the overall network will achieve the expected performances, as specified by the beneficiary – the management team of the INRMFB. The output of the simulation will be used to support the design of the real knowbots.

3. Designing the survey for data collection

In order to give an answer to the first objective defined in section 2 we have created a survey that is used to reconstruct the existing relational systems from the INRMFB, including questions that collect some demographics, additional details to characterize the existing links within the network, and quantitative data. In addition to the traditional SNA data collection, we collect more qualitative information through interviews to each subject to elicit their perceptions about the quantity and the quality of the knowledge flows by implementing a knowledge audit (Liebowitz, 2010).

The main sections of the survey are:

- *Section 1:* Demographics: name, department, profession, no of years within INRMFB;
- *Section 2:* Knowledge resources: knowledge resources types (databases, magazines, books, people – within INRMFB and external experts, Internet), and frequency of use;
- *Section 3:* Knowledge use: directly retrieving answers to specific questions, analyze and/or synthesize to answer a specific question, routine and/or variable procedures, designing reports, educational or promotional materials. The questions in this section also include the ways people store and share within their peers the received / retrieved information;
- *Section 4:* Knowledge flows: connections between the Knowledge categories and the Staff categories within or outside the INRMFB.
- *Section 5:* Knowledge needs: main constraints in accessing different pieces of knowledge, risks faced by the critical knowledge within the INRMFB departments due to the turnovers in organization or lack of backup expertise in knowledge storage.

Within these sections, a set of questions were designed to capture information about the following issues:

- Do you have enough information to do your job?
- Which kind of additional knowledge and information would be helpful for you to have?
- Through which channels and knowledge sources you fill these knowledge gaps?
- Which are the criteria guiding knowledge search and evaluation?

As a node of the network we have also included the Internet, information systems and other IT-based devices or channels that members of the community may use to access information inside or outside their organization. For instance, it is reasonable to expect that members already access external knowledge sources through the Internet. That's way we also expect to find that some of the tasks they perform manually could be delivered in an automated way or facilitated by the knowbots.

4. Data analysis for the Rehabilitation Clinic no. 3 and 4

Until now, the questionnaires were distributed through participants in all four Rehabilitation Clinics. At clinic no. 3 data collecting is now complete; we succeed to secure an 83.34% response rate in this unit (30 professionals out of 36), and we have already processed the data. In the Clinic no. 4 we have so far a 65% response rate and the data collecting is just at the beginning for clinics no 1 and 2.

Since the results obtained analyzing data for clinic no 3 are very detailed and comprehensive (almost 25 pages were delivered to and analyzed with the clinic head), we have selected for this paper only some particular ones, relevant for our paper's goals.

4.1 Knowledge networks for the Rehabilitation Clinic no. 3

Data collected through the field analysis have been used to model using SNA different kinds of knowledge networks within the team operating in the Rehab unit of the INFRMB (general advice, management knowledge, subject-matter expertise, knowledge about organizational procedures). The networks have been visualized through social graphs and we have performed an analysis of centrality.

The objective of this analysis is to answer to the questions: "Are there central actors in knowledge sharing? Who are the central actors?" For this purpose, we have used the measure of "degree centrality", based on which we can assess if there is an actor more involved in knowledge sharing process and, consequently, represents a knowledge hub in the group. The degree of centrality can also be reflected in the distribution of links in the analyzed network; in the case in which a few nodes are very central this distribution tends to a power law.

4.1.1 Job in general network

First, we have considered the network composed by all the people mentioned by interviewees in questions from the second section of the survey. We name this network "Job in general" network (figure 3). This network is actually the aggregation of the following knowledge networks: "General Advice" Network; "Management and leadership knowledge/advice" Network; "Subject-matter expertise/content knowledge" Network; and "Knowledge about the organization and its procedure" Network. The red circles are interviewed actors worked in Clinic 3, blue squares are actors working in INRMFB but in other Clinics, black up-triangles are external experts.

From this network we can infer to which extent the team members search for knowledge outside their team and organization and if there are external experts who are central and more involved in knowledge sharing process.

