E-CITY KNOWWARE: KNOWLEDGE MIDDLEWARE FOR COORDINATED MANAGEMENT OF SUSTAINABLE CITIES

10.4237/gtp.v4i2.103

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ABSTRACT

The realization of e-city is a necessary component for achieving the green city. This paper outlines a vision for an e-city platform that is based on knowledge brokerage in the green city. The proposed platform will be a venue for creating dynamic virtual organizations to harness collective intelligence of knowledge hubs to analyze and manage sustainability knowledge in urban areas. Knowledge assets of participating organizations will be presented in three dimensions: process structures, human profile and software systems. These three facets of knowledge will be accessible and viewable through a self-describing mechanism. Cities can post their geospatial and real-time data on the net. Relevant environmental and energy-use data will be extracted using topic maps and data extraction services. Local decision makers can synchronize work processes (from participating hubs) to create an integrated workflow for a new ad hoc virtual organization to collaboratively analyze the multifaceted nature of sustainable decision making.

An e-city platform is envisioned in this paper that will be realized through intelligent, agent-like, domain-specific middleware (KnowWare). Through triangulation between people, software and processes, these KnowWare will discover, negotiate, integrate, reason and communicate knowledge (related to energy and environment) from across organizations to the right person at the right time. KnowWare is fundamentally, a portal of social semantic services that resides on a cloud computing infrastructure. Knowware exploits thee main tools: 1) existing ontologies to represent knowledge in a semantic manner, 2) topic maps to profile sources of knowledge and match these to the complex needs of sustainability analysis, 3) domain-specific middleware for knowledge integration and reasoning.

Keywords: e-city; Information Technology; green city;

1. INTRODUCTION

The city of the future, indeed the whole economy, is being shaped around knowledge systems. Nations are competing not only by what individuals can create physically, but by the "knowledge products" that their citizens can collectively create. This evolving reality is gaining momentum as a result not only of the impressive advances in communication technologies but, more importantly, due to the unprecedented embracing of such technologies by society. The web is no longer a medium for people to exchange text or to link software. It is morphing into a new socioeconomic space where people interact and harness "collective intelligence" to achieve goals. The hallmark of these goals is "sustainable development".

The realization of e-city is a necessary component for green city. Researchers, industry, communities and governments are becoming aware that, in any decision, environmental stewardship and energy conservation should be optimized as much as economic returns and social advancement. This desire for sustainable development along with globalization and the emergence of knowledge economies are reshaping infrastructure as a global e-industry. Soon, virtual enterprises and "knowledge products" (in the form of web services) will flourish as valuable commodities in a new e-market for civil infrastructure. Many efforts have been dedicated to address the nexus between city management, sustainability (including citizen engagement) globalization and knowledge economies.

The massive and complex nature of rebuilding our urban environment is magnifying the inefficiencies in the current approaches: focus on short term costs (in contrast to life cycle costing); lack of coordination and sporadic project developments (in contrast to coherent integrated development); limited community engagement; inadequate tools for quantifying sustainability-related costs; and lack of mechanisms to harness, use and share knowledge.

The proposed vision ushers infrastructure into the knowledge economy. The aim is to create a breakthrough in city and urban infrastructure planning and management. The objective is to use best practices in informatics and networked society to harness, retain and exchange knowledge using ICT and knowledge management (KM) tools to enhance the design and management of sustainable, safe and energy-efficient urban infrastructure.

Technically, KnowWare can be seen as middleware for virtual knowledge organizations. While traditional middleware are not domain specific and focus only on the linkage of software, KnowWare are 1) domain-specific--can understand civil issues (e.g. through a set of ontologies) and, 2) capable of presenting processes and profiling human experts to be matched within the scope of a social semantic web. The proposed KnowWare are the glue of virtual knowledge organizations that goes beyond linking software to integrating business processes and matching human experts.

2. THE CURRENT GAP

Knowledge can be seen as spanning three spheres: software (means for static capture of knowledge), work processes (reflection of best practices and value generation), and human judgment (the wisdom / intelligence of human experts). It is sad to notice that except for the software facet, knowledge management practices in the infrastructure domain have lagged almost every other industrial sector. Extensive work has been dedicated to achieve interoperability in the software sphere. For example, client-server systems, distributed computing, middleware, and XML, and data exchange standards (such as industry foundation classes-IFC) have been introduced to address data interoperability problems in the domain.

However, there is very limited application of business process management (BPM)—such as enterprise content management (ECM). More alarming, communication protocols in the industry are normally based on verbal or paper-based techniques. Application of traditional web sites is now increasing in the domain. However, more sophisticated tools such as customer relationship management (CRM) techniques are not used, yet very much needed.

