Investigating New Business Models for the Rise of Agent-Based Systems within Sustainable Urban Design

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Abstract
A *Big Question* is do we “Europe” have agile infrastructures, network systems and operational models for developing and maintaining smart grid applications for our city districts and can we extend our Hyper Connected World through Internet of Things and Big Data? This paper will evaluate architecture models for designing complex systems such as the rise of agent-based systems and their potential to apply knowledge in the form of rules to transform input to output facts for decision making purposes that can adapt to their behaviour. As the preferred alternative model is expanded to help manage the system throughout its life cycle, New Business Models are designed based on operations to capture value i.e. upstream supply chain and downstream distribution. This paper will investigate business models that focus on energy management at the neighbourhood level within a marketing context. The final section will discuss the results of choosing a model suitable for multi-agent based systems for sustainable district and urban design.

Keywords: Business Models, Internet of Things (IoT), Sustainable Urban Design, Agent-Based System Architectures, Energy.

1 Introduction

Yanrong et al. (2014) acknowledge that an integrated understanding of the smart city concept, smart city projects are part of a general concept of city modernization. They also recognize that the contribution and benefits of Information Communication Technology (ICT) to modernization can be considerable, smart city projects should never be seen in isolation, but as one element in a city’s (or regions) continuous effort to find the next best way of operations.

Chen (2009) stated that business models have to take into account the capabilities of Web 2.0, such as collective intelligence, network effects, user generated content, and the possibility of self-improving systems. He suggested that the service industry such as the airline, traffic, transportation, hotel, restaurant, ICT and online gaming industries will be able to benefit in adopting *business models* that take into account the characteristics of Web 2.0.

This paper will show the new challenges for the European Union in relation to smart grids and integration. It will also highlight the European Energy Union strategy for bridging the gap analysis associated with an energy market, security and decarbonisation requirements and risks. Two desktop case studies are presented in order to show; i) how European products are being developed through Agent-based technology as a financial instrument and ii) collaboration with China via successful business models for infrastructure development. The paper categorizes a traditional business model strategy in contrast to Business Process Re-engineering (BPR) for Web service development, thus outlining the need for new innovative approaches to new market segments. The final section highlights Europe’s potential to be a leader in multi-agent systems.

2 State the problem

The need for reducing energy emission is not only about environmental impacts but also financial. IMF (2008) have recognised that the current unsustainability patterns of energy usage do not only relate to costs and risks but also require large investments in green energy sources relating to the transition to a low energy emission model. Eyraud and Benedict (2012) identified that this has created a market for investing in renewable energy such as solar, wind, biofuels, biomass and geothermal heat which has increased from $7 billion a year to $154 between 2000 and 2010. Runyon (2016) further emphasized the market opportunities and competitive advantages of clean energy investments with China, Africa, the U.S., Latin America and India driving the world to the highest ever figure of $329.3 billion in 2015 with more investors set to enter the market in 2016.

The European Union stresses the fact that utilities and Distribution System Operators (DSOs) are facing new challenges in managing their grids with increasing penetration of variable distributed generation, especially with integration of renewables (expected to be up to 50% by 2030 as a clear target established by the European Commission). However, a *Big Question* is does Europe have agile infrastructures, network systems and operational models for developing and maintaining smart grid applications for our city districts and can we extend our Hyper Connected World through Internet of Things and Big Data?

2.1 Energy Union

In order, to achieve customer requirements, controls (such as; applicable laws and regulations, industry standards, agreements and project procedures) and enablers (organization/enterprise policies, procedures, and standards, organization/enterprise infrastructure and project infrastructure) must be considered as part of the technical analysis and decision making processes (INCOSE, 2011).

On 25 February 2015 the European Commission unveiled a Strategy and Action Plan for creating an Energy Union. The strategy focused on; i) a fully integrated European energy market, ii) addressing energy security through solidarity and trust, iii) promote energy efficiency to moderate demand, iv) decarbonise the economy and (v) support the necessary research, innovation, and competitiveness.

