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Leveraging the capabilities of service-oriented decision support systems: Putting analytics and big data in cloud

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ABSTRACT

Using service-oriented decision support systems (DSS in cloud) is one of the major trends for many organizations in hopes of becoming more agile. In this paper, after defining a list of requirements for service-oriented DSS, we propose a conceptual framework for DSS in cloud, and discus about research directions. A unique contribution of this paper is its perspective on how to servitize the product oriented DSS environment, and demonstrate the opportunities and challenges of engineering service oriented DSS in cloud. When we define data, information and analytics as services, we see that traditional measurement mechanisms, which are mainly time and cost driven, do not work well. Organizations need to consider value of service level and quality in addition to the cost and duration of delivered services. DSS in CLOUD enables scale, scope and speed economies. This article contributes new knowledge in service science by tying the information technology strategy perspectives to the database and design science perspectives for a broader audience.

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1. Introduction

In today's very complex business world, organizations must find innovative ways to differentiate themselves from competitors by becoming more collaborative, virtual, accurate, synchronous, adaptive and agile. They need to be able to rapidly respond to market needs and changes. Many organizations noticed that the data they own and how they use it can make them different than others. Data and information are becoming primary assets for many organizations. That's why, today, most organizations try to collect and process as much data as possible. According to the Gartner Research, the worldwide market for data warehousing and business intelligence solutions is forecasted to reach US$10.8 billion in 2011 [34]. And it is ranked number five on the list of the top ten technology priorities for chief information officers in 2011. That's why having efficient and effective decision making processes with right data that is transformed to be meaningful information with data-driven discoveries (e.g. analytics) are becoming mainstream processes for companies to run smarter, more agile and efficient businesses [13].

There also are data related challenges for organizations. For instance, there is the challenge of managing large amounts of data (big data), which is getting increasingly larger because of cheaper storage and evolution of digital data and information collection devices, such as cell phones, laptops, and sensors. For example, Facebook, a social-networking website, is a home to 40 billion photos, and Wal-Mart handles more than 1 million customer transactions every hour, feeding databases estimated at more than 2.5 petabytes. There are 4.6 billion mobile-phone subscriptions worldwide and 1–2 billion people use the internet [46]. There is no question that we are living in an era of data and information explosion. Also, there are more people who interact with information, and more information is shared. According to the Economist Report [46] between 1990 and 2005 more than 1 billion people worldwide entered the middle class, and by 2013 the amount of data transferred over the internet will reach 667 exabytes annually, and according to Cisco the quantity of data continues to grow faster than the ability of the network to carry it. Companies like Amazon's Web Services, AT&T's Synaptic Hosting, AppNexus, GoGrid, Rackspace Cloud Hosting, the HP/Yahoo/Intel Cloud Computing Testbed, the IBM/Google and MicroStrategy BI Cloud are providing various types of clouds services to ease the data storage problems.

Besides the challenges posed by fast growing amount of data, there are also ample opportunities for the world as it becomes more and more digital allowing context-specific aggregation and analysis of data. For example, information and/or knowledge extracted from digital records can make doctors' job easier in accurately diagnosing and treating illnesses, and bring down healthcare costs for providers and patients, and hence improve the overall quality and efficiency of healthcare [15]. Similarly, digitized data (institutional and public—mostly internet-based) can be accessed and analyzed to bolster success on fighting crime more effectively and efficiently.

Service-oriented thinking is one of the fastest growing paradigms in information technology, with relevance to many other disciplines such as accounting, finance and operations [16]. According to Babaie

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et al. [4], worldwide end-user spending on IT services will grow at a 6.4% compound annual growth rate through 2010 to reach US $855.6 billion, with positive growth in nearly all market segments. As a future trend, Gartner predicts that at least one-third of business application software spending will be on software-as-a-service, instead of as product licenses, by 2012. Also, 40% of capital expenditures will be made for infrastructure as a service by 2011 [38]. And more recently, Pike Research expects the growth in cloud computing revenue to continue worldwide between now and 2015 at a compound annual growth rate of 28.8%, with the market increasing from $46.0 billion in 2009 to $210.3 billion by 2015 [37].

For many companies (especially small and medium size), the pay-as-you-go service-oriented computing model (cloud computing), with having someone else worrying about maintaining the hardware and software are becoming very attractive [31]. Cloud computing is reminiscent of the software-as-a-service, infrastructure-as-a-service, database-as-a-service paradigms [6]. Cloud computing platforms, like those offered by Amazon Web Services, AT&T's Synaptic Hosting, AppNexus, GoGrid, Rackspace Cloud Hosting, and to an extent, the HP/Yahoo/Intel Cloud Computing Testbed, and the IBM/Google cloud maintain more than the hardware, and give customers a set of virtual machines in which to install their own software. Resource availability is typically elastic, with a seemingly infinite amount of computing power and storage space available on demand, in a pay-only-for-what-you-use pricing model [1]. In this paper, we adopt and use the National Institute of Standards and Technology's (NIST) definition for "cloud." NIST defines cloud computing as "… a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [33].