BPM standards such as business process execution language (BPEL) have had a long history of success in other domains-not only in describing and managing processes, but more importantly, in breaking the barriers between the process and software spheres. The result is the overwhelming success of e-business. The rise of globalization and the knowledge economy is pushing for a more complete integration of all three spheres. Ontologies and semantic web have been introduced as means to create common understanding of human-relevant knowledge among these three spheres. Semantic systems not only allow for integrated business, but also intelligent business. The social web (a parallel breakthrough) allows for linking people (not just web pages). Virtual multi-national organizations, indeed communities, are emerging and "living" on the web.

The challenge now is to integrate the three spheres at the human-relevant semantic system. How can a human with simple instructions extract knowledge from existing software systems? Can this be integrated with daily business and technical processes? Can such knowledge be extracted or delivered from/to the right person at the right time? In summary, can we make access and manipulation of knowledge ubiquitous across all three spheres? In other words, let us assume that a human understands his/her needs, has access to intensive real-time data (such as videos of an accident or contamination levels in a water line), is aware of existing software systems (in a different agency) that can help in processing such data, has a set of collaborating colleagues who possess a set of expertise, and these colleagues follow certain process structures to use their knowledge and make decision. Can he/she expose, compare and match the expertise of these colleagues to each other? Can they synchronize their work processes to allow for a meaningful/purposeful and relevant flow of data and decisions from one activity to other? Can they share, document and package their knowledge?

3. THE VISION OF E-CITY

The fundamental thesis of this vision is that: we need e-city to achieve green city. In other words, we cannot build 21st century cities without coherent business-savvy and human-oriented informatics solutions. Sustainability is a multidisciplinary domain (encapsulating engineering, environmental, management, economic and social sciences). It relies on knowledge and human wisdom as much as it relies on data and information. Moreover, sustainability relates to relatively larger scales (city, regional, national and international), hence its need for intensive data management. Finally, given that the concepts of sustainability are relatively new, it is impossible to allocate all required "human" expertise in one place, hence sustainability analysis is by default "networked". Consequently, while it is important to develop new knowledge in sustainability, it is more important to "integrate existing knowledge". This is needed to handle the overwhelming and conflicting transactions associated with management of sustainability.

The vision of e-City includes building a knowledge integration platform to realize g-city. Decision makers will be able to draw on the expertise of knowledge hubs. First, they can send/share real-time data (GIS maps, traffic videos, sensor data, satellite imagery) of their city to these hubs. Engineers can share options for new infrastructure systems (a new transit lines, or a new electrical power station). Decision makers can then bid the "sustainability assessment" work to interested hubs. These hubs will posses knowledge (software, processes and personnel). By synchronizing the processes of these hubs, the output of one analysis will be fed to another and an expert from one hub can work with another to resolve a conflict or pursue a new plan altogether. For example, an ITS knowledge hub can estimate traffic flows in all proposed routes. The information can then be fed into an emission management hub to calculate the amount of CO_2 generated. Similarly, a construction knowledge hub can estimate the life cycle costs of each proposed plan. They can also study the impact of combining the route of a watermain and the transit line or integrate their construction schedules (to reduce construction time and energy use). An economic knowledge hub can study the impacts on business activities and the resulting economic development and taxation. An environmental hub can study the impacts of different routes on local environment. Based on this information, decision makers can study the tradeoffs between options. Through balancing the environmental, energy, economic and social impacts (the very essence of sustainability) they can go back to urban planners and engineering designers with information about the best route. Contractors can be linked to this virtual organization to provide input and start arranging their construction plans. Interested citizens can log on and participate through voicing their input.

The proposed platform will be a venue for creating virtual organizations through weaving knowledge from various sources (see Figure 1). Participating organizations will be presented through their process profiles, human profile and software. The three elements of knowledge will be accessible and viewable through a self-describing mechanism. Cities can post their geospatial and real-time data on the network. Using topic maps and data extraction services, relevant environmental and energy use data will be extracted from GIS tables. Users (such as local decision makers) can use KnowWare to select (drag and drop) elements of work processes from each hub to create the workflow of the new organization. Weaving the new process from existing processes allows access to the actors, software and data at existing organizations. Data will flow between software and human experts can negotiate and integrate the results.

