Semantic Web Applications: A framework for industry and business exploitation – What is needed for the adoption of the Semantic Web from the market and industry

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Abstract: The Semantic Web Research has resulted in the last years in significant outcomes. Various industries have adopted semantic web technologies, while the "deep web" is still pursuing the critical transformation point, in which the majority of data found on deep web will be exploited through semantic web value layers. In this article we analyze the Semantic Web applications from a "market" perspective. We are setting the key requirements for Real World information systems semantic web enabled and we discuss the major difficulties for the semantic web up-take that has been delayed. This article contributes to the literature of semantic web and knowledge management providing a context for discourse towards best practices on semantic web based information systems.

Keywords: Semantic Web Applications, Semantic Web based Information systems, Best Practices, Ontological Engineering.

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1 Introduction

The Semantic Web Research on industry and academia has contributed significantly to the evolution of information systems [Lytras (2005) ; Lytras (2006) Lytras and Sicilia (2005); Vossen et al (2007)]. What is still missing is the mass commercialization of solutions and products targeting to the huge market of IT services. In this article we try to analyze the key parameters that cause a critical delay to the adoption of semantic web technologies from the market and industry.

In the last years, in the context of the Special Interest Group on Semantic Web and Information Systems in the International Association for Information Systems, we tried to analyze the evolution of Semantic Web and its impact in various industries and computer science domains. In this article we will try to elaborate on key findings and observations concerning real world semantic web applications. This article is organized as follows. In section two we are summarizing the semantic web applications exploitation context, in other worlds we define the "value" carriers of semantic web technology. It is evident in various implementations of semantic web R&D funded projects that there is a myopic consideration of semantic web as a panacea for all the "data", "knowledge" management related inefficiencies of the last years. In section three we provide a roadmap for a Real World Semantic Application, emphasizing on a stage model that is summarizing the critical steps for the so call Semantic Web Engineering Approach. It is also evident in real world terms that this is a key obstacle in delivering the "business" value of an application. There is a critical knowledge gap concerning methodologies and practices for the adoption of Semantic Web Technologies in a real business context. This is also partially due to the low adoption of such methodologies/practices to commercial products by major IT solutions vendors.

2. Semantic Web Applications Exploitation Context

Dealing with the industry and the market and responding to their requirements it is a kind of relation that is needed to be developed on the basis of a simple equation. The “value” of applications must be recognized and delivered in the context of real problems. Due to this aspect, sometimes semantic web applications seem to be out of the “business” understanding of decision makers in companies and organizations. In simple worlds, semantic web evolution is related to the understanding of value offerings from decision makers since the investments on the related technologies have to be justified with business rules.

In this context it is more than critical to develop an upper layer of business intelligence that will link Semantic Web applications and investments with the critical business terms that decision makers use to justify their strategic planning priorities.

Sometimes it is really disappointing to realize how people with different origins or expertise are failing to collaborate due to an absence of “a semantic web exploitation framework”.

People with a background in computer science use to focus on technologies that unfortunately are out of the context of understanding of business people that typically are responsible for making decisions on investments. In a way the two cornerstones of Semantic Web Applications, namely the semantics and the ontologies, require a multiplier that is provided by the business logic.

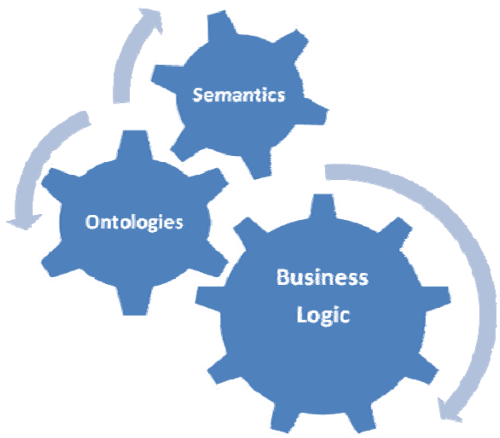

Figure 1: A three-tier approach to semantic web exploitation in a business context

With the evolution of standards, technologies and commercial products it is evident that nowadays companies and organizations worldwide have a significant range of options in order to exploit in a “semantic” and “ontological” way their data.

In this paper the main emphasis it is paid to the clarification of some answers related to the practical issues organizations face when they decide to enter to the “Semantic Web

Era”. In simple worlds we try to explore which are the main obstacles, difficulties and requirements for a successful semantic web application.