Given the emerging services paradigm, it is time to rethink IT and IS from new organizational and technical vantage points [39]. After briefly reviewing the impact of service-orientation on information systems, herein we present a conceptual model that supports evaluation of theory and methods for the management of service-oriented decision support systems (SODSS). Then, based on the proposed conceptual model, we explore some of the pressing issues and promising opportunities and their potential contributions to the new managerial knowledge of SODSS.

In the next section, we begin with a brief overview of the foundation for "services paradigm" and identify the key requirements for SODSS. In Sections 3 and 4, we conceptualize the SODSS, and review the relevant and leading methods, models and theories, and then discuss about where foundational knowledge of the emerging service-orientation (in cloud type environment) can be developed. The last section summarizes our contributions and lists the limitations of this research.

2. The foundations for service orientation and unique characteristics of service

Growing knowledge of information and communication technology (ICT) design, execution, storage, transmission and reuse along with the evolution of internet is creating opportunities to configure information technologies into service relationships that create new value [12]. More specifically, proper ICT provides the means to improve effectiveness, efficiency, and innovativeness of organizations through: 1) making it possible to commoditize none-core competencies (e.g. outsourcing, out-tasking); 2) improving the collaboration (e.g. inter- and intra-organizational workflows and business processes); 3) decreasing the risk of information security breaches; 4) facilitating new types of services (e.g. Google, online banking); 5) separating production and consumption of a service, allowing better storability, transportability, and access to knowledge-based services (e.g. tax software, online classes); 6) coordinating service systems (e.g. online broker systems, information markets, open innovation platforms) [17]; 7) reducing the costs of service production (e.g. semi- and fully automated call centers); 8) improving customer-perceived service quality (e.g., ability to standardize elements of service as well as customize to the individual's preferences when appropriate); and 9) integrating customers into service creation and delivery (e.g., online educational services, health information systems, business-to-business solutions) [2,5,42].

The convergence of ICT—service-oriented – architecture, – infrastructure and – business processes, the emergent Web applications, Web 2.0, Web 3.0, grid computing, cloud computing, internet-enabled smartphones, RFID, and advanced sensing and data analysis—is driving the next information technology inflection point. And this technology inflection is setting the stage for business transformation. "Services" and "service platforms" are central to this evolution [18].

Spohrer et al. [44] defines a service as the application of competence and knowledge to create value between providers and receivers. This value accrues from the interactions of service systems that involves people, technology, organizations, and shared information in addition to language, laws, measures, models, and so on [44]. Service systems are complex business and societal systems that create benefits for customers, providers, and other stakeholders, and include all human-made systems that enable and/or grant diverse entities access to resources and capabilities such as transportation, water, food, energy, communications, buildings, retail, finance, health, education and governance [43]. When we analyze information systems, we see that there is a fundamental connection between information systems and service systems. Checkland and Howell [10] indicate that a consequence of the nature of the process, in which intentions are formed and purposeful action are undertaken by people who are supported by information, is that 'information system' has to be seen as a service system: one which serves those taking the action. Decision support systems are also types of information systems and service systems.

For many years, various versions of system/software product development life cycles have been used to develop and maintain information systems and decision support systems, e.g. waterfall, rapid, spiral and agile development methodologies. The major limitations of the design principles of these life cycles with respect to decision support systems are as follows:

2.1. Focus

Current system development methodologies are focus on goods (e.g. applications) not on services. They follow traditional product-oriented development logic such as application acquisition, build to handle peak, install, configure and maintain. One of the major questions is that how to capture users' dynamically changing requirements and expectations; support those with dynamic business processes. They need to follow service-oriented platform such as federated architecture, rent instead of buy model, dynamic workflow choreography and orchestration, service level agreements rather than purchase contracts and virtualization.

2.2. Scope

DSS design must take into account that there are multiple channels that may need to be integrated into service deliveries; they can't have conflicts between the channels; they may need to share state among channels; speed and reliability of the channel integration may become the key for adaptive service delivery.

2.3. Standardization

Until recently, standardization has been the key in order to get the benefits of economies of scale and cycle time reduction. Today, users are looking for more customization with personalized services. Also, users expect equal treatment and equivalent remedial strategies for service deliveries. Current methodologies cannot handle this conflict.

2.4. Quality and innovation

In production methods, the goal is to build quality systems with cost reduction through manufacturing efficiency. Today, it is about revenue expansion through innovative services. Also, the operational metrics are different in service-oriented development environment. The performance and cost per usage can be more important than traditional cycle time calculation.

2.5. Relationship building

The original purpose of early information systems was to perform tasks by executing transactions. Service systems are more about building the long term value of the relationship rather than performing short term transaction executions.