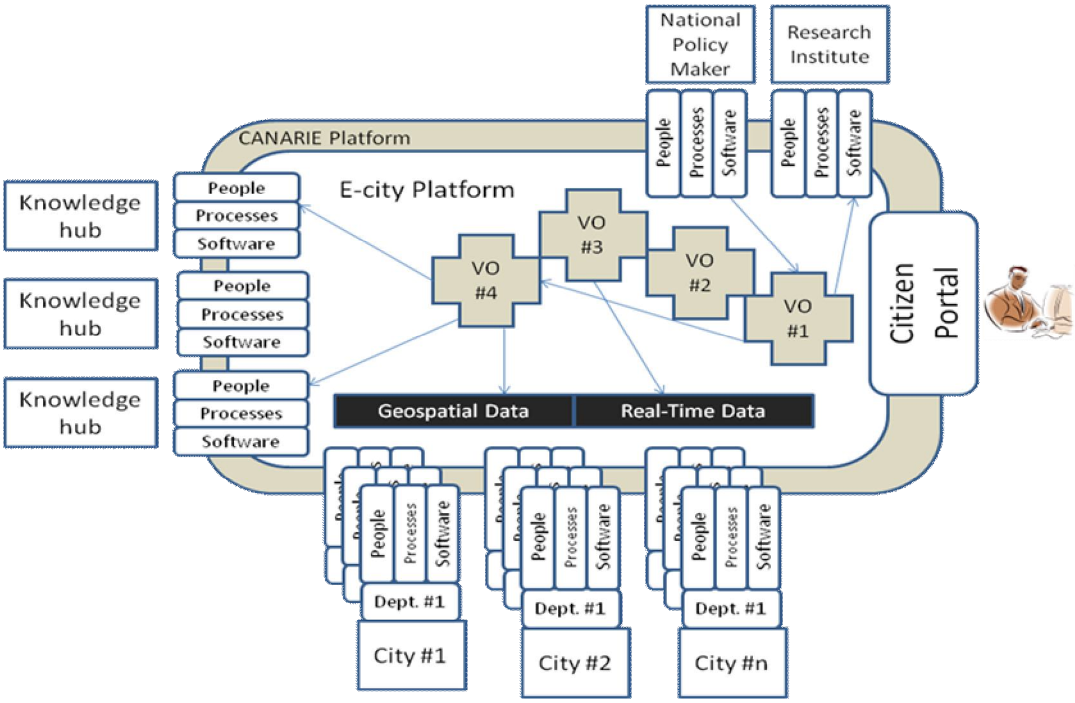

Figure 1: Creating Dynamic *ad hoc* Virtual Organizations

4. VIRTUAL E-CITY ORGANIZATIONS

Fundamentally, the aim is to build a user-friendly service-oriented integration platform. This platform sits on top of existing software systems, databases and process structures of civil infrastructure. Three fundamental tools will be used in this regard (See Figure 2):

1. Ontologies: existing ontologies will be used to allow knowledge resources and end users to define themselves in a semantic interoperable manner.
2. Topic Maps: This will be used to map existing (pre-defined) knowledge resources and also to map user problems. The map charts a sphere of knowledge three elements.
3. KnowWare: these domain-specific middleware will provide the services to allow end users to define their problems and communicate information back and forth.

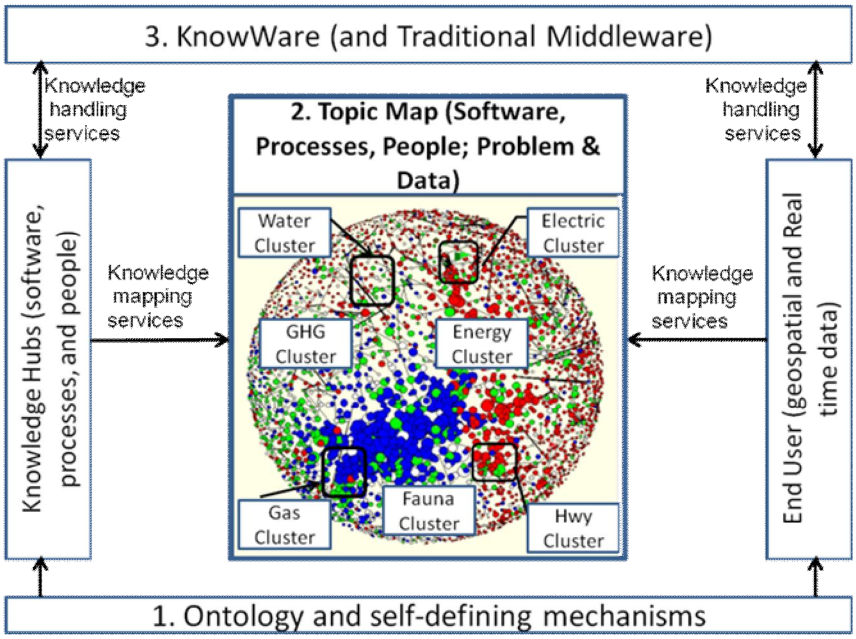

Figure 2: Mapping Sustainability Knowledge

KnowWare will help weave a set of basic web services that discover, parse, combine, and compare civil infrastructure data, as well as integrate data flow from one civil infrastructure software to another in order to allow seamless flow of data. The web services also parse the process structure of civil infrastructure to find out who needs what information at what stage of the process, who makes what decision, who should receive what information and in what format. This includes the following layers (see Figure 3):

- Knowledge encapsulation: this is a layer of standards for representing the three dimensions of knowledge. This includes existing and future ontologies, data standards, data exchange protocols, and process exchange protocols. the platform will link to a sample of existing standards in this regard (ontologies, BPEL and IFC).
- Knowledge Cloud (resources and representation): this layer includes the three elements of knowledge: software used for analyzing aspects of infrastructure systems, actual work processes of parties that are engaged in

the management of infrastructure systems, and the people working in these processes (at variant roles, responsibilities and skills).