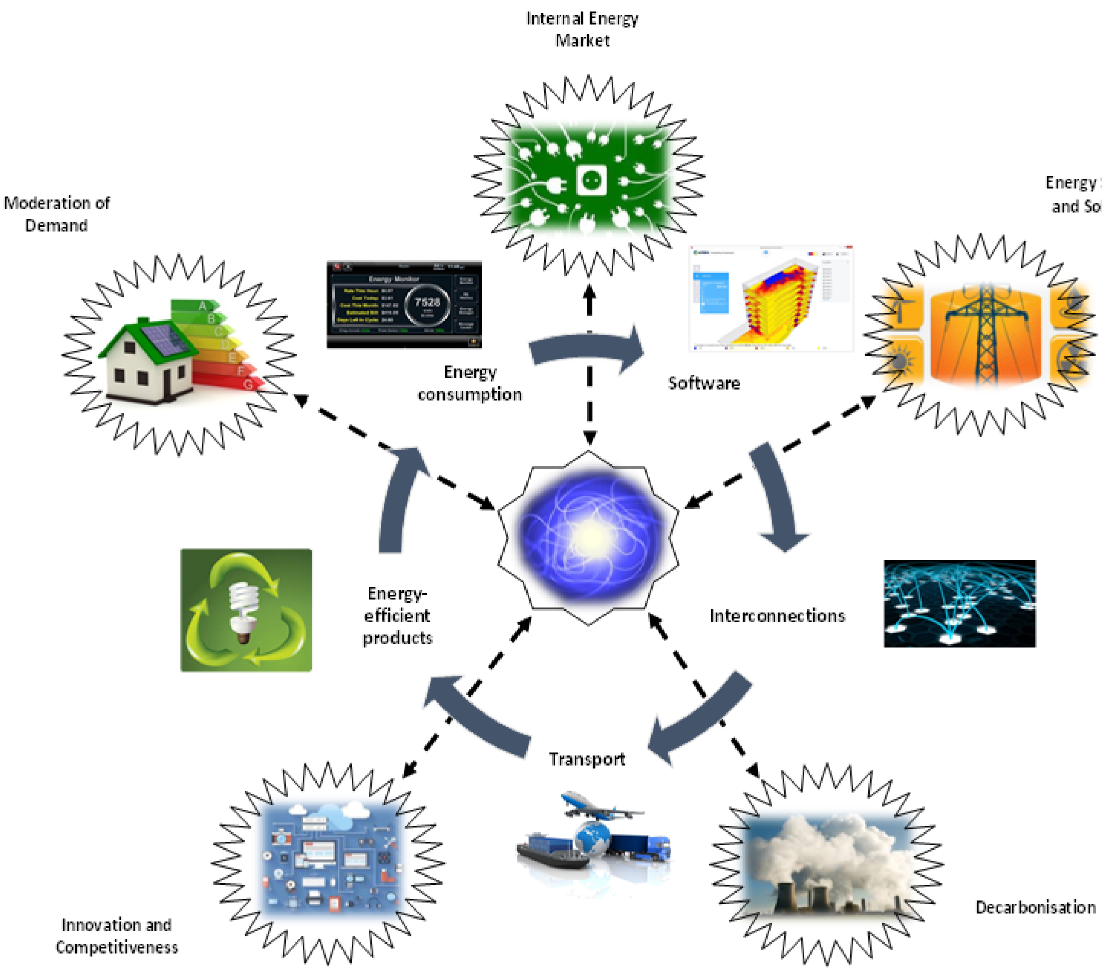
European energy market – the report suggests that a ‘software update for the energy market, rules’ is needed to make energy flow freely across borders. It identifies that market integration should not be held back by nationally focused regulation because this process has created “unnecessary administrative and transaction costs and discouraged investments”. The report does acknowledge that Europe is replacing these national rules with EU Network Codes that set a framework for cross-border energy trading.

Energy security – the interconnections of energy flow requires a fully functioning, EU wide energy grid that connects Member States within the internal market. The report promotes the assisting of integrated renewables, promoting intelligent energy use and ending disconnected energy ‘islands’. Projects such as the proposed European Fund for Strategy Investments, as part of the investment plan for Europe includes energy infrastructure. In order, to eliminate energy islands the report shows that electricity highways from the emerging ‘Northern Seas’ offshore grid (covering the English Channel and the Irish, North and Baltic Seas), giving life to a truly pan European electricity system.

Promote Energy Efficiency - the report outlines that consumers globally pay the same for oil and goal on the international market in contrast to different electricity and gas prices. With regards to gas prices, the report explains that these prices are often national or sub-national (a region within nation) and they have the greatest effect on consumer prices and risk of undermining the Single Market. The problem not only relates to the consistent rise in electricity and gas prices but also the difference between different national prices from not converging in European prices and improving market efficiency. This issue creates additional costs on European house-holds and affects Europe’s global competitiveness. As part of the renewable energy sector commitment, European Renewable Energy Companies employ over a million people, and have a combined annual turnover of €129 billion, and hold 40% of all patents for renewable technologies.

Decarbonise the economy – in order to create an energy-efficient and decarbonised transport sector the report emphasizes that support must be given to the build-up of infrastructure for alternatives fuels and electricity and the market uptake of vehicles. In essence "transport electrification has been identified as been crucial, requiring full integration with urban mobility policies and the electricity grid." *Support the necessary research, innovation, and competitiveness* – initiatives such as the European Innovation partnership (EIP) on Smart Cities and Communities have assisted European cities in growing smarter together. As the report demonstrates there has been 370 commitments to fund and develop innovative solution to challenge and bridge gap analysis such as traffic congestion, air pollution, and high energy costs. These commitments have been marked with monetary support via co-funding through the Horizon 2020 Smart Cities lighthouse projects that will create smart cities and thriving hubs for innovation (European Commission, 2015). Figure 1 created by the authors shows a graphical representation of the Energy Union strategy.