Considering the involvement of internal and external experts we have:

- The search for specific expertise involves a high number of subjects and most of them are external to the organization;
- While knowledge is shared with external experts, experts are not shared! Actually, more than 90% of them have just 1 inbound link. This means that the each team member accessing external expertise has his/her personal network of contacts and those are not shared with team members;
- The frequency of exchange is reasonably high: on average 52 % of experts are involved monthly, 18% weekly, 24% quarterly, 3% between monthly and weekly, 3% between quarterly and monthly.

The job in general overall network exhibits three important characteristics:

- Internally, knowledge is shared in a centralized network characterized by the presence of a few hubs and in which the knowledge distribution seems quite inhomogeneous, with a substantial presence of marginal actors;

- Externally, the team members consult with a high number of experts but this sources of knowledge belong to personal networks and are not shared;
- There is a high degree of correlation between in-degree centrality and number of external links: this implies that those who are more engaged into internal knowledge sharing are also those who consult more with external experts. These subjects play at the same time the role of internal knowledge hub and the role of external knowledge brokers that are able to acquire new knowledge from the external environment and diffuse it in the team.

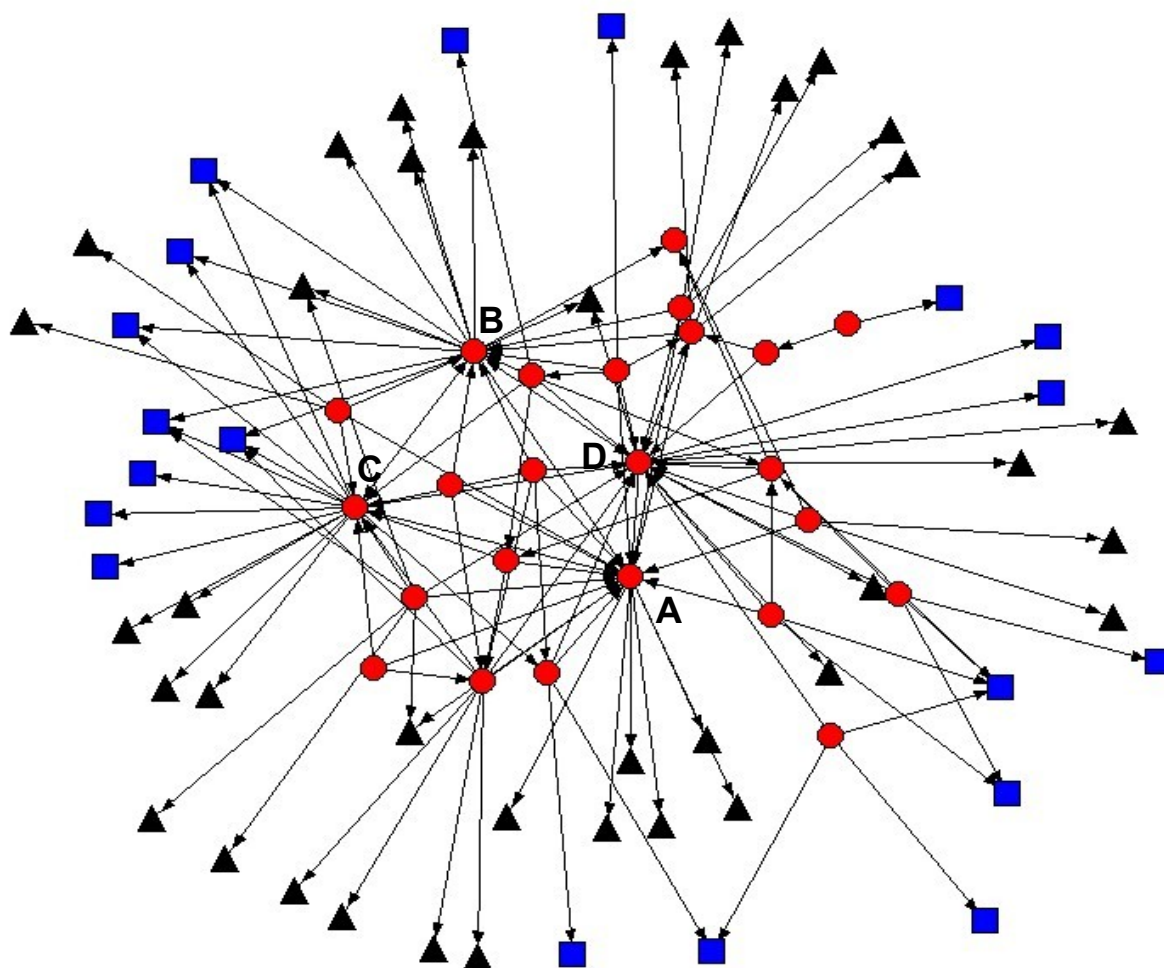


Figure 3: The “job in general” network for Clinic no 3

4.1.2 General advice network

Considering again all the actors we obtained the following network that display the ways team members of the clinic no 3 seek for general advices in performing their activity (the size of each node is proportional to its degree centrality).

We have the following results:

- Also in this case the network is very centralized (power law distribution);
- The actors who are more involved in knowledge sharing process are the following, namely for privacy actor A, actor B, actor C and actor D:
- There is an intensive use of external experts to get general advice.