Overall, the society is undergoing a revolution in information technology and services. Agility needs, IT capabilities and complexities are growing rapidly, but scientific understandings are still immature. There is a need to apply robust research findings to assist in answering several important questions: how can we build and use SODSS to enable organizations to become agile, and in the meantime reduce the complexity of IT landscape? SODSS must enable data, information and analytics as services that are easy to use, easy to understand, and easily re-deployed, role-based and data centric. A sample list of SODSS requirements is provided in Table 1.

Table 1
A summary of requirements for SODSS.

Accurate	Reducing time in decision making by having an operating framework that can process existing data and analytics into new forms of information and knowledge
Secure	Secure data, information, analytics models and etc.
Governance	Efficient and effective DSS governance practices
Compliance	Complying with regional and sector regulations
Collaborative	Working closely with up/down value stream partners to achieve common goals through new ways of organizing data to facilitate more effective decisions
Intra- and Inter-organizational	Supporting the need for common and normalized business semantics when describing processes internally and externally
Synchronous	Coordinating data and information flow and process execution throughout the value chain to optimize performance
Agile	Anticipating business process changes and reacting quickly
Commoditization	Supporting the commoditization of business processes, software and hardware (inter-organizational business process support)
Adaptive	Adapting and modifying key business processes and more quickly delivering applications
Reuse and Integration	Providing the ability to respond to business changes quickly and accurately while reusing functional and integration components
Virtual	Extending control over key processes and assets without owning them
Service-oriented	Support work with data and information without concern for what application is involved or where the data comes from and work with task-centric procedures. Establish platform and guidelines for service-oriented DSS development, capabilities for • loosely-coupled solutions rather than tightly-coupled applications • coordination oriented rather than function oriented development • customization rather than standardization • enterprise solutions rather than application silos • incrementally built and deployed rather than prolonged development cycles • build to last rather than build to change • distributed federated model rather than centralized governance model.

3. Emerging conceptualizations of the service-oriented decision support system

The Organization for the Advancement of Structured Information Standards defines service-orientation as "A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer, discover, interact with and use capabilities to produce desired effects consistent with measurable preconditions and expectations" [35]. Service orientation describes a type of architecture framework that supports the design, development, identification, and consumption of services across the enterprise, thereby improving the reusability of software components and creating agility in responding to change, and supporting intra- and inter-enterprise collaboration through access to autonomous, implementation-independent interfaces to software and data services [41]. Fig. 1 provides an architectural view of the layers that typically exist in a service-oriented decision support environment. These layers range from low-level infrastructure services including servers, network equipment, memory, CPUs, disk space, data center facilities, etc. and dynamic scaling of infrastructure (scales up or down based on resource needs) to middle-level that hosts software services across the internet where there is network-based access to, and management of, commercially available software. The top level hosts the dynamic choreography of business processes.

Service-oriented computing and the prevailing global shift to a services-based economy, however, have together altered the delicate equilibrium between enterprise computing infrastructures and the support they provide for service-generating business processes. In the emerging services model, the infrastructure for provisioning collaborative enterprise services is characterized by market-driven volatility. This volatility has major implications for dynamic sourcing strategies, requiring a deeper knowledge of how volatility affects interoperability within the horizontal layers and through vertical cross-sections of the layers — a concept that IBM refers to as component business modeling. These dynamic sourcing strategies also imply a need for intelligent and autonomic behavior with respect to participation in collaborative activities [32] supporting self-monitoring, self-healing, and self-management of the service environment in response to the dynamics of the business-to-business (B2B) and the business-to-customer (B2C) contexts [28]. Also, computing power is elastic to response changing conditions in the service-oriented DSS, DSS-in-cloud. The concomitant consumption, co-production, and delivery of services require new scientific foundations, research methodologies and trained scholars to investigate emerging equilibrium issues and to realize self-alignment principles.

Research Direction 1 (The Commoditization of Platform, Business Process, Workflow, Software and Infrastructure of DSS): Research should address how to outsource platform, software architecture and infrastructure resources efficiently and effectively.

When outsourcing opportunities became available, many organizations jumped into the band wagon and outsourced their business processes and technology to reduce the cost without thinking about the risks. Today, many vendor companies are discussing about providing DSS capabilities in the cloud. We call a research on what should be transformed in cloud and how should this be done with minimum risk.

Service oriented thinking is one of the fastest growing paradigms in today's economy. Most of the organizations have already built (or in a process of building) decision support systems that support agile data, information and analytics capabilities as services.