2.1 A framework for contextualizing the Semantic Web Application Development process

The understanding for the Semantic Web exploitation in a business context must be based on a detailed analysis of the knowledge-oriented performance that is linked to every business process. Furthermore it is also important to understand the “alignment” of every organization to its internal and external environment. In simple words the potential benefits for an organization from the adoption of the semantic web have to be specified and analyzed in two basic pillars of business operation:

- The support to the overall performance of internal business processes and the degree of Enterprise Application Integration
- The enhancement of organizational networking and exploitation of business synergies with other business partners or potential market and various individuals or business “stakeholders”.

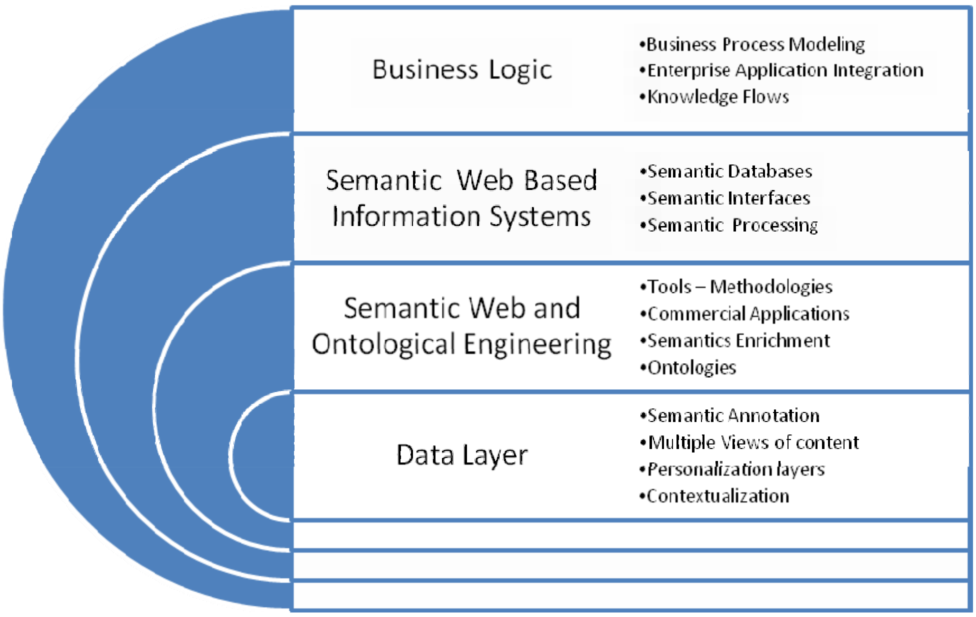

Figure 2: A context based approach for the exploitation of semantics in a business context.

In Figure 2 there is an introductory analysis of factors, that have to be analyzed in depth in order to understand the key issues every organization is facing towards its evolution to the semantic web era. It must be also made clear from the beginning, that within this process two enablers are of critical importance: The development of “semantic web” standards and the availability of “commercial” applications, tools, development environments, that will permit to any company the design and implementation of real world semantic web applications and not prototypes of limited functionalities.

From an engineering perspective we claim that 4 levels of analysis are the most important, namely:

1. **The Data Layer**
   When we are dealing with information systems the core component relates always to the data that are integrated to products, services, transactions including tangible and intangible items of knowledge, with less or more formal specification. From a semantic web perspective there is a critical question: Given the investments of companies for years in applications that "represent" the data according to database schemas or specific formalizations including relational databases, object oriented or multidimensional databases what is the required "killer transformation application" which will handle the "annotation of data' to the semantic web "standards". From a practical point of view, business organizations need to realize which is the added value of semantic web to the "core data and knowledge" of the business. Furthermore they have also to measure the return on investment of semantic web technologies, since the decisions for investments in IT are always based to a cost benefit approach.
2. **The Semantic Web and Ontological Engineering Level**
   The Semantic Web and Ontological Engineering Layer, is mostly related to the standards, tools, products, methodologies and best practices available to the "community" for the unified approach to Semantic Web programming and applications development. At this early stage of adoption and the first pick of maturity, for the Semantic Web, there is documented a critical gap on training and teaching on Semantic Web technologies at a global level.
3. **The Semantic Web based Information systems Layer**
   At this level the key objective is to be able to integrate semantic web components in the context of context-based semantic web applications. Of critical importance at this level are the components related with "semantic web enabled" databases, Semantic web oriented interfaces, and systems incorporating meaningful processing mechanisms either in the form of agents or intelligent infrastructures.
4. **The Business Logic/Intelligence Layer**
   It is critical to realize that for any business or governmental organization the core of the business relates with the Business Logic, the Business Services and all the supporting mechanisms that define the "business" in all levels ranging from the functional/daily/routing level to the Strategic planning level. Within this continuum, we have also to recognize that in the global economy level, any company has to consider also the exploitation of their "business logic" from external applications according to mutual business benefits or regulations and standardization. From another point of view the interoperability of "business logic" is a key milestone towards integration of business IT infrastructures to "greater" coalitions of business logic.