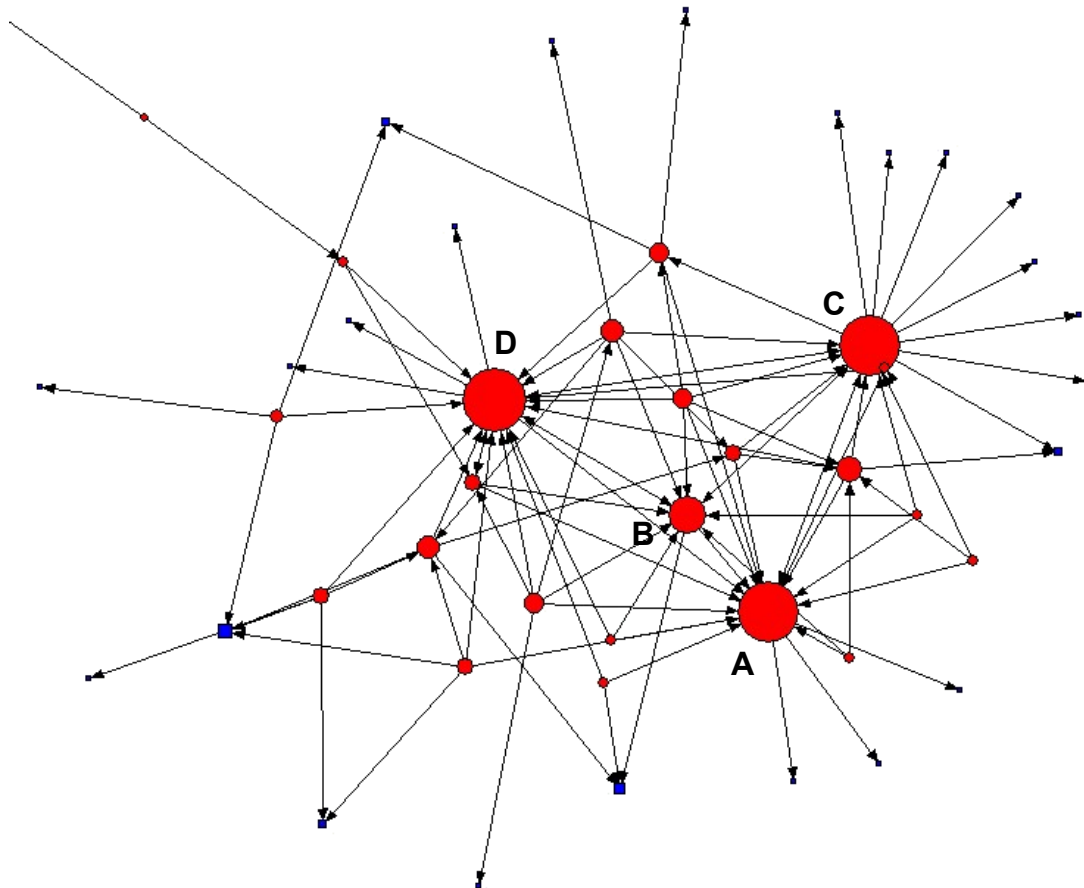


Figure 4: The “general advice” network for Clinic no 3

Actors	# Inbound links
Actor A	16
Actor D	16
Actor C	10
Actor B	9

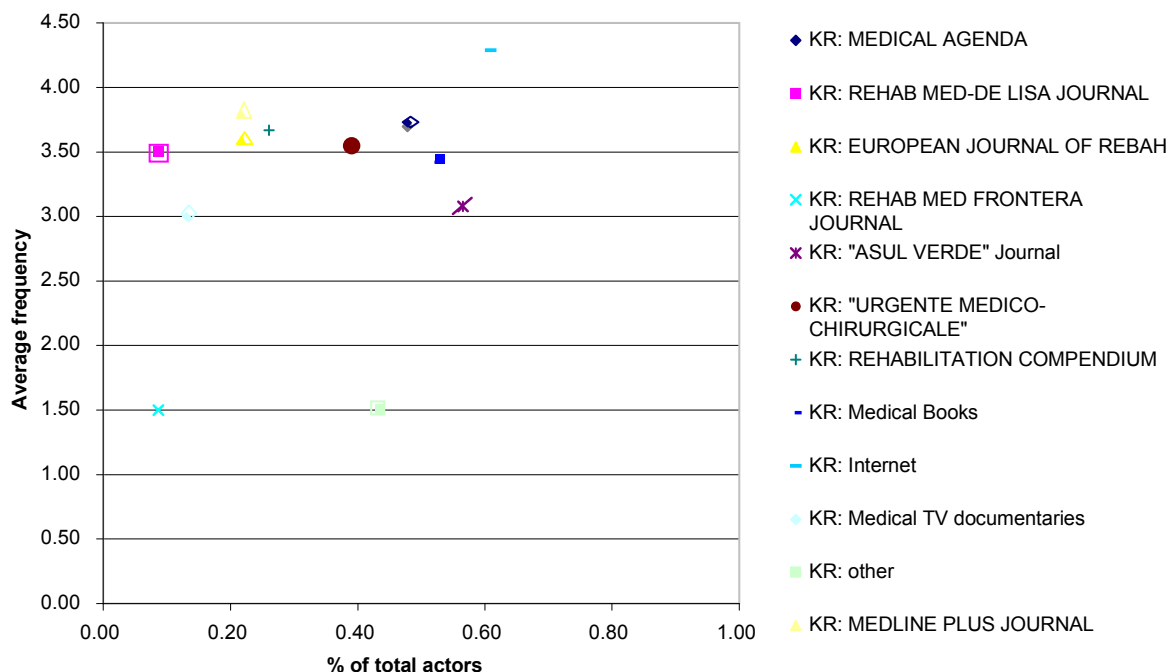
4.2 Knowledge sources and use

Because the SNA does not tell much about the ways participants use that knowledge, the motivations behind knowledge exchange, and the non-human knowledge sources used by subjects to perform their work, additional analyses have been carried out on the network humans/knowledge tools and resources, the organizational roles that are more involved in knowledge sharing, and the knowledge tasks that are more or less routinely performed by workers. Specifically we tried to answer to the following questions:

- Do the team members use the same knowledge tools to perform their work?
- Do they use the same information or knowledge resources to perform their work?
- Which knowledge tasks they use their knowledge for?
- Which organizational roles are more involved in knowledge exchanges?

Concerning the second question, for example, we have found that knowledge resources include a variety of sources: medical journals, books, internet, videos, etc. The difference with knowledge tools is that resources are just passive repository of potentially useful data but they are not used to perform work tasks, if not indirectly.