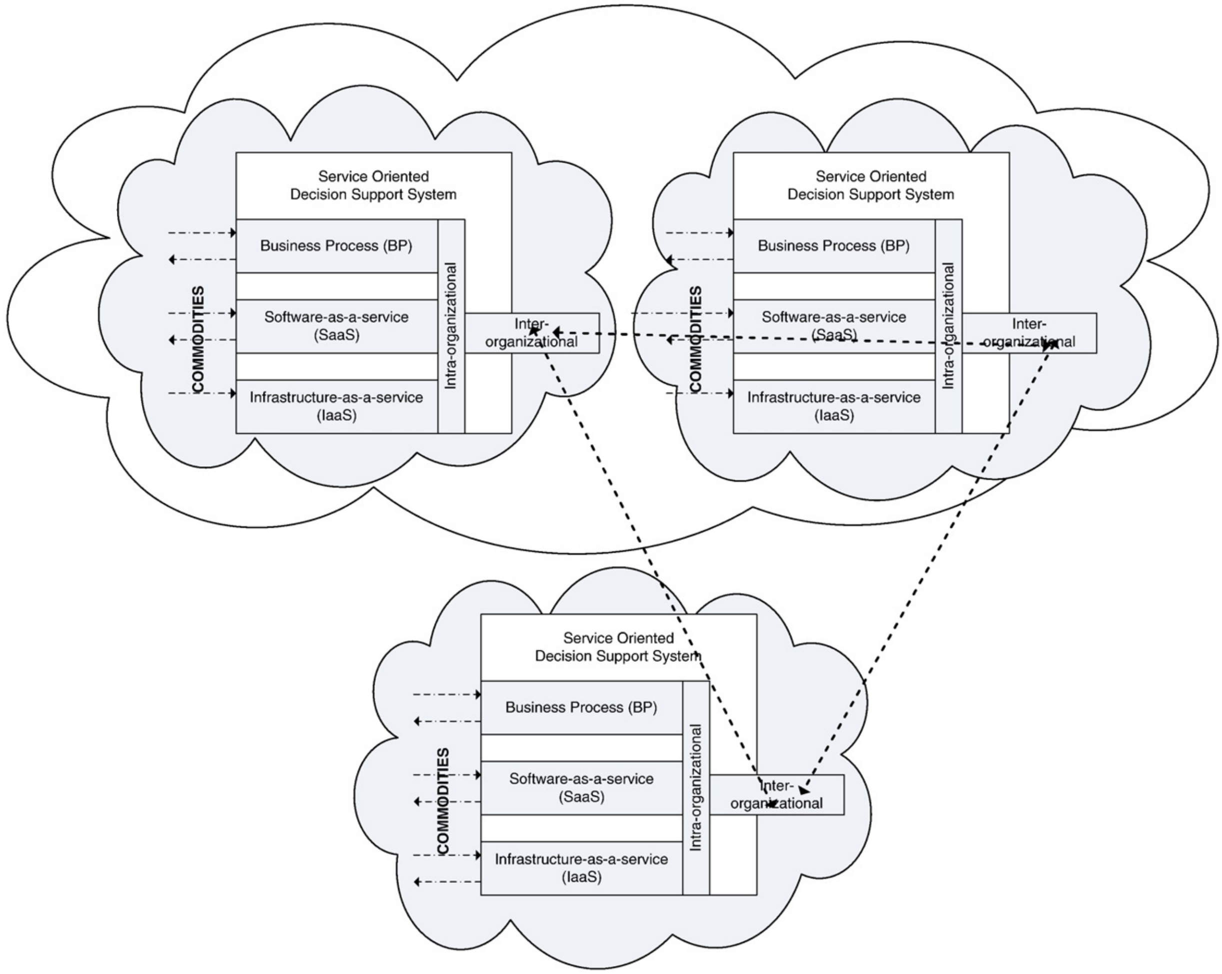

Fig. 1. A sample building block of SODSS.

Let's look at the implications of service-orientation on DSS. One of the main premises of service orientation is that service-oriented decision support system will be developed with component-based approach that is characterized by reusability (services can be re-used in many workflows), substitutability (alternative services can be used), extensibility and scalability (ability to extend services and scale them, increase capabilities of individual services), customizability (ability to customize generic features, and composability—easy construction of more complex functional solutions using basic services), reliability, low cost of ownership, economy of scale and so on.

Research Direction 2 (The Definition of DSS Service): Research should be undertaken to define type of services in DSS environment based on component-approach model discussed above.

There are significant amount of research on objects and modularity. Defining DSS services based on component-approach is limited. There is a need for defining what is a service or product in DSS environment. If a service is defined based on component approach, how granular it should be. For example, can we define a specific ETL process as a service? If we do, how can we quantify this service? What should be the metrics and measures for such quantification?