3. A Road Map for Real World Semantic Web Applications

The "realization" of the business case for the semantic web is related directly to the understanding of the state of the art and its exploitation towards an improved business performance. A common mistake of IT/CS people is their overestimation concerning the maturity of technologies to build competitive advantage for an organization and consequently their misunderstanding to integrate their expertise in the business priorities. Sometimes it is also difficult for promoters of semantic web technologies to justify the strategic role of semantic web based information systems.

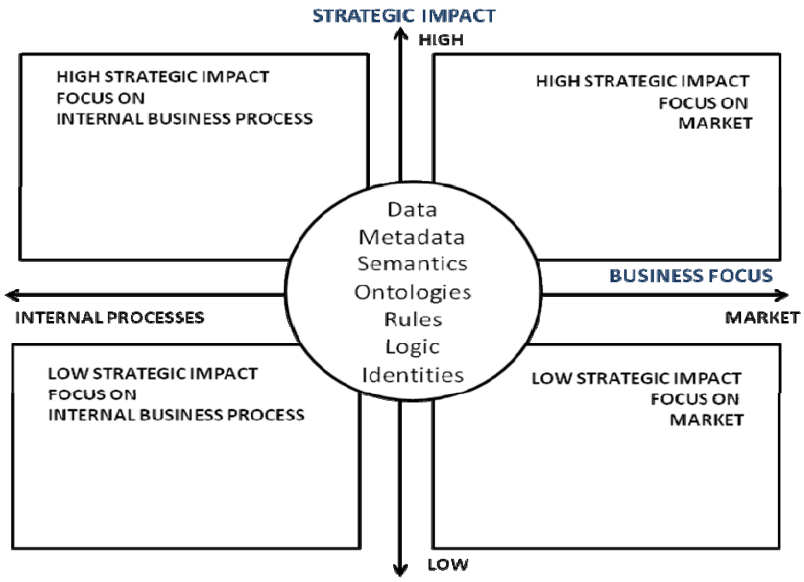

Figure 3: Positioning Semantic Web with a strategic point of view.

In figure 3, we provide an initial grid in which Semantic Web applications are classified according to their potential strategic impact and their focus on internal business processes of the market. A further analysis is provide in the next two subsections. What has to made clear is the fact that the evolution in standardizing tools for the representation of Data, Metadata, Semantics, Ontologies, Rules, Logic is only one of the key aspects of business adoption of Semantic Web. What needs to communicated further at different stakeholders group is the capacity of SW to support strategic impact.

3.1 Semantic Web State of the Art

We will go now through the four layers of the Semantic Web framework in order to see the technological state of the art. Starting from the basis, the Semantic Web is rooted on a data model, a way to represent data, geared towards interoperability. It is based on a directed graph, i.e. a set of nodes connected by edges with a direction, from node A to node B. This graph model constitutes the first building block for semantic interoperability because a graph can be used to represent many other kinds of data structures.

For instance, it is easy to model a tree using a graph -it is just a graph without cycles- or a table -each row is represented by a node that is connected to the different row values by edges labelled after each column name. This makes it easier to integrate data coming from XML documents or relational databases into the Semantic Web. Moreover, it easier to mash-up data from disparate sources into a graph because the result is always a graph.

The Semantic Web graph model is named RDF, Resource Description Framework (Tauberer, 2008). However, this is not enough. We can put it all into a graph but, how do we tell the computer that one part of the graph can be joined to another part because they refer to the same thing? And, what is even more important, how do we put restrictions on how the graph is built in order to make it model interesting things and avoid that it becomes a messy bunch of nodes?