The empirical data (figure 5) shows that, unlike with knowledge tools, knowledge resources are used very frequently, though mainly only by doctors. The fact that other categories of workers do not use knowledge resources can be explained in several ways: i) their work is less knowledge intensive; ii) there is a lack of knowledge resources specifically developed for less skilled workers; iii) less skilled workers obtain the knowledge they need directly from more skilled workers acting as knowledge brokers.



Legend: 5 for daily, 4 for weekly, 3 for monthly, 2 for quarterly, 1 for other, 0 for never

	How many actors use it?	% of total actors	Average frequency
KR: MEDLINE PLUS JOURNAL	5	0,22	3,80
KR: MEDICAL AGENDA	11	0,48	3,73
KR: REHAB MED-DE LISA JOURNAL	2	0,09	3,50
KR: EUROPEAN JOURNAL OF REBAH	5	0,22	3,60
KR: REHAB MED FRONTERA JOURNAL	2	0,09	1,50
KR: "ASUL VERDE" Journal	13	0,57	3,08
KR: "URGENTE MEDICO-CHIRURGICALE"	9	0,39	3,56
KR: REHABILITATION COMPENDIUM	6	0,26	3,67
KR: Medical Books	12	0,52	3,416
KR: Internet	14	0,61	4,285
KR: Medical TV documentaries	3	0,13	3
KR: other	10	0,43	1,5

Figure 5: Knowledge sources and their use

In order to check if different categories of workers have the same behaviour in the use of knowledge sources and tools, we have disaggregated our data and our sample articulated in the following categories:

- Doctors;
- Medical assistants;
- Physiotherapists;
- Physical-physioterapist;
- Physical therapist;

- Nurses;
- Statistician;
- Clerk;
- Other.

In order to compare the importance of a knowledge source we consider that a knowledge source is important if it is shared by at least 50% of categories and it is used at least monthly. In the figure 6, we consider the average frequency, and we obtained the following data (a red box means that nobody in that category use that tool, while the green box means that more than 50% of members of that category use that tool with a frequency greater than 3):

	Doctor	Medical assistant	Physiotherapist	Physical-physiotherapist	Physical-t-herapist	Nurse	Statistician	Clerk	Other
INRMFB wide-database					4,00		5,00		
INRMFB web page or Intranet	3,67	4,40					4,00	4,00	
The Clinic's database									
My own database or contact list file	5,00			4,00	4,00		5,00	5,00	
The database of another workplace	4,00			4,00				4,00	
INRMFB policy/procedures manual or guidelines									
Clinic's specific procedures manual or guidelines									
Other procedures manual or guidelines	4,00	3,60		4,00			0,00	4,00	
Own notes or procedures	4,67	4,00		4,00			5,00	5,00	

Figure 6: The importance of knowledge sources for categories of medical staff

The institutional tools (the clinic database, INRMFB wide-database, clinic's specific procedures manual or guidelines, INRMFB policy) are used by almost all categories but with a low frequency. All categories (excepting the Nurses) prefer to use their own databases or procedures. The Nurses and the Physiotherapist do not use any tool at all, while doctors are those who make more frequent use of diverse tools.

4.3 Knowledge flows

The main findings obtained by the section 4 in the survey concern: types and direction of knowledge flows and suggested improvements, the aim being to identify:

- Which are the knowledge categories that are more shared and with whom;
- How the knowledge flow can be improved according to the suggestions provided by the interviews;
- Which are the obstacles that make knowledge sharing less efficient, and
- Which kind of critical knowledge is at risk to be lost or forgotten.

This part of the survey uses open questions. In order to perform the analysis, we have analyzed the text contained in each answer to identify recurrent factors and group them into higher level categories. The knowledge categories that are shared among the participants are:

- Scientific knowledge (Medical knowledge, new rehab techniques, news & updates, case studies, educational);
- Practical knowledge (Medical practice, Routine tasks, massage techniques, patients care, training);
- Managerial knowledge;
- Administrative knowledge;
- Social (conversations, relationships, team building).