Figure 1 The Five Key elements of the Energy Union strategy



2.2 Internet of Things and Big Data

Biggs et al. (2015) recognized that Internet of Things as a function emerged as early as 2005, based on the hyper-connectivity of our technological advances in fields such as wireless and mobile connectivity, nanotechnology, radio-frequency identification (RFID) and smart sensor technologies. Biggs et al. identified that by connecting these services through an embedded automated internet there would be an increase in productivity and enhance the wellbeing of human welfare. ITU (2012) report defines IoT as, "A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable ICT."

With regards, to IoT application in the energy sector, in developing countries, Biggs et al. have noted the rapid adoption of off-grid solar panel systems that can provide a steady electrical power to low-income families. The report acknowledges the challenges associated with grid availability, cost of services and frequent service interruptions that is in contrast to this new technology featuring photovoltaic cells, battery system and communication model. Biggs et al. identified that the off-grid IoT service enables individuals to purchase the system at a discounted rate with the capital costs repaid over the initial purchase period. Furthermore, after installation the customers are able to utilize the electricity generated from the solar cells to power their homes and regular payments can be obtained through mobile money systems. The IoT system provides a service that can also remotely monitor the amount of electricity captured/stored for future use. However, the report does also acknowledge challenges and in particular technical difficulties for ICT such as, i) reliability with regards to the durability of devices to withstand external conditions and the calibration of sensors to ensure proper measurements, ii) scalability for example; data centers require electrical power, cooling resources and space to design advancements while the connectivity to billions as opposed to millions of connected objects will create significant demands on IP networks managing the scale of device connectivity, iii) power - relating to requiring more bandwidth, iv) cost and ownership of shared models – cost of sensors and connectivity prohibitive many rural engagements and models such as sensors as a service and community ownership has proprietorship issues.

3 Investigate Alternative Models

3.1 Agent-Based Systems

According to Clymer (2009), “An agent-based system architecture is a network of intelligent agents that share facts with other agents and adapt their behavior in response to these shared facts; indeed, intelligent agents apply knowledge in the form of rules to transform input to output facts and to make decisions to adapt their behaviour.” The key to this statement is the fact that due to collaboration an agent-based system achieves its overall system goals plus it often exhibits emergent behavior and in some systems agents are able to learn new rules and evolve new shared facts. Section 5 of this paper ‘Performance Assessment’ will demonstrate the use an OpEMCSS model. The Operational Evaluation Modeling (OpEM) is a graphical language that describes interacting concurrent processes and how to implement them using simulation i.e. it enables experiments with complex systems and conducts simulation-based systems engineering. The Context-Sensitive Systems (CSS) relates to library blocks used to model complex systems such as, a distributed vehicle traffic control network located in a large city requiring traffic flow to optimize light timing and minimize local vehicle waiting time.

3.2 Agent-Based Technology – Desktop Case-Study

The Energy Hub (E-Hub) was a collaborative European project partially funded under the seventh Framework programme. Its objective was to demonstrate the full potential of renewable energy by providing 100% on-site renewable energy within an “Energy Hub District.” The concept of the Energy Hub (E-Hub) is to provide a mechanism for exchanging energy via grids (households, renewable energy plants, offices, businesses) between its members which represent both consumers and suppliers. These members exchange information on their energy production needs within the Energy Hub. A key component of the E-Hub is the Multi-Commodity Matcher (a simulation platform based on matching supply and demand). The case study tests focused on districts in Amsterdam, Leuven, Freiburg, Bergamo and Dalian (China). In order, to meet the aim of achieving low energy districts a simulation platform was developed as a consultancy tool and within this platform *Business Models* were identified as a main element.

The consultancy tool defined typical stakeholders associated with the business model as end users interested in a low energy bill, a DSO interested in peak saving or reducing imbalance in the grid or society as a whole with CO_2 mitigation. The technology used to match supply and demand of energy was ‘Agent-based technology’ and it comprised of agents representing devices operating in a market with an auctioneer agent as shown in Figure 2. The diagram illustrates that i) each agent offering a bid to the auctioneer as indicated by the curve in figure 2. This bid curve shows how much electricity the device is willing to supply or consume at different prices, ii) because producers are interested in high prices the red curve denotes a negative demand, iii) consumers in contrast are interested in consuming electricity when the prices are low, this is reflected with the blue dotted line, iv) the auctioneer aggregates all bids and arrives at a price where electricity demand and supply are equal. The result is that each device will produce the amount of electricity in its bid curve at the price. For instance; if an auctioneer determines that a price is too high for certain consumers then no electricity will be supplied to them e.g. a refrigerator with internal temperatures rising will have to pay a bit more for electricity by modifying its bid curve. Overall “the higher prices can stimulate supply at critical times and lower prices will stimulate demand therefore when there is an adequate energy supply the supply can be balanced by load shifting (E-Hub, 2012).