It is possible to accomplish these features using schemas and ontologies, at the Semantic Web and Ontological Engineering layer. First of all, they guide graph construction by providing restrictions on how nodes are connected to other nodes using different kinds of edges, called properties. For instance, it is possible to say that a node represents a person and that it is related through properties called “name”, “e-mail” or “friend” to nodes providing the corresponding values for them.

RDF Schema is the simplest tool that allows modelling these restrictions (Daconta, Obrst, & Smith, 2003). It provides primitives similar to those from object oriented programming so it is possible to define classes with defined sets of properties and appropriate values. Classes are then used to categorise the things represented by nodes, called the resources, in order to apply the corresponding restrictions to them.

For instance, there is a class “Person”, associated to the relevant properties for persons, which is applied to a node representing a given person. From this point, it is possible to guide how that person is described by the graph and, more importantly, the computer can interpret a description for that resource following the guidelines provided by the “Person” class.

Ontologies also provide ways to restrict how the graph is modelled, and how it should be interpreted by the computer (Fensel, 2004). They are a more sophisticated way to do so and are based on logic formalisms. This makes it possible to use logic reasoners in order to deduce new things about the data being managed. These kinds of deductions are a key feature in order to enable scalable data integration by computerised means. Computers use the clues and rules captured by ontologies in order to make sophisticated data integration at the semantic level, such as realising that two pieces of data match together or the kind of product that an invoice is referring to, e.g. from what the ontology says about the invoice, the customer, etc.

The Web Ontology Language (OWL) is used in order to define Semantic Web ontologies (Lacy, 2005). There are three sublanguages with different levels of complexity, which require increasing computation power but provide more expressive ways to pose restrictions. The simpler is OWL Lite and the more complex and expressive OWL Full. In the middle there is OWL DL, which is based on Description Logics (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2003) and provides a trade-off between complexity and expressiveness. Ontologies provide the basis where semantic processing and sophisticated semantic databases can be build, at the Semantic Web Based Information Systems Layer.

The technologies previously described provide the means for semantic interoperability at the data level. Additionally, interoperability is also required at the operational level and, nowadays, Web services are the common approach to solve this issue. However, the foreseen Web of services where applications can be built from the combination of services published all over the world in an almost automatic way has not yet come true.

The barrier continues to be the difficulties to integrate the disparate data models that services process and the different ways to describe their functionality. It might be the case that two services that can be used interchangeably, but the different terms used to describe what they do make it impossible for the computer to realise that one can be used in place of the other. The Semantic Web approach for this problem is also to use semantic descriptions of the services, called Semantic Web Services (Cardoso, 2007).

There are some approaches (Yu, 2007) to Web services description that allow to say what they do, how they do it, what kind of data they get as input and what is the output, etc. The simpler way is to put semantic annotations into the Web Service Description Language (WSDL). This proposal is called Semantic Annotation for WSDL (SAWSDL). There are also two Web services ontologies that provide richer ways to describe them, an OWL-based Web service ontology (OWL-S) and the Web Service Modelling Ontology (WSMO).

Semantic Web Services are at the Business Logic layer. They are complemented with semantic rules languages (Schroeder, Kaminker, & Wagner, 2003), like SWRL, that provide the means to model business rules in the context of the Semantic Web. These rules take profit from the underlying ontologies and make it possible to share business logic rules, for instance along a value chain from suppliers to customers.

3.2. Practical Requirements for Business information Systems from a semantic web perspective

In the business world it is hard to explain to business people and decision makers the technical aspects of Semantic Web. In simple words it is impossible for them to understand the technical aspects of the Semantic Web towards the interoperability of information systems and the exploitation of knowledge that resides to “data warehouses”. The only thing that is relevant to the Business Community relates with the Business Logic and the Strategic Objectives aligned to the investments in information systems and information technologies.

As always computer scientists and information systems experts are enthusiastic for new “trends” in technology, fascinated by the ultimate objective of informatics to go beyond artificial intelligence to develop infrastructures with “logic” and meaning processing mechanisms. Within this context it is obvious that there is an ultimate question: “Who is the buyer of Semantic Web enabled Information Systems?”

Let us elaborate further in this intriguing question. Consider the case of a Multinational Company with branches around the World, with thousands of employees and with hundreds of business processes. Data flows, data sets, intranets, extranets formulate high demanding knowledge ecology. It is obvious that the discussion in the previous section provides several insights to the Semantic Web contribution for the X multinational company.

We will emphasize in this section in only one business process, for the merits of this article we will use the typical name PROCUREMENT.