The subjects with whom the above types of knowledge are shared are:

- Physicians;
- Trainees (Young doctors, Students, Residents MDs);
- Medical assistant;
- Physiotherapists (includes the various types, e.g. masseurs);
- Managerial staff;
- Administrative staff (e.g. statistician, clerks, ...);
- Nurses;
- Patients' family, friends and volunteers.

The data show that practical knowledge is deemed as more critical by the interviewees compared to other categories as social, managerial or administrative. Also interesting is that social knowledge, here intended above all in terms of the ability to deal with patients and their families as well as to build trust and reciprocity with the colleagues internally, is perceived critical only by the medical assistant and the physiotherapists consider important scientific knowledge as well as practical. Furthermore, managerial knowledge category is perceived as critical only by doctors.

Knowledge Category	Staff-Knowledge Category						
	Physicians	Medical Assistant	Nurse	Physiotherapist	Managerial and administrative staff	Young doctors, Students, Residents MDs	Patients' family and friends and volunteers
Practical (19)	0,37	0,58	0,58	0,42	0,05	0,21	0,58
Managerial (2)	0,50	1,00	0,50	0,50	1,00	0,00	0,00
Administrative (4)	0,00	0,00	0,00	0,00	1,00	0,25	0,00
Social (1)	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Scientific knowledge (9)	0,44	0,67	0,67	0,44	0,00	0,78	0,00

The following table reports data about the relationship between knowledge categories and staff types that are the target of knowledge sharing. In practice the table helps to answer to the question: "Which types of knowledge are critical and with whom are they shared?" For example, out of 19 interviewees that have answered to this part of the survey reporting as critical the "practical" knowledge, 37% of them share this type of knowledge with physicians. We can observe that only for the administrative and managerial knowledge category all actors have a similar thinking while for the other knowledge category we observe different thinking.

The data show that practical and scientific knowledge are the most mentioned (by respectively 19 and 9 subjects). With the exception of the management and administrative staff, practical knowledge is widely shared among all staff categories. Scientific knowledge instead is transferred only between medical personnel.

4.4 Findings based on the sections 4 and 5 of the questionnaire

The analyze of the actual structure of the INRMFB and especially of the Rehabilitation Clinic no. 3 and 4, based on the section 4 and 5 of the designed survey, has conducted us, so far, to the following findings / conclusions:

- The Rehabilitation Clinics no. 1 and 2 are placed into a different location than the Clinics no. 3 and 4. This makes the communications among the four medical CoPs an exception instead of a frequent habit;
- Among the four clinics and also among them and the management of the INRMFB the communication is based on the old classical methods - printed documents transfer;
- The INRMFB has no Intranet. Due to the distances among the fourth clinics, the absence of the Intranet makes the information/knowledge transfer very slow, and often produces losses of

valuable information/knowledge for some of (or all) the clinics, and also for the managerial team of the hospital;

- The spatial separation of the INRMFB's departments has also effects over the results from the research activity of the Institute. Within this particular hospital there are several research team: (1) Balneo-climatology; (2) Cellular breeding; (3) Mineral waters and therapeutic mud testing; (4) Immunology lab; (5) Bacteriology lab for mineral waters. In the actual organizational structure, these labs and scientific teams rarely communicate among them and share their activity results;
- There are no virtual libraries or repositories within the INRMFB. So, the only categories of medical staff that can access these knowledge resources are those doctors who are also professors at the Bucharest "Carol Davila" Medical University which has its own such library. The absence of virtual repositories results sometime in losing important documents, patients' medical files, tests results or managerial decisions transcripts.
- There are no policy/procedures manual or guidelines neither within the INRMFB or within the clinics / departments;
- There are no real boundary spanners, the effective connection among diverse groups within the Clinic no 3, for example, this task being (informally) on charge of the chief of the clinic. Because of this, the chief of the clinic is overloaded with her work and with administrative and information sharing tasks;
- In order to benefit for a second opinion (when need it), doctors within Clinic no. 3 usually contact they own personal connections via Internet (often foreign specialists) rather than call a fellow colleague who works into another clinic within the INRMFB;
- One interesting aspect for the Rehabilitation Clinic no 3: each month the chief of the clinic organizes a so-called "essay day" when all the doctors, the residents and the therapists are involved in presenting a paperwork describing the most recent events / aspects / achievements of their activity in the hospital. This method is used in order to exchange knowledge, but also to improve the communication techniques of the Medical Staff.
- The absence of the two categories of specialists – the social workers and the occupational therapists – hardeners the process of medical rehabilitation for both CoPs – Medical CoP and Patient CoP. Doctors are forced by this circumstance to involve them selves in the process of social reintegration of the impaired people, both by psychologically assisting the patients, and by dedicating a lot of time in educating and training the patients' families for coping with their disabled family member condition.