- Interoperability Layer: interoperability between software systems will be achieved through the use of middleware. Interoperability in process representation will be achieved through adhering to BPEL standards. Future expansions of this work could adopt additional process representation standards and the required bridges between such standards. Representation of human profile will be done through existing protocols developed.
- Integration Layer: this is a SOA platform that will host web services that integrate the flow of knowledge across software, processes and people. This platform will utilize topic maps, markup languages (such as ColdFusion) and UDDI to manipulate knowledge and achieve seamless exchange of information.
- Communication Layer: because humans are at the centre of KM, this layer will utilize mashups to deliver the right information to the right person in the right format. It will also allow people to drag-and-drop process flows to build ad hoc virtual organizations or communities of practices. It will also utilize social web tools to build communities of practice (CoP).
- Interpretation Layer: Interpretation is done by knowledge consumers (experienced actors). Ultimately, the proposed platform is semi-automatic. It aims at delivering the right knowledge to the right human expert to make decisions.

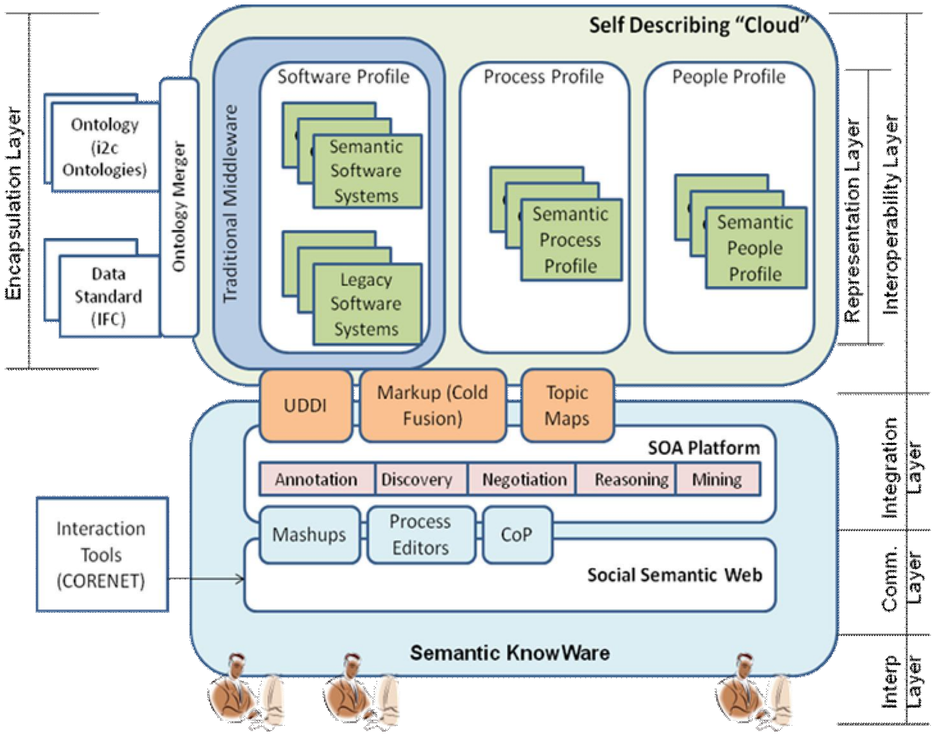

Figure 3: e-City Conceptual Architecture

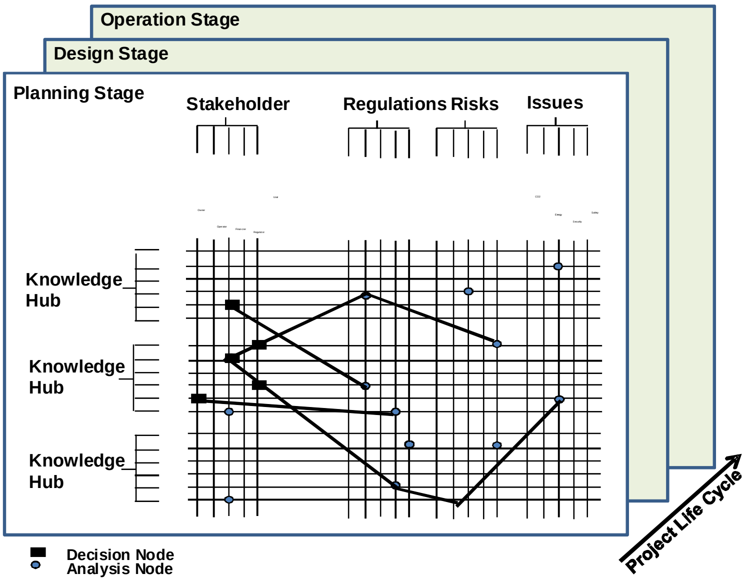

Figure 4: Mapping Sustainability Knowledge

5. SUSTAINABLE CITY SCENARIOS

Sustainability requires the utilization of networked knowledge to analyze various and conflicting issues across project life cycle. There is a need to integrate relevant knowledge to coordinate decisions and balance the needs of various stakeholders. e-city platform will allow for this through the following (see Figure 4):