Also, we should not forget about the unique characteristics of services. First, DSS services include high involvement of people for delivery and usage. Human are the primary resources and stakeholders who use DSS services for decision making. Also, decisions are not touchy or feely; they are intangible. Some of the DSS services (for example, an ETL procedure) can be stored for later usage, but decisions cannot be stored in inventory for later use. Therefore, management of demand and capacity, and pricing decisions are very crucial in the provision of services [21]. It requires shorter response times. Many DSS services are produced and consumed simultaneously. Many DSS services are delivered to customers with collaboration of distributed service providers. For example, within a single organization, data and software services can be highly distributed and deployed among multiple computing platforms. Most organizations must also compete on a global scale, participating in distributed collaborative commerce by conducting electronic business through contact with distributed service providers [30]. A multi-organizational manufacturing supply chain provides an example of this type of collaboration, creating a virtual organization where business is conducted through distributed systems integration with complex, high-volume, transactional and data warehousing activities that must be concerned with requirements such as security, auditability, availability, and service level agreements [19,24]. Other examples of distributed applications can be found in banking, credit card processing, health care, and homeland security, requiring either material flow, information flow, knowledge flow, and/or cash flow between multiple organizations. Lastly, simultaneity of production and consumption of services occur in complex service environments due to interaction of people, processes, technology and shared information.

Research Direction 3 (The Distributed Collaboration of DSS Services): Additional research should be done to analyze the opportunities and risks of providing B2B services to consumers.

In a service-oriented DSS environment, most of the services are provided with distributed collaborations. Various DSS services are produced by many partners, and consumed by end users for decision making. In the mean time, partners play role of producer and consumer in a given time

4. Service-oriented DSS

In a SODSS environment, there are four major components: information technology as enabler, process as beneficiary, people as user and organization as facilitator. Fig. 2 illustrates a conceptual architecture of service-oriented DSS.

In service-oriented DSS solution, operational systems (1), data warehouses (2), online analytic processing (3) and end-user components (4) can be individually or bundled provided to the users as service. Some of these components and their brief descriptions are listed in Table 2.

In the following sub-sections we provide brief descriptions of the three service models (i.e., data-as-a-service, information-as-a-service and analytics-as-a-service) that underlie (as its foundational enablers) the service-oriented DSS.

4.1. Data-as-a-service (DaaS)

In service-oriented DSS environment (such as cloud environment), the concept of data-as-services basically advocates the view that – with the emergence of service-oriented business processes, architecture and infrastructure which includes standardized processes for accessing data "where it lives" – the actual platform on which the data resides doesn't matter [20]. Data can reside in a local computer or in a server at a server farm inside a cloud computing environment. With data-as-a-service, any business process can access data wherever it resides. Data-as-a-service began with the notion that data quality could happen in a centralized place, cleansing and enriching data and offering it to different systems, applications or users, irrespective of where they were in the organization, computers or on the network. This has now been replaced with master data management (MDM) and customer data integration (CDI) solutions, where the record of the customer (or product, or asset, etc.) may reside anywhere and is available as a service to any application that has the services allowing access to it. By applying a standard set of transformations to the various sources of data (for example, ensuring that gender fields containing different notation styles [e.g., M/F, Mr./Ms.] are all translated into male/female) and then enabling applications to access the data via open standards such as SQL, XQuery and XML, service requestors can access the data regardless of vendor or system.

With DaaS, customers can move quickly thanks to the simplicity of the data access and the fact that they don't need extensive knowledge of the underlying data. If customers require a slightly different data structure or has location specific requirements, the implementation is easy because the changes are minimal (agility). Second, providers can build the base with the data experts and outsource the presentation layer (which allows for very cost effective user interfaces and makes change requests at the presentation layer much more feasible—cost effectiveness), and access to the data is controlled through the data services, which tends to improve data quality because there is a single point for updates. Once those services are tested thoroughly, they only need to be regression tested if they remain unchanged for the next deployment (better data quality). Another important point is that DaaS platforms use NoSQL (sometimes expanded to "not only SQL"), which is a broad class of database management systems that differ from classic relational database management systems (RDBMSes) in some significant ways. These data stores may not require fixed table schemas, usually avoid join operations, and typically scale horizontally [45]. Amazon offers such a service, called SimpleDB (http://aws.amazon.com/simpledb/). Google's AppEngine (http://code.google.com/appengine/) provides its DataStore API around BigTable. But apart from these two proprietary offerings, the current landscape is still open for prospective service providers.

On the other hand, with DaaS customers have little choice where data is stored. Moving data off premises from the customer site increases the number of potential security risks, and appropriate measures need to be taken. Also, in cloud computing, the data is physically located in a particular country and is subject to local rules and regulations. For example, in the United States, the US Patriot Act allows the government to demand access to the data stored on any computer; if the data is being hosted by a third party, the data is to