With respect to the obstacles in the knowledge flow, about 61% of actors identify the most important obstacles for knowledge sharing in organizational factors, and primarily organizational culture and work organization. Also, almost all the actors indicate as knowledge at risk of lost the "Documents and medical data concerning the patients and their rehabilitation progress".

5. Conclusions and future developments

The analysis presented above is based on a single case study and the findings cannot be generalized to represent typical ways in which Rehab teams work, exchange or create knowledge. However, the generalization of the results lie outside the scope of our work while the primary objective is to use the findings of the analysis to inform the redesign of the network and the introduction of knowledge tools and intelligent agents able to alleviate criticalities and make knowledge flow more efficient and fluid.

In this respect, we list in the following the characteristics of the knowledge networks emerged from the field analysis. Its can be analyzed to identify opportunities to improve the efficiency and effectiveness of knowledge sharing through the redesign of the organizational network. Such a redesign involves the identification of a socio-technical network made up by human and non human agents (as showed in figure 7).

First of all, we can assert that the classical organizational structure of the Rehabilitation Clinic no. 3 (as well as of the entire INRMFB) needs to be improved both physically and virtually:

- The real structure has to be improved by hiring professionals for *social workers* and *occupational therapists* positions. This could be done immediately by launching a call for specialists on the European and/or international labour market. A better solution which nevertheless requires more

time consists in enrolling Romanian students within the EU universities that provide academic programs on these particular professions;

- Virtually speaking, the organizational structure of the Clinic no. 3 has to be augmented with Intranet that needs to be populated with virtual species like Knowbots. These virtual agents can facilitate the knowledge creation, retrieval and sharing inside the Medical CoPs, among these and the managerial team of the INRMFB, and also among the human resources of the hospital and the (social, medical, and economical) macro environment. Knowbots should have a particular role in create for the *Patient* CoP useful knowledge that can help them in the rehabilitation processes.