1. Knowledge hubs will be identified through existing ontologies and the proposed self-description mechanism.
2. Stakeholders, their profiles and needs will also be identified in the same manner.
3. Issues, risks and related regulations will be also identified.
4. Topic maps will be used to map knowledge in the knowledge hubs and knowledge needs at stakeholders.
5. KnowWare will support the matching of knowledge needs and resources, resolve conflicts, and marshal data and instructions back and forth.
6. In each phase (such as planning, design and operation phases), through the help of KnowWare, knowledge managers will weave a flow of knowledge that identifies major decisions to be made and the required analysis that needs to be done.

<u>Planning and Design:</u> KnowWare will roam on top a network of entities (identified through topic maps) that represent available knowledge resources that can interact on a real-time basis. A knowledge manager (of a new project) can use the e-city platform to establish a project GIS portal that lists existing area statistics and relevant information along with project objectives and proposed layouts. The manager can then use a “procedure KnowWare” to list/weave a map of needed knowledge that support elements of design—for example, calculating green house

gas emissions (GHG) associated with a certain highway layout, estimating noise levels associated with a certain highway barrier design, studying the impacts on flora and fauna due to a new sewer line, estimating the energy wasted due to leaks in an existing water line, estimating the impacts of a highway layout on prices of houses in local communities. Knowledge hubs can perform some of these as services. They will use the e-city platform to map and integrate their work processes and software systems to develop some of these estimates and update the project GIS portal.

In the same supply chain, a service provider could document a certain permitting cycle into a for-rent service that can be used to contact different jurisdictions and prompt their systems with the required documents (or drawings) for permitting. The permitting service could then receive the approval and update the procedure KnowWare to proceed to the next step. At some point a decision maker may request using a software to evaluate certain criteria. KnowWare could invoke such software through its proxy, prepare and send proper input and receive, configure and direct results to the next step.

In essence, infrastructure development process will be transferred to an “assembly” of modular self-contained software packages that can be reused by different users. Meta KnowWare could be established to coordinate the timing of decisions and component interdependency. The KnowWare could also handle citywide coordination among various infrastructure systems. Outside entities like bankers, investors and contractors could be informed with the ongoing component performance and decisions and could adjust their plans accordingly.

e-Society: e-society refers to the process of engaging members of the community in identifying strengths and opportunities, problems and potential solutions for community issues upon designing new infrastructure. Current community engagement initiatives are focused on one-way communication that provides limited information to community. In contrast, citizens in knowledge cities are knowledge savvy. They posses enough KM acumen to actively participate in criticizing project designs, compose new ideas and vote on designs in an informed way. As shown in Figure 4, residents, business owners, NGO's can use the platform to exchange ideas, study existing design options, assess of impacts; vote on different design schemes; collaborate on the development of new design options; and even promote new/alternative project to developers.

Figure 5: e-society on Second Life

Evidence and early applications of knowledge-empowered communities are starting to be a reality. As a case in point, in 2004 the Mayor of Paris announced plans to build the Les Halles garden in central Paris. Originally, the land was the central wholesale market for the Paris region until the 1970s when it was razed to the ground to make way for a shopping centre. The local residents' association Accomplir (Accomplish) objected to the inadequate level of residents involvement. In 2007, they launched a second life competition to encourage locals not only to comment on their needs but also to create doubles of themselves (avatars) and actually design their own garden (Accomplir, 2007). The winning project (see Figure 5) was revealed in June 2007 and received a reward of 275,000 lindens, the currency used in Second Life (equivalent to 785 Euros). Even though it was developed by a French group, people in China, Canada and Germany took part and came up with ideas for a new garden.

Construction: coordinating construction site work is one of the most challenging processes. The challenges facing project managers during construction are compounded by the ever-increasing complexity of projects. Most projects take place in congested urban areas where layers and layers of utilities are buried; construction has major impacts on traffic and local business activities; and construction can have negative impact on local environment, including harming flora and fauna and the associated noise levels. It is not possible to list all the possible scenarios where the new platform will help alleviate some of these challenges. One possible example includes the use of virtual reality to enhance the development of nD maps/CAD files of urban utilities. The current manual practices of developing the actual location of these utilities after they are done (called as-built drawings) is laden with inaccuracy. This results in frequent hits of underground utilities. Hitting a water or sewer main means interruption to traffic and local business. Hitting an electric cable or a gas line could be fatal.