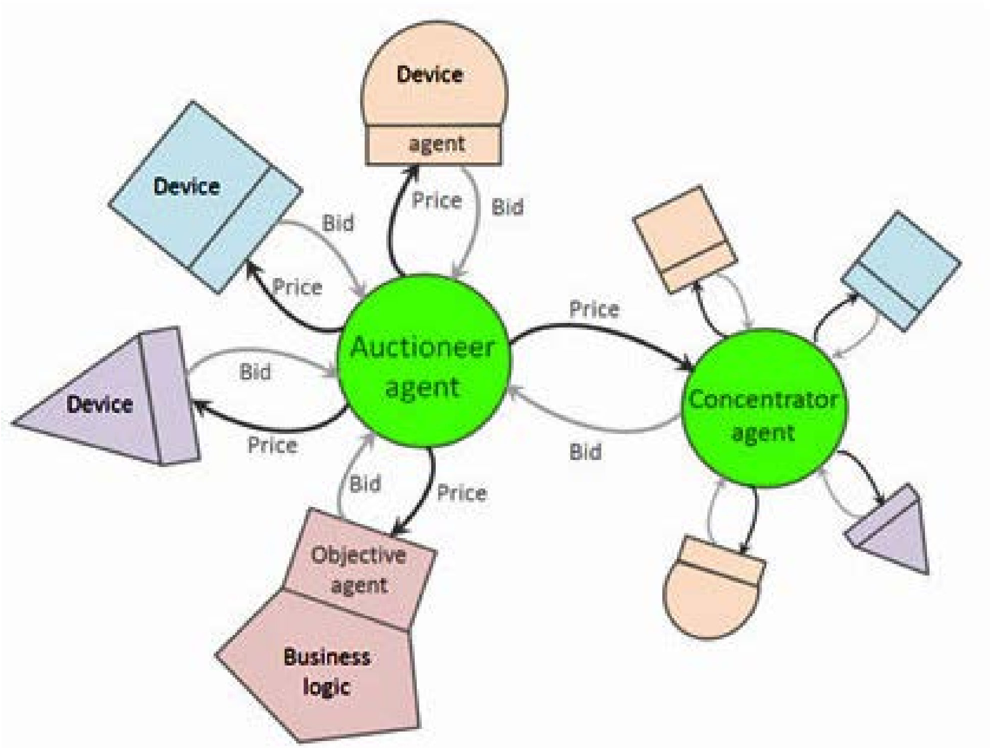


Figure 2 Agents representing devices operating in a market with an auctioneer agent (sourced from http://www.e-hub.org/agent-based-technology.html)

4 New Business Models

Chen (2009) emphasized that Business Model 2.0 needs to take into account not just the technology effect of Web 2.0 but also the networking effect. He gave the example of the success story of amazon in making huge revenues each year by developing an open platform that supports a community of companies that re-use Amazon’s on-demand commerce services. Brynjolfsson and McAfee (2014) quoted “As massive technological innovation radically reshapes our world, we need to develop *new business models*, new technologies, and new policies that amplify our human capabilities, so every person can stay economically viable in an age of increasing automation.”

The B2B2X use case ‘Amsterdam ArenA Innovative Centre (AAIC) produced an array of technological solutions as one of its main aims is to provide testing facilities for applied inventions (such as traffic and transport, City Wi-Fi and intelligent cameras) on a large scale covering an entire metropolitan region. Through the collaboration initiative between the City of Amsterdam and Huawei (Chinese company) and as part of their agreement, Huawei created the largest open-access wireless LAN infrastructure in the Netherlands. Its connectivity is based on HD Wi-Fi evolution (eLTE), heterogeneous networks and City Wi-Fi. The Living Lab open Innovation Platform provided city applications tests to be conducted such as hackathons having full access to live data sets, Application Performance Interfaces (APIs), and latest technology allowing developers to combine their mobile application with any IoT device, open data source, open API or Cloud-based services. From Huawei advantage the results of the tests assist Huawei implementing this network service globally and from the City of Amsterdam's viewpoint it assists companies (including start-ups) in creating new technologies that will provide more sustainable urban environments. Figure 3 shows the common four business models associated with smart cities for which option 4 Build Operate Manage was the main model for Huawei and ArenA (Corcoan and Piva, 2014).