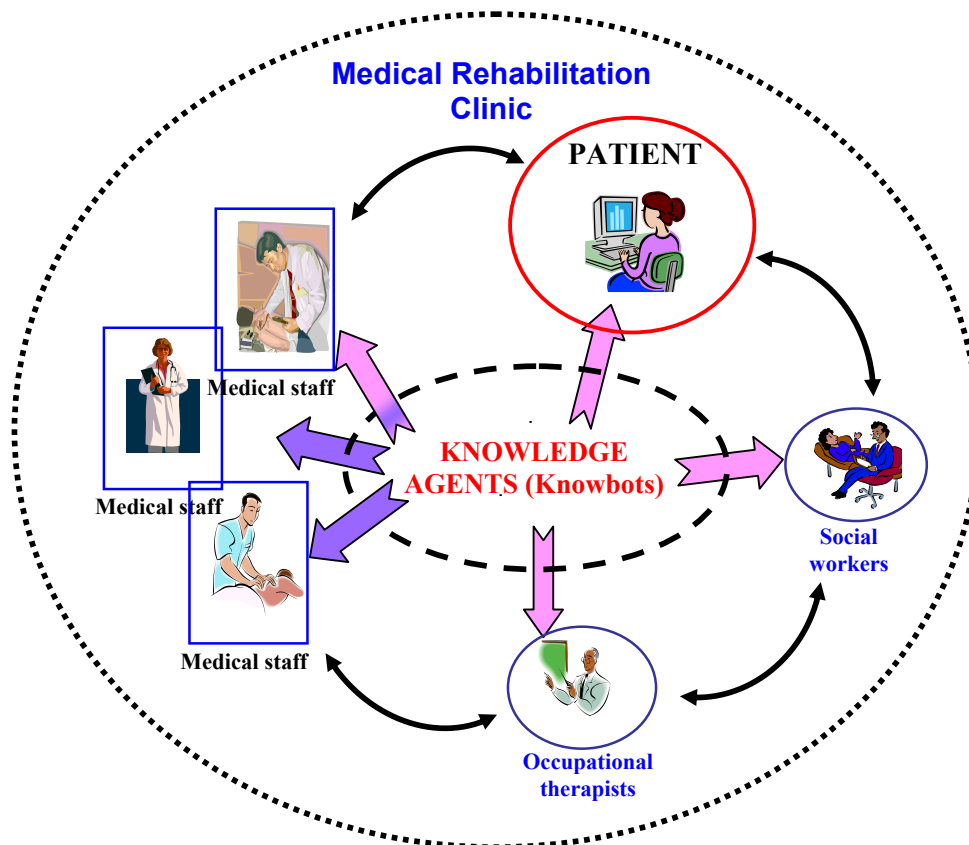


Figure 7: The new knowledge-oriented (augmented) structure of the Rehabilitation Clinic no. 3 of the INRMFB-micro level

Secondly, the results of our study highlighted some interesting characteristics and allowed us to identify a number of opportunities for possible improvements.

1. In terms of *Knowledge centralization*, the data shows that all the knowledge networks in the case are heavily centralized and that the several sub-networks are always centered on the same hubs. The individuals playing the role of hubs are also charged with management functions, and they are also the ones who are most connected with external experts. They play the role of brokers diffusing internally knowledge that is acquired externally. The opportunities for improvements are:

- Redesign organizational roles and processes so to favour the decoupling of brokerage from hubs;
- Create local knowledge bases of procedures and practices: the high indegree level of the most central nodes is due to the need to search for help from more skilled workers.

2. Concerning the *external experts*, the analysis shows the individuals that are more connected internally are also those who are more connected externally, especially when it comes to subject-matter expertise. Besides, the sources of expertise are not shared and seem to belong more to personal than to inter-organizational networks. This lack of sharing identifies as opportunities for improvements:

- At least for specific cases and sub-practices, it can be suggested to develop expert systems able to provide answers more quickly and economically than external experts;

- Encourage the use of existing social media professional platform to support team members in sharing contacts and membership to groups and communities of practices;
- Start a wiki for the collaborative description and solutions of problems. The wiki could contain a repository of the questions that are made to external experts as well as the answers that are collected and the name of the experts.

3. There is clearly a *lack of sharing in terms of knowledge tools and resources*. Conversely, almost all the team members do perform cognitive tasks of the same types (though arguably at different level of complexity). Thus, while cognitive work is widely performed, it is not supported by tools or it is limitedly so through the use of personal tools. The opportunities for improvements here are:

- Make a knowledge elicitation exercise to assess if some of the tools invented and used at the personal level can actually be improved and implemented at the team level or organizational;
- Implement the intranet and provide all team members with mobile internet access allowing workers to access knowledge and data on the go;
- Create an information systems able to track and monitor the entire medical life of a patient from the beginning of the treatment until to the dismissing;
- Encourage the use of web 2.0 tools to create bottom up shared knowledge repository, e.g. collections of video, articles, publications, presentation and other useful materials tagged with relevant keywords to facilitate search and reuse;
- Use eLearning to reduce knowledge gap in the team and increase the absorptive capacity of less skilled members.

The representation in figure 7 is the general frame under which we will further develop our study following the three main aimed objectives enounced in section 2 of the paper. Within the new knowledge-based organizational structure, one interesting idea open for discussion is which are more important to focus on, *nodes* (human and virtual agents), or *links* between them (direct / indirect connections and/or relationships)?

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