Instead, KnowWare systems can be used to create accurate as-built using augmented reality. Many modern excavators and construction equipment are equipped with GPS tools. Mounting a digital camera on the boom of an excavator can provide images of the pipes being laid. Algorithms already exists to identify the specific coordinates of the pipe through linking the boom movements and dimensions to the location of the equipment (as defined by the GPS tool). Similar algorithms exists to parse and combine several digital images (of the pipe) to create a 3D model of the pipe. This goes beyond the location identification to an exact description of the quality of installation and the conditions of the pipe. Given that existing pipes have to be exposed in many cases to install new ones, the same technology can be used to accurately develop the location of old systems too.

The result is a nD description of existing utilities that includes conditions, location and relationship to existing street elements. This is very crucial to future budgeting, planning and operation phases. Moreover, using these accurate nD asbuilts, the operator of a construction equipment (nearby a gas line) can program the excavator to stop once the distance between the boom (as defined by the GPS tool) and the gas line (as accurately portrayed by the nD model) approaches a safe threshold. Some algorithms and prototypes of this scenario already exist.

The automation of site information means that managers of construction sites can build the project in virtual reality first before they actually do it. nD modeling and planning software can be invoked by those managers to study every safety and sustainability detail of the project. They can solicit input from experts (in a knowledge hub) to simulate various scenarios for the best construction sequence. Once the project starts, they can use the actual data collected and the progress of installation to measure productivity and coordinate a just-in-time delivery of material. This will be very beneficial in reducing required storage space, which comes at a premium in congested urban areas and could cause significant reduction in street areas available for use by traffic and local community. The managers can also use the simulated virtual installation process to study the energy and noise levels of various equipments (some algorithms already exist to perform such tasks).

<u>Utility Routing and City Planning:</u> It is important here to point out that given the existence of multi-dimensional representation of new and existing utility lines along with main features of surrounding areas (traffic flow, land use, community composition), more optimized routing of utility lines can be developed. An algorithm that was developed (Osman, 2006) already exists to help urban planners find the most "sustainable" route of a utility line. This includes consideration of the following factors: Constructability (the ease of building), functionality (assuring best coverage to the service area now and in the future), community disruption, traffic impacts, utility conflicts, seismic and geological considerations, environmental impacts, permitting regulations, and right-of-way issues.

KnowWare can transfer this algorithm into a reality by weaving software and experts from all nine areas together.

Another KnowWare can help the decision makers put the results of the simulations and the input from the experts in the nine areas on Second Life for members of community to comment on it. This means that a tool like Second Life (or GIS) can now be transferred into a social semantic system (encompassing and communicating with many stakeholders based on systematic and interoperable representation of knowledge) instead of just being a “visualization” tool.

Real-Time Operational Management: the day-to-day management of the knowledge city requires the manipulation of tremendous volumes of data. Most cities collect real-time data from highways (loop detectors, images and videos), water systems and electrical grid. e-city platform can be used for collecting and managing standard performance indicators, and benchmarking the values across cities. However, data collection and analysis are done mostly manually with limited accuracy. Further, operators can monitor the quality and pressure in water distributed systems and make decisions in real-time. They can intervene in the case of any safety-related issues (such as fire, explosion). Some cities cannot afford the required hardware to process the massive data volumes. Smaller cities (which cannot afford full-time staff) can outsource some of this to qualified knowledge hubs. Some of this could include a daily status report about the performance of the facilities, an estimate of the daily energy consumption in the city, or a daily estimate of emissions. If linkage is made between this and the national weather services, cities can predict smog days before they happen and act accordingly. Citizens/businesses can use these services to estimate their own ecological footprint.

Emergency management: in e-city, infrastructure and major urban elements will be digitized in 3D drawings. These can be produced through a company that specializes in satellite imagery (not necessarily located in the same city). If a fire takes place (say in a small town with limited human resources), the 3D image can be accessed by experienced fire fighting department (in another city) and they can view the fire in real time (through existing camera or iPhone images) they can then develop a fire fighting strategy and communicate that to local firefighters. The result is a virtual organization that brings best human expertise (that is not necessarily local) with advanced media (3D drawings and real-time videos) along with communication technology to optimize the management of emergencies. Similarly, if a sensor detects some contamination in a small or rural city (where experienced operators are rare), a consulting firm (in another city) or a collaborating water works department in a larger city (with proper expertise) can receive this data. Through access to simulation models of the small city network and recent rain data (from national weather services) and through access to ministry of environment reports about water quality in nearby streams and levels of ground water, can draft an actions strategy. This includes access to experts in all these agencies, exchange of data to define the level of emergency and estimate the consequences of each action. They can then direct local officials to the required actions, including shutting which valves, providing water to affected areas through best practices in emergency water services, and alerting maintenance crews to start working on the required repair, and finally, given the green light for water reuse once sensor data indicate that water is safe.