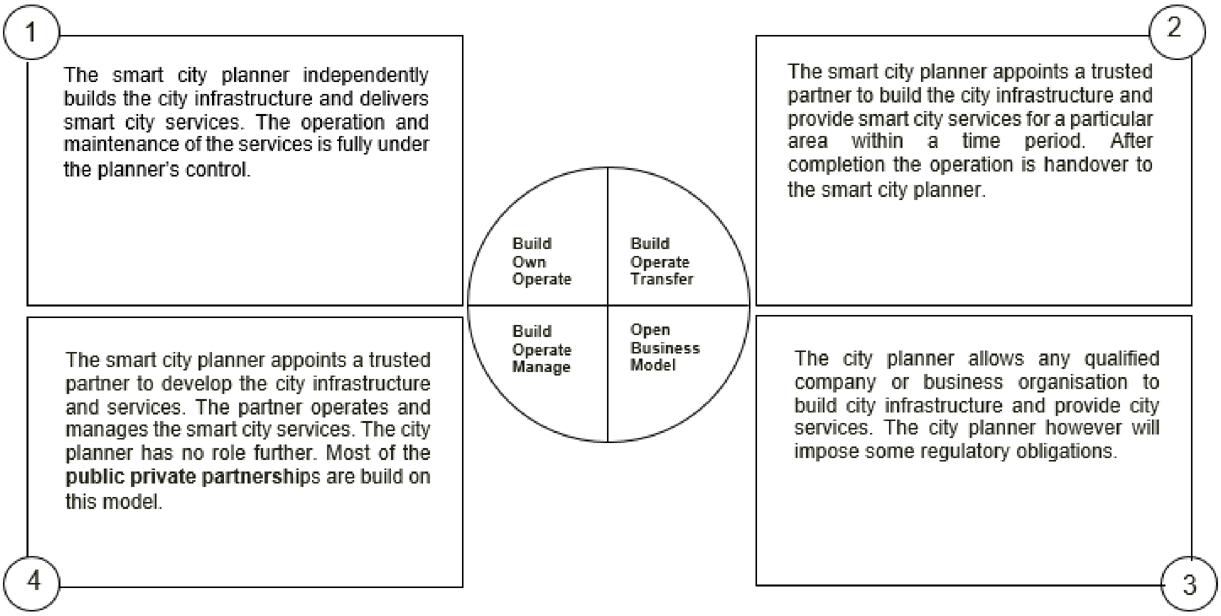


Figure 3 Common Business Models for City and ArenA (sourced with permission from Corcoran and Piva, 2014)

The market concern for Europe is not just the purchasing and development of software that we use for monitoring and utilizing energy efficient products but the infrastructure associated with IoT and testing applications i.e. Wi-Fi connectivity etc. As the Chinese government seeks to control their Internet infrastructure and develop its own Big Data Analytics centers, Cloud Computing service applications will become more prominent in the Chinese market-place. This type of business model will enable the Chinese government to secure all rights to their services, thus eliminating the need for proprietary licensing agreements. This vertical integration strategy, has enabled Chinese companies to own their own supply chain i.e. The Chinese-based company Alibaba has built its dominance in eCommerce by acquiring complementary companies in a variety of industries including delivery and payments.

Yanrong et al. (2014) identified that business model cities are exploring new business models to fund their smart city projects such as i) Cloud computing (pay-as-you-go models), ii) creating revenue from data, iii) pilot projects and iv) smarter procurement. They also recognized that as part of pilot projects there has been a number of support schemes to assist innovative businesses to start-up or to demonstrate and deploy smart city innovations. For example, "in 2012, the Australian government committed to AUD 100 million to develop a Smart Grid and in 2013 the Ministry of Housing and Urban-Rural Development (MOHURD) cooperated with the China Development Bank and issued pilot projects with the line of credit to 80 billion RMB. Also in June 2013, the Energy Market Authority of Singapore were rewarded research grants totaling SGD 10 million (circa USD 8 million) for 6 pilot projects on Smart Grid technologies." As part of analyzing EU and China pilot projects for Smart Cities, the report acknowledges that, "Few examples were identified where a smart city has commissioned analysis to assess different business models for commercialising smart city services and to identify the best business model (s) for the city".