The Pharmaceutical Company of our example has a well defined procurement department. More than 250 different product items are produced through several

manufacturing lines in three factories of the company and for this more than 600 suppliers are used contributing 15.000 different "raw" materials for the production.

The managers of the Multinational Pharmaceutical company want to develop a new information system for the better performance of the Procurement Department. The question seems obvious but it is critical:

How semantic web technologies can contribute to a better performance and which is the "unique" value proposition of the semantic web. It is really interesting to try giving an answer to these practical questions. Many times scientists miss the opportunity to explain in simple words the simple steps, the methodological aspects of an engineering approach towards a solution enabled by an emerging technology. And this question directly relates with the need to provide at a glance the "RICH PICTURE" for the required know-how in the context of SW engineering.

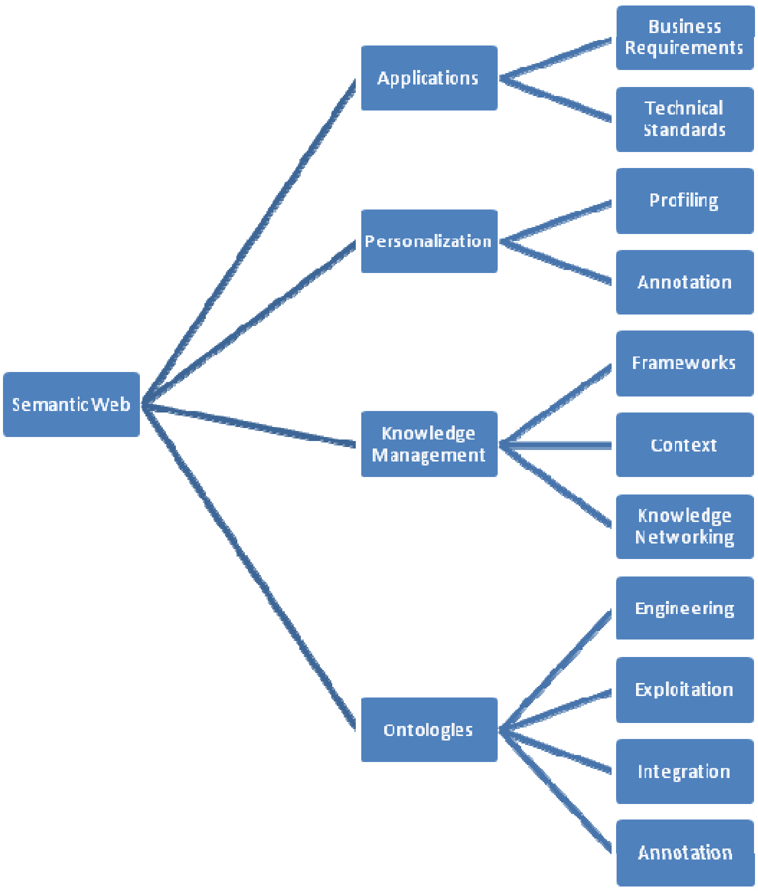

Figure 4: Semantic Web key themes

For the company of our case, some keywords summarize the potential role of Semantic Web. The company is interested in **Semantic Web Applications** which interpret business requirements, exploit technical standards and promote specific business objectives. Two of these critical objectives are linked to the quest of **Personalization** and the effective **Knowledge Management.** The provision of personalized services to customers, business partners and market require a unified approach to profiling and annotation of information with metadata/semantics components aiming to a better match of knowledge demand and supply. Additionally concerning knowledge management the design of knowledge networking and the provision of knowledge flows in the context of business operation is a key challenge. The performance gaps documented in various processes and business transactions challenges the design of a strategy for the management of intangible assets of the company. From a semantic web perspective the problem to be solved has traditional characteristics. A number or quality criteria must be met in order data in the information systems of the company must be accurate, verifiable, accessible, etc. From this point of view it is obvious that if we apply an engineering approach for the exploitation of the SW in a business context we need guidelines and documentation of best practices, that will link business objectives to a continuum of actions related to the exploitation of a different semantic web mix.

In the next section we will try to communicate a semantic web engineering approach from a market and business perspective.