Policy Making: Provincial and Federal policy makers can use the e-city platform to access city-level designs from all cities to forecast the overall emissions levels or estimate total energy consumption. To do this, policy makers can establish a virtual organization that includes major cities, national weather services, research centres that work on energy consumption and estimates. The designs by the cities will be analyzed and synthesized to estimate the overall energy use and emission patterns. Policy makers can then plan for these issues, advice cities about the level of performance of their plans in this regard, provide incentives where they are needed to cities that comply with certain standards or achieve certain levels of performance. Similarly, policy makers can study the demands for material, labour and funding as a result of knowing city plans ahead. They can plan their resources accordingly and in case of resource shortage, can prioritize their actions--where and when to fund which project and what is the best sequence and level of engagement.

International venturing: most of the above scenarios can be replicated internationally. Banks, construction companies, consulting firms and other knowledge centers can collaborate to provision a project internationally. They will supervise local resources to design, build and operate infrastructure projects. On a smaller scale, a company can take over the task of digitizing urban form data, or the task of coordinating design , or project planning in an international city as part of a multi-national consortium. In all cases, they will be selling their knowledge (labour, material and equipment will be provided locally).

6. E-CITY APPROACH: ON-DEMAND ENTERPRISES

The platform is poised to move city operations from doing e-business online to a business-on-demand paradigm through the implementation of Enterprise 2.0 (E2.0) concepts (see Figure 6). E2.0 is a framework for advanced knowledge-enabled organizations. The change into a "knowledge-based economy" will not be just on the technology front. Work processes will be reengineered to harness knowledge and fully exploit its potential. Enterprise 2.0 concepts (such as web services, mashups and service oriented architecture) are an

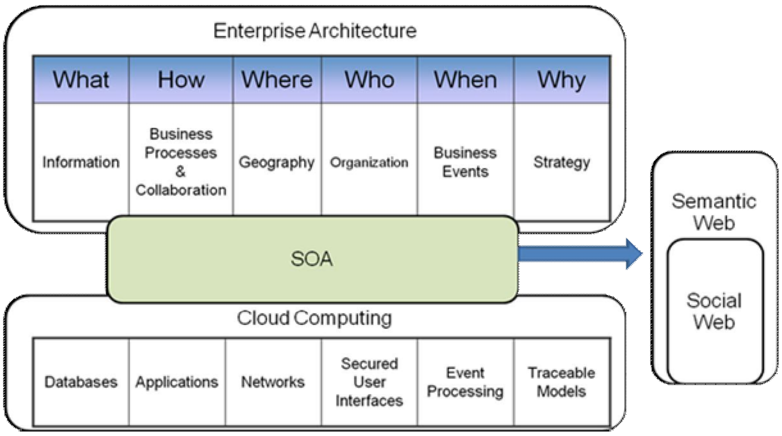

Figure 6: e-city Approach

effective means to translate knowledge into action. E2.0 integrates technical and business process along with organizational structure and human resources into a harmonious framework. E2.0 best practices will be used for advanced knowledge harnessing and communication techniques to allow for seamless flow of information and integrated efficient decision making. Business process reengineering techniques will be utilized to embed knowledge in decision making, optimize work flows, and create a culture of learning, knowledge generation and sharing to sustain competitiveness.

Social Semantic Web: The final deliverable of this platform is a social semantic web portal (see Figure 6) that can visualize, link, marshal services between knowledge hubs and knowledge users in a virtual network. Cloud computing tools will be used to provide on-demand scalable access to knowledge resources. Along with access to computational resources (through the cloud), a dynamic knowledge organization can only be achieved if the enterprise business architecture is aligned with such resources. Linking cloud computing to semantic web technologies provides for machine-processable information. Through the use of ontologies, users can exchange information in an interoperable manner. Finally, the platform will utilize social web technologies on top of semantic web and cloud computing. SOA will be used to bridge the gap between the computing aspects (of cloud computing) and the business aspects of the organization: the integration of enterprise architecture and work processes with computational services.