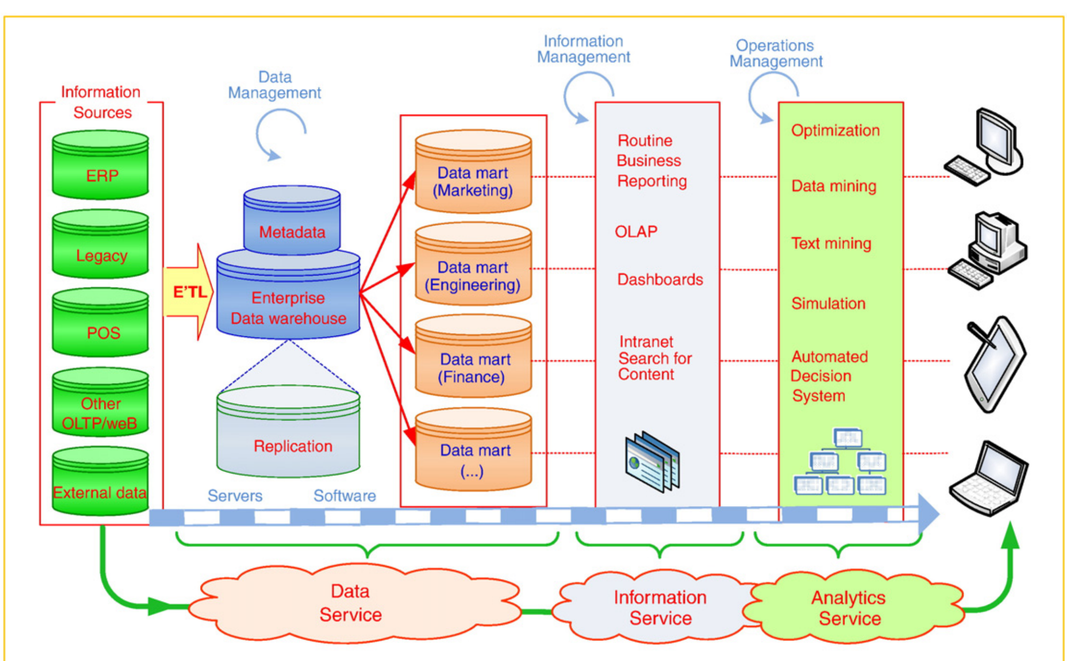

Fig. 2. Conceptual architecture of service oriented DSS.

Table 2
Major Components of service-oriented DSS.

	Component	Brief description
Data sources	Application programming interface	Mechanism to populate source systems with raw data and to pull operational reports.
Data sources	Operational transaction systems	Systems that run day-to-day business operations and provide source data for the data warehouse and DSS environment.
Data sources	Enterprise application integration/staging area	Provides an integrated common data interface and interchange mechanism for real-time and source systems.
Data management	Extract, transform, load (ETL)	The processes to extract, transform, cleanse, reengineer and load source data into the data warehouse, and move data from one location to another.
Data services	Meta data management	Data that describes the meaning and structure of business data, as well as how it is created, accessed and used.
Data services	Data warehouse	Subject-oriented, integrated, time-variant, and nonvolatile collection of summary and detailed data used to support the strategic decision-making process for the organization. This is also used for ad hoc and exploratory processing of very large data sets.
Data services	Data marts	Subset of data warehouse to support specific decision and analytical needs and provide business units more flexibility, control and responsibility.
Information services	Information	Such as ad hoc query, reporting, OLAP, dashboards, intra- and inter-net search for content, data and information mashups.
Analytics services	Analytics	Such as optimization, data mining, text mining, simulation, automated decision system.
Information delivery to end users	Information delivery portals	Such as desktop, web browser, portal, mobile devices, email.
Information management	Information services with library and administrator	Optimizes the DSS environment use by organizing its capabilities and knowledge, and assimilating them into the business processes. Also includes, search engines, index crawlers, content servers, categorization servers, application/content integration servers, application servers, etc.
Data management	Ongoing data management	Ongoing management of data within and across the environment (such as backup, aggregate, retrieve data from near-line and off-line storage).
Operations management	Operations and administration	Activities to ensure daily operations, and optimize to allow manageable growth (systems management, data acquisition management, service management, change management, scheduling, monitor, security etc.).
Information sources	Internal and external databases	Databases and files.
Servers	Operations	Database, application, web, network, security, etc.
Software	Operations	Applications, integration, analytics, portals, ETL, etc.

be handed over without the knowledge or permission of the company or person using the hosting service [47]. Since most cloud computing providers give the customer little control over where data is stored (for example, Amazon S3 only allows a customer to choose between US and EU data storage options), the customer has little choice but to assume the worst and that unless the data is encrypted using a key not located at the host, the data may be accessed by a third party without the customer's knowledge.

Research Direction 4 (*Data-Security-as-a-service*): *New models and methods need to be developed to address the security risk of data that resides in cloud.*

In a service-oriented DSS environment, data can be hosted in a location/country that may have high security risk. New encryption methods need to be developed or new processes need to be defined to separate core vs. none core data to reduce the security risk hosting data in cloud.

In DaaS environment, data loss or data unavailability is one of the high risk items that can be penalized through the service level agreements (SLA) [3] and hurt the business reputation [8]. Data durability and availability are usually achieved through replication without letting the customers know. Large cloud computing providers with data centers spread throughout the world have the ability to provide high levels of fault tolerance by replicating data across large geographic distances.