3.2.1 Practical Requirements for Business information Systems from a semantic web perspective

It is quite interesting from the beginning to deal with the semantic web building blocks. And this kind of view is better initiated if we make clear the business requirements. So let us start by setting the first question:

Question 1: *The New Procurement System of the Multinational Company will co-operate with business information systems of suppliers and customers?*

INTEROPERABILITY: According to Semantic Web vision, interoperability is a key milestone of the semantic web. We want to build systems and infrastructures that will permit to “intelligent” computer-based components the application of various “intelligent reference mechanisms” on the top of data. So a simple question is do companies want to pay for the merit of interoperable information systems? And, if they want, is the interoperability a case of BUYING and CUSTOMIZING available standards and technological components?

From a business perspective this has also one more interpretation: To what level [e.g. to whom] a company wants to provide access to its interoperable system so that the benefit of the interoperability will be multiplied. And given the fact that our era is an era where Security Concerns are more significant than ever to what level a company would like to open the systems to intelligent agents who want to explore the wealth of their data?

In simple words at a bigger context is there any benefit for a company to permit exploitation at an interoperability context for their infrastructures? Because according to semantic web vision a key “objective” is also to be able to explore the **deep** web or the data that are stored in data warehouses that have owners. It seems that there is a key obstacle.

KNOWLEDGE REPRESENTATION

According to the vision of the Semantic Web as it was initially defined a critical milestone for the evolution of the semantic web is the development of a metadata ecology anchored to ontological structures that will permit machine understandable items of wisdom within information systems and data flows. This agent-oriented manifesto requires a key evolution in the way that data are structured, stored, and exploited. The building blocks of this new era are related to ontologies and metadata that annotate the real data [Barriocanal et al (2006); Kanellopoulos et al (2007) ; Lytras and Pouloudi (2006); Adamopoulou et al (2007) ; Sampson et al (2004) ; Sicilia and Lytras (2005a); Sicilia and Lytras (2005b); Sicilia et al (2006)]. Let us bring to our discussion one more question related to the Example we are using in this article:

Question 2: *Which is the key requirement for the transition of data in the Pharmaceutical Data warehouse of products and raw materials in the "semantic web era"? Or in simple words how do we structure the data and especially the existing data in the multinational company?*

The answer to this question is really critical. Several times the semantic web discussion is structured around ontologies, metadata, annotation but it is also evident that the commercialization of semantic web components was slower than expected. Vendors of Databases and Data-warehouses are moving fast to the launch of commercial platforms that permit the "semantic and ontological enrichment of data".

From a practical point of view there are few questions that require further exploitation:

- Who is developing the ontologies? In simple words what kind of ontologies are available for the multinational pharmaceutical company and is there an option for the company to invest in the development and the maintenance of an ontology? Furthermore how can the "selected" ontology, contribute to the milestone of the interoperability? Additionaly if the ontology is adopted and used is there a requirement for vendors and customers in order to transact with the information systems of the company to use relevant technologies?
- How can we integrate ontologies in a real world application?
- Who provides semantics?
- How can semantics and ontologies be integrated to business logic?
- How do we design queries on top of ontologies and semantics?
- How is Semantic Web Engineering differentiating in comparison to traditional web engineering?
- Which are the commercial tools we can exploit for Semantic Web based Information systems?

It is obvious from this list that the business requirements have always two interpretations: First of all it is critical to document and to quantify the business objectives. Then it is critical to apply a technical feasibility study, to review the available technological components and to document the required mix of technologies for the achievement of the desired objectives. This is something that in general is missing in the literature of the semantic web. There is rather a narrow discussion for this kind of knowledge that is required for the adoption of Semantic Web. In our oppinion this gap is oneof the main reasons for the slow adoption of the semantic web.

3.2.2 Response to Requirements

For the question about where are semantic web ontologies, we can observe that in most cases there are existing sources that can be formalized as ontologies. In the case of the pharmaceutical company, the European research project NeOn has produced or adapted existing classifications systems (Herrero & Pariente, 2008).

This project has produced ontological versions for the Anatomical Therapeutic Chemical (ATC) Classification System, one of the most widely used classifications of drugs supported by the World Health Organization.

At a first glance, this might seem a simple transformation of the classification to a new format that adds little value apart from this change. However, the real benefit of semantic web technologies is that once represented using them, the ATC Classification System can be easily integrated with other classification systems, taxonomies and ontologies, once they are also modelled using these technologies.

Concretely, the ATC has been integrated with SNOMED[1] (a medical terminology covering most areas of clinical information), the Medical Subject Headings (a huge controlled vocabulary in the life sciences including drugs and pharmaceutical preparations), MedDRA (a terminology used mainly in pharmacovigilance) or the Unified Medical Language System generated by the National Library of Medicine.