Table 1 Traditional Business Strategy and Business Process Re-engineering

Traditional Strategy	Overall Market	Definition	Marketing goals	Comprehensive plan	
				Right product mix	Maximum profit potential, Sustain the business
		Market Potential	Upper limits of the market	Sales value or Sales volume	
		Development Status	Growth strategy	New market segments	New geographic segments, new demographic segments, new institutional segments or new psychographic segments, New sales for the product
		Technologies, Regulation and Standard			
		Main Shareholders	Requirements,	Exploratory Research	Questionnaires, Surveys etc.
			Constraints		
		Market Access	Drivers, barriers, benefits		
	Main Present Offers	Stakeholder Description Market Position			
	SWOT (Strength, Weakness, Opportunities, Threats)	Internal factors	*Strengths* and *weaknesses* internal to the organization	Human resources Physical resources Financial Activities and processes Past experiences	
		External factors	*Opportunities* and *threats* presented by the environment external to the organization	Future trends The economy Funding sources Demographics The physical environment Legislation	
Business Process Re-Engineering (BPR) (Avsion and Fitzgerald, 2003)	Formal Belief Network	Developing a Business Vision	Business Strategy	Concept Documents, Stakeholders Requirements, Initial Requirements Verification and Traceability Matrix	
			Drivers, Barriers and Benefits of the Solution		
			Business Model	Operation, Strategy, Structure (Lim, 2010)	
			Market Requirements	General Characteristic, Operating or Behavioural Characteristic, Physical Characteristic, Service Aesthetics (Wasson, 2006)	
		Identifying a Process to be Designed	Risk Analysis	Simulations i.e. OpEMCSS	
				Program Summary Analysis	Trade-Study
		Understanding and Measuring an Existing Process	Quality Function Diagram	Select Preferred Architecture Solution	MOP, MOE, RVTM
	Design and Build a Prototype of the New Process	Business Process mapping			
		Functional Architecture	Interface Control Document		
		System Architecture	Test-Bed	Verification Methods (O.Grady)	Test Plan
		Software Process	Spiral (Boehm, 1988) SCRUM		

Table 1 shows a traditional strategy associated Business Models, highlighting from left to right with key elements such as development status that consists of growth strategy featuring new market segments. The table shows that new market segment comprises of new geographic segments, new demographic segments, new institutional segments or new psychographic segments and new sales for product. The lower half of the table introduces an alternative business model designed by the authors to incorporate the importance of software and system engineering. As previously noted in section 2.1 a 'software update for the energy market, rules' is needed to make energy flow freely across borders, and in this section EU-China collaboration focus has started to shift towards "software's" significant role in Smart-Cities development. The techniques mentioned can be incorporated with other agile development techniques such as SCRUM ("the term comes from a game of rugby, and it refers to the way a team works together to move the ball down the field i.e. careful alignment, unity of purpose and clarity of goal come together," Sutherland and Sutherland, 2014). The SCRUM process requires "Sprint Planning meetings in order to accomplish tasks by the end of an iteration. The concept of iteration is also essential in the Spiral process as risk analysis are a major focus of prototyping. The risk-driven sub setting of the spiral model steps allows the model to accommodate any appropriate mixture of a specification-oriented, prototype-oriented, simulation oriented, automatic transformation-oriented, on the approach to software development" (Boehm, 1988).

5 Performance Assessment

5.1 Emergent behavior (proof of concept)

Clymer (2009) defined the visualizing of a system as i) structural model where interface mechanisms connect one component to another, ii) functional model where inputs are transformed into outputs by each function in the network of functions, iii) the external is based on viewing the system from the outside and evaluating the interactions of the system with its external system. Overall, Clymer explains that 'The concept of function is to consider whether functional decomposition assumes defined inputs i.e. in complex systems, process threads adapt to the current environmental or system state through inputs and collaboration with other functions in order to achieve the requirements of the system.'

As part of a decision making process within an overall business model, Figure 4 has been designed to functions-based systems engineering method (INCOSE, 2011) that characterizes tasks that must be performed to achieve a desired output. Figure 4 shows the main activity tasks of an online energy and cost analysis design process from 1.0 – 6.0. However, tasks 3.0 'connect to BIMsie (BIM service information exchange) and 4.0 'Insert OpenStudio Models (OSM) file into EnergyPlus & OpenStudio relates to the file arrival process where the agents components need to be capable of perceiving and acting on their own behalf. This agent autonomous process is further decomposed into child tasks 4.0 – 5.0 that incorporate 'split action blocks' (4.2 Task 2 and 4.3 Task 3) that can be performed simultaneously but require a simulation waiting time to define the most appropriate sequence. The child agent tasks are reconnected with the top level female agents block 5.0 'integrate with SCM, CRM and BI systems. This process is shown in detail in Figure 5 using OpEMCSS. The OpEMCSS-level model provides the structure and ontology (top-level formalisms) required to attach detailed component models for Simulation-Based Systems Engineering (SBSE). The OpEM language and OpEMCSS graphical library blocks are the background to the agent-based system architecture (Clymer, 2009). For example; Figure 4 exemplifies a list of tasks required for an online energy and cost analysis design process.