Research Direction 5 (*Data-Replication-as-a-Service*): *Research should be undertaken to investigate the opportunities and risks with data replication in cloud and, how SLAs need to be defined to reduce the risk for service providers as well as customers.*

The customer needs to be careful to understand the details of the replication methods and models. For example, when a customer delete part of data from an instance, this operation needs to be repeated in all data instances, and how and when the provider provides this service.

4.2. Information-as-a-service (information on demand) (IaaS)

Most organizations have information repository approach that has been built in silos. This issue typically is increased further with processes, models, architectures and infrastructures that are not well designed to either gather or move information to the appropriate destinations, and if exist, the integration among the silos is too complex (Fig. 3). Overall idea of IaaS is to making information available quickly to people, processes and applications across the business (agility). Such a system promise to eliminate silos of data exist in systems and infrastructure today, to enable sharing real-time information for emerging apps, to hide complexity and to increase availability with virtualization. The main idea is to bring together diverse sources, provide a “single version of the truth”, make it available 24 by 7, and by doing so, reduce proliferating redundant data and the time it takes to build and deploy new information services. IaaS paradigm aims to implement and sustain predictable qualities of service around information delivery at runtime and leverage and extend legacy information resources and infrastructure immediately thru data and runtime virtualization, and thereby reduce ongoing development efforts. IaaS is a comprehensive strategy for the delivery of information obtained from information services, following a consistent approach using SOA infrastructure and/or internet standards. Unlike enterprise information integration (EII), enterprise application integration (EAI), and extract, transform, and load (ETL) technologies, IaaS offers a flexible data integration platform based on a newer generation of service-oriented standards that enables ubiquitous access to any type of data, on any platform, using a wide range of interface and data access standards [51]. Forrester Research names IaaS as Information Fabric and proposes a new logical view to better characterize it [50]. Two examples of such products are IBM's Web Sphere Information Integration and BEAs AquaLogic Data Services. These products can take the messy underlying data and present them as elemental services — e.g. a service that presents a single view of a customer from the underlying data. These products can be used to enable real-time, integrated access to business information regardless of location or format by means of semantic integration. They also provide models-as-services (MaaS) to provide a collection

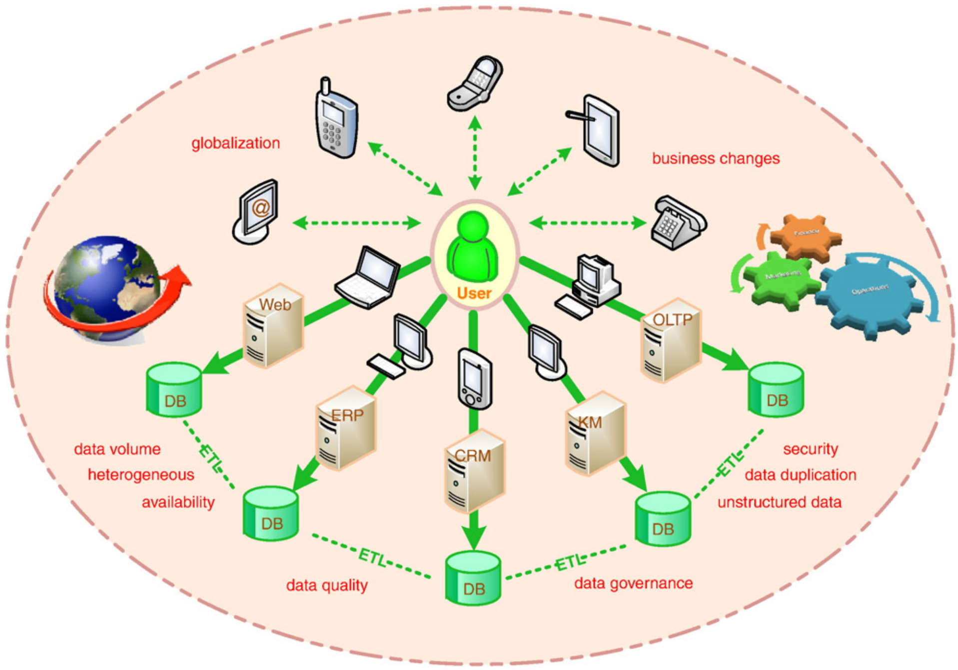

Fig. 3. Silo data and information architectures and infrastructures.

of industry-specific business processes, reports, dashboards, and other service models for key industries (e.g., banking, insurance, and financial markets) to accelerate enterprise business initiatives for business process optimization and multi-channel transformation. They also provide master data management services (MDM) to enable the creation and management of multiform master data, provided as a service, for customer information across heterogeneous environments, content management services, and business intelligence services to perform powerful analysis from integrated data.