The resulting network of ontologies can be connected with existing legacy systems and reduces interoperability costs at differents levels in the pharmaceutical scenario, i.e. intranet among the company information systems, extranet among suppliers and customers information systems and event in the open world of the World Wide Web.

However, how is this vision put into practice? Are there real world systems capable of dealing with them? Some years ago, there were just some toy implementations with serious scalability issues that made it impossible to implement this vision in real business scenarios. However, in the recent years, many commercial tools have been developed, which are making possible to deploy semantic web technologies in the core of organizations information systems.

One of them should be highlighted because nowadays it is commonly found in many organizations. The Oracle database since version 10g take profit from the graph representation capabilities is has, initially intended in order to support geographic information systems, in order to represent the graph models inherent to semantic web metadata[2].

A part from semantic metadata storage capabilities, Oracle 10g and the newer 11g version provide scalable and reliable indexing and querying mechanism which are enriched with a rules engine operating on semantic metadata and ontologies. Overall, Oracle provides an integrated and scalable tool for semantic web benefits deployment in real world scenarios, from data to business logic rules through ontology-based information integration.

In order to develop and maintain ontologies and business rules, there are also commercial tools that hide semantic web technologies subtleties and provide a powerful semantic web engineering environment. For instance, there is TopBraid Composer[3],

[1] Systematized Nomenclature of Medicine
[2] Oracle Semantic Technologies Center,
http://www.oracle.com/technology/tech/semantic_technologies
[3] TopBraid Composer, http://www.topquadrant.com/topbraid/composer

based on the Eclipse development platform[1], which makes it much easier to develop and maintain complex ontologies, semantic web rules and test semantic queries.

With the help of this tools traditional web engineering is leveraged to semantic web engineering. The main benefit of semantic web engineering is that it helps concentrating the engineering effort on more abstracts aspects and makes it easier to move them to the implementation stage in an automated way. Consequently, engineers can concentrate their efforts on capturing stakeholders' requirements using building blocks much more comprehensible for them, i.e. concepts and relations among these concepts relevant to the stakeholders' expertise domain. Once captured as ontologies and rules, these concepts and relations are much more easily translated into computerized means that fulfill the initial requirements.

3.3 A stage model for Semantic Web Based Information Systems and Applications

The purpose of this article is to provide a piece of skepticism for key issues that slow down the adoption of the semantic web. From a consulting point of view it is required to develop detailed well documented best practices.

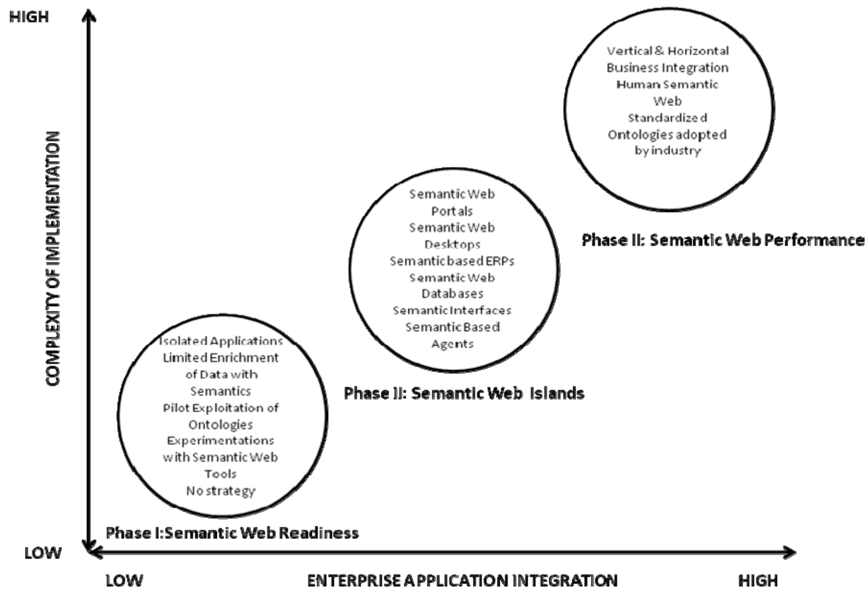

Figure 5: Semantic Web Adoption Phases

From a research point of view this context describes a new "domain/line" of research within the semantic web research community which is dominated by technical propositions and limited contribution to business consultation. In this section we provide

[1] Eclipse development platform, http://www.eclipse.org

an introduction for a forthcoming article in which we summarize best practices for semantic web adoption in business.