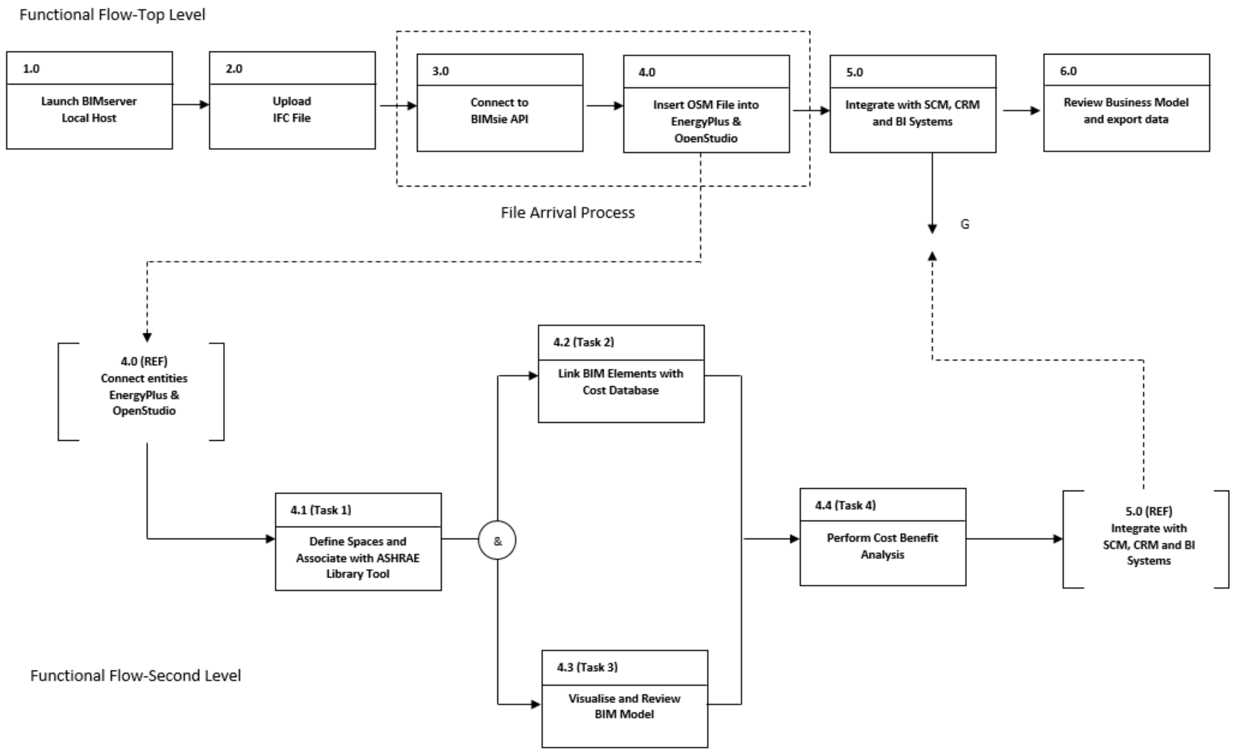


Figure 4 Functional Flow Decomposition Diagram, legend (SCM – Supply Chain Management, CRM – Customer Resource Management, BI – Business Intelligence)

Figure 5 models this Goal-Oriented activity into an organized functional flow that examines concurrent and sequential operations. This simulation defines the possible operational sequences i.e. each task has been allocated an arbitrary time unit (see task figures 1 to 4, 8 minutes have been chosen for task 2).