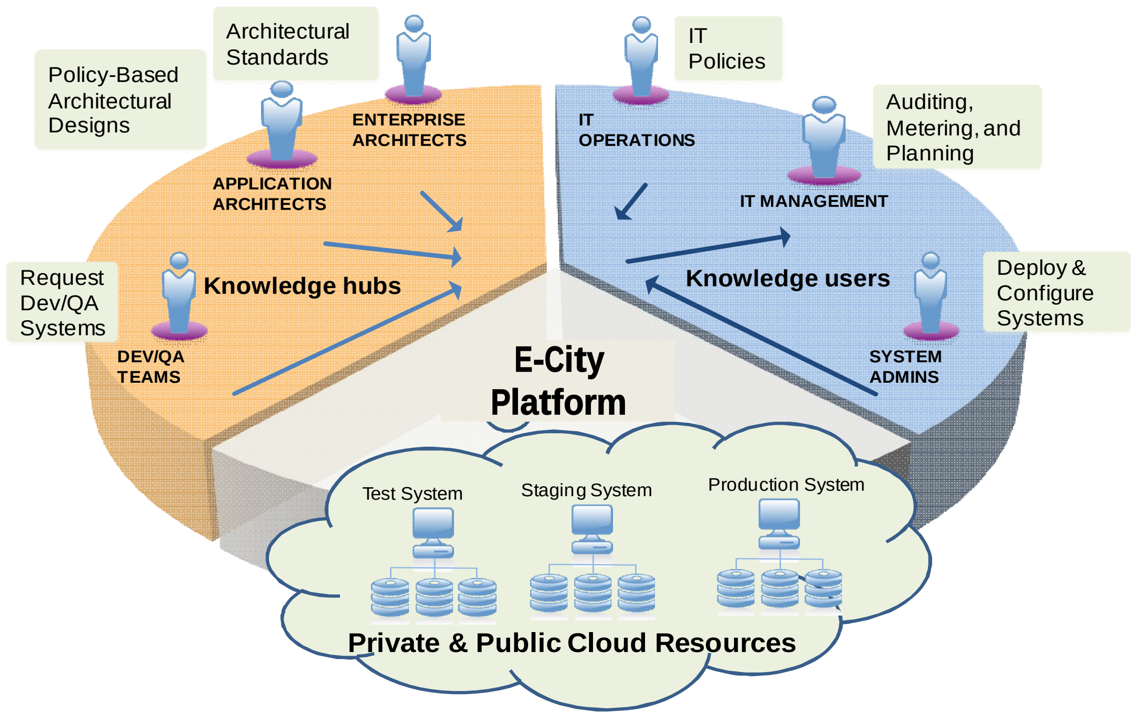

Figure 7: e-city High Level Architecture

Cloud computing: Linking cloud computing to semantic web technologies provides for machine-processable information. Cloud computing presents a suitable fit for knowledge brokerage and management in dynamic virtual organizations. Cloud computing tools (e.g., Amazon EC2 and S3) will provide transparent access and visualization of the services that will be developed within the e-city KnowWare project. Through the use of ontologies, users can exchange information in an interoperable manner. In addition, the "cloud" provides on-demand services provision including (see Figure 7):

- Create Virtual Applications
- Establish Service Environments
- Create Service Provider Agents (SPAs) and Service Level Agreements (SLA)
- Provide elastic storage capacity for city Data.

The advantages include:

- Easy access to service: Service visibility is achieved through social semantic web; interoperability is achieved through semantic web, middleware, or wrapper systems; platform independence is achieved through cloud computing tools.
- Business value: developers and users can scale applications according to user demand; users pay only for what they use; sharing reduce capital, support and maintenance costs.

The following services will be provided for both developer and users of knowledge resources:

- Internal Services: Facilities and logistics management, service configuration management, resource and hardware management
- Licensing and security services
- Descriptive services (self describing and access systems): metadata, ontologies for configuration, reservation and description of services and dependencies.
- Life cycle operations: management of change, scale and recovery
- Governance: access, scalability, and security

Service Oriented Architecture: The full benefits of cloud computing can only be realized by agile enterprises. Service oriented architecture will be used to develop an agile enterprise architecture that allows knowledge hubs to effectively manage the demands of knowledge users in real-time. Some of the major drawbacks of traditional organizational structure that can impede an organization from competing in the knowledge economy include: traditional stand-alone production culture (lack of awareness of global economy opportunities), background of people, static roles and responsibilities, unclear value proposition, lack of clear guidance for collaboration.

SOA increase stakeholder participation through easier communication, breaking organizational barriers and clarification of roles through a service-cenetred mentality. SOA can also simplify the big picture in software development and use through using atomic service components that are loosely coupled and arranged in a flexible layered architecture. SOA also makes service envisioning, planning and development more efficient through its support for iterative development, effective management and matching of skills in different stages of service delivery and management and the layered/component-based layout.

SOA increase product acceptance by facilitating better participation of stakeholders, enhances return on investments due to resource sharing, provide value through filling gaps in enterprise architecture. This is normally done in a dynamic manner thanks to the plug-and-play nature of SOA in addition to its component-based and layered layout.

To assure coordination between the cloud resources and the enterprise architecture, three components will be included:

1. Reference architecture: this will include reference models for performance, service components, data and other business or technical aspects.
2. Enterprise architecture (EA): this is the specific architecture of a knowledge hub or a user. It includes instantiation of the previous reference models.
3. SOA enabled EA: this is the service-savvy architecture that utilize SOA to shield users from EA.

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