In our approach a first important pair of parameters that affect Semantic Web maturity and adoption relates to the degree of **Enterprise Application Integration (EAI)** and the **Complexity** of the implementation. With such a simplistic mapping, we have a first evaluation for the strategic impact of the semantic web adoption. The level of EAI is a good measure for the strategic impact of SW for a business organization, since it provides a good measurement for the level of data, business and services integration in the organization. What is missing from this approach and needs further discussion is the evolution of current information systems the non-semantic web enabled. For any business this is the first question that has to be answered. If we invest money in emerging semantic web technologies, what is going to happen with our current data/systems/applications/processes? In this way we have one more parameter of analysis to the business consulting for SW adoption: Is there a master plan which "documents" and provides practical requirements for the enhancement of current ERPs, Datawarehouses and other systems with Semantic Web capabilities? This is for sure a very complex requirement to be answer in few paragraphs.

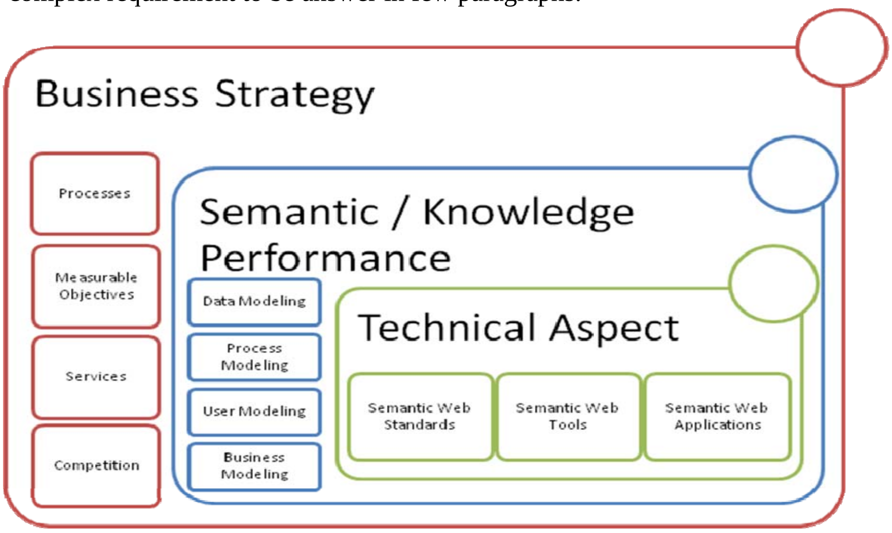

Figure 6: A framework for Strategic Adoption of Semantic Web in Business/Market

In Figure 5, we distinguish three different phases of semantic web adoption, namely Semantic Web Readiness, Semantic Web Islands, and Semantic Web Performance. What is missing from the current approaches to semantic web is an ontological agreement for the key aspects/success factors of a SW implementation. According to our proposition a 3-tier model provides a framework which guides all the practical implementations.
This model is briefly presented below in figure 6. The simple idea behind this approach is that no semantic web application can be successful without alignment to the key strategic objectives of companies. And furthermore nobody can realize the benefits of Semantic Web evolution without a direct analysis of business performance factors that can be enhanced / supported by semantic web and ontological engineering Lytras and Naeve (2006), Lytras et al (2005a) ; Lytras et al (2005b) ; Lytras et al (2002) ; Naeve et al (2006) , Sakkopoulos et al (2006)] Performance factors in the case of any business are different but fall always in the same categories. We are in the process of modeling such ontology of business performance factors which can be exploited further for the provision of semantic web enabled services.

4. Discussion and Conclusion

The purpose of this article was to communicate a critical point of view for the slow adoption of the semantic web in business and industry. The main contribution relates with the discussion of the missing gap between the business adoption and the technological evolution. We emphasized on a number of parameters related to guidelines and business best practices that are missing in the relevant literature of the semantic web. In a next article we will summarize a Best Practices Research on Semantic Web emphasizing on the business integration of semantic web technologies within a business context. The main idea is that the detailed Business Performance Factors / Business Process Modeling and the development of an Enterprise Application Integration Strategy provides an ontological agreement for the exploitation of semantic web technologies in a real world case.

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