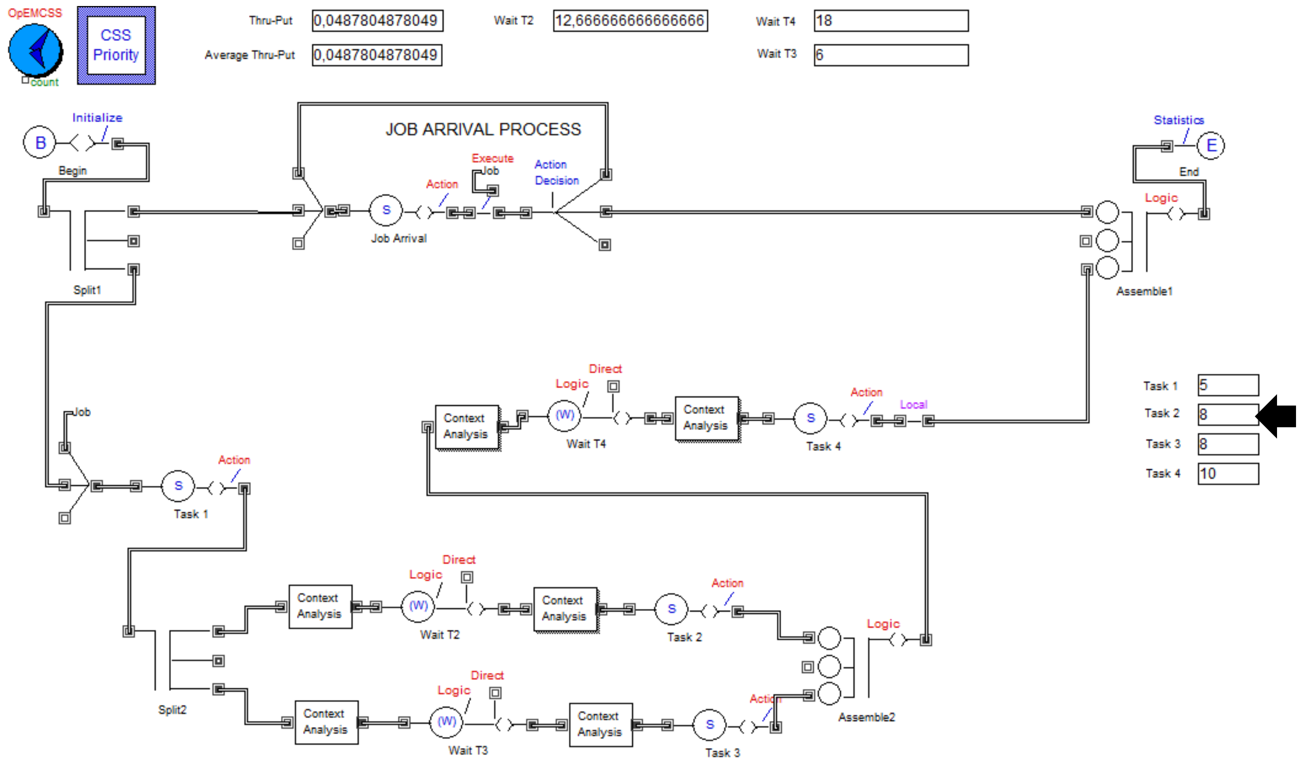


Figure 5 Agent-Based System Architecture for an online energy and cost analysis process

Task 2 reaction time block represents linking BIM elements with a cost database, in reality a structured query language (SQL) database would be required as a fully functioning relational database that automatically updates the cost of material as the products profile changes (Redmond et al. 2016).

The purpose of this exercise is to find the time it takes to execute the tasks. The assemble event block waits for both concurrent processes 2 and 3 to complete before task 4, modeled by a reaction time event can start. The wait until event block shows the time required to wait until the next event is started. On Figure 6 these are indicated via cloned layer function; wait 2 – 12.666 minutes, wait 3 – 8 minutes and wait 4 – 18 minutes. The significance of this simulation is briefly explained in section 5.2.

5.2 Future Agent Interactions

As part of evaluating and optimizing a design solution, Figure 5 simulation was based on a simple exercise to define when each task should be executed and it also provided results that could be analyzed in order to choose an alternative path through alternate action blocks (proof of concept). However, for a next phase agent-based system architecture Clymer identifies that agents will need to act without human intervention for example; the agents will decide for themselves when and how to interact with other agents and select the agents with whom it will collaborate. In relation to Figure 5, message event action blocks should be added in order for the agents to have the option of deciding which task to collaborate with based on input precepts, sending and receiving messages and changing internal functions. In real-time, agents in a multi agents system such as Web services for costing and energy analysis can communicate and collaborate with other agents in other systems to perform additional service i.e. Supply Chain Management, Customer Resource Management and Business Intelligence. Once the design concept is specified with alternative concurrent process for each decision-oriented function and describe how each agent will be implemented and interact with the system then the architecture can be measured by its technical performance MOEs (Measure of Effectiveness – operational measures of success) and MOPs (Measure of Performances – system efficiency and resource utilization). The simulation data would be passed onto the Web service software engineer in order to create a multi-agent based service utilizing the Semantic Web based on existing ontologies languages such as OWL and inference rules to perform the autonomous tasks (generating new relationships) for designing sustainable energy efficient buildings in urban environments.

6 Conclusion

This papers main question related to whether Europe has the agile infrastructures, network systems and operational models for developing and maintaining smart grid applications for city districts and the capabilities of extending a Hyper Connected World through Internet of Things and Big Data. In order, to investigate this question challenges such as Europe's *business models* and agile infrastructures were analyzed. The paper presented the E-Hub case study as an example of Agent-based technology that implemented smarter financial instruments that can increase investment in new technologies for city districts. The AAIC case study illustrated the technological innovation provided by a Chinese company in developing an open-access wireless LAN infrastructure in the Netherlands. The business models presented highlighted how new technologies can provide more sustainable urban environments from a network service view point using Cloud-based services. For Europe to continue collaborating with China in respect to Smart Cities, Web service applications will need to become more pronounced. Section 5 demonstrated agent-based software technologies for costing materials based on an energy analysis. The benefits of shifting to such a model has the potential for agents to communicate and collaborate autonomously in a multi-agent system. Europe has the capabilities to lead the world in smart grids applications but the European energy and security market needs an integrated electricity system to fully develop the potential of IoT.

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