There are a number of major challenges for organizations to be able to use IaaS solutions effectively. First, data virtualization brings structured and unstructured data from multiple sources into a unified, logically virtualized data layer for consumption by nearly any front-end business solution including portals, reports, applications, and more. Integration of data from virtual data storages and federation of information are extremely complex processes. Second, when there is a need for fast and reliable access to frequently used data by automatically and dynamically partitioning data in-memory across multiple servers, creating continuous data availability and transactional integrity, even in the event of a server failure is very difficult, therefore new recovery approaches are needed [26]. Third, in a shared infrastructure, local processing power to perform real-time data analysis, in-memory grid computations and parallel transaction and event processing are also needed. Fourth, in a virtual runtime environment, runtime control and execution enforcement of ensuring the right work gets done at the right time with the right resources – virtual data, virtual access, distributed availability, etc. – are matched as infrastructure services with client and application sessions based on policy and entitlement [7].

Research Direction 6 (*Integration of structured and unstructured data and information*): *Integration of structured and unstructured data and information from distributed, heterogonous virtual clouds need further research.*

Research Direction 7 (*Failure-as-a-Service*): *New failure recovery theories, models and methods need to be developed to address the risk of server or desktop failure when lots of data and information are processed in the memory.*

According to the Forrester report, the current IaaS market (software, licenses and services) is expected to grow up to $6.7 billion by 2012 [51]. One of the major concerns of the organizations is how to handle failure in cloud environment. For example, when Google's email service failed, many users' emails, labels, themes, folders, and other personalized settings have all been erased [9], making many of us wonder whether we are doing the right thing by becoming too much cloud dependent? In this context, we are calling researchers to investigate new data integration and failure recovery methods.

4.3. Analytics-as-a-service (AaaS)

Analytics and data based managerial solutions – the applications that query data for use in business planning, problem solving and decision support – are evolving rapidly and being used by almost every organization. Gartner predicts that by 2013, 33% of BI functionality will be consumed via handheld devices, by 2014, 30% of analytic applications will use in-memory functions to add scale and computational speed, and will use proactive, predictive and forecasting capabilities, and by 2014, 40% of spending on business analytics will go to system integrators, not software vendors [48]. And Forrester Research reports that by 2011, the BI analytics trends as self service (in customer-facing business processes, the self-service portal channel is a key to delivering personalized service, speeding transactions, and enhancing the customer experience), pervasive (making analytics pervasive across all channels, touch-points, transactions, and business processes), social (leveraging social networking and inline analytics to improve ad-hoc exception handling), scalable (scaling inexorably toward petabytes to support the increasingly complex content databases required by social media analytics, geospatial applications, clickstream crunching, and other leading-edge applications), cloud (analytics-as-a-service), and real-time (monitoring of social media for gaging customer awareness, sentiment and propensity to automatically flag, escalate, and respond to urgent issues) [29].

With the need for predictive analytics driven business insights growing at an ever more increasing speed, it is clear that current departmental stove–pipe implementations are unable to meet the demands of increasingly complex KPIs, metrics and dashboards. After years of cost cutting, organizations are striving for top-line growth again. They are finding that with the proliferation of front-end analytics tools and back-end BI tools, platforms, data marts, the burden/overhead of managing, maintaining and developing the "raw data to insights" value chain is tremendous. It is becoming more and more necessary to restructure the islands and stovepipes of platforms/tools/information into much more centralized but flexible analytical infrastructures.

The concept of analytics-as-a-service (AaaS) – by some referred to as Agile Analytics – is turning utility computing into a service model for analytics. AaaS is not limited to a single database or software, rather it has the ability to turn a general purpose analytical platform into a shared utility for an enterprise with the focus on virtualization of analytical services [40]. With the needs of Enterprise Analytics growing rapidly, it is imperative that traditional hub-and-spoke architectures are not able to satisfy the demands driven by increasingly complex business analysis and analytics. New and improved architectures are needed to be able to process very large amount of structured and unstructured data in a very short time to produce accurate and actionable results. The "analytics-as-a-service" model is already being facilitated by Amazon, MapReduce, Hadoop, Microsoft's Dryad/SCOPE, Opera Solutions, eBay and others. For example, eBay employees access a virtual slice of the main data warehouse server where they can store and analyze their own data sets. EBay's virtual private data marts have been quite successful—hundreds have been created, with 50 to 100 in operation at any one time. They have eliminated the company's need for new physical data marts that cost an estimated $1 million apiece and require the full-time attention of several skilled employees to provision [49].

AaaS in cloud has the economies of scale and scope by providing many virtual analytical applications with better scalability and higher cost savings. With growing data volumes and dozens of virtual analytical applications, chances are that more of them leverage processing at different times, usage patterns and frequencies [27]. A number of database companies such as Teradata, Netezza, Green-plum, Oracle, IBM DB2, DATAllegro, Vertica and AsterData, that provide shared-nothing (scalable) database management applications are well-suited for AaaS in cloud deployment.

Some of the challenges of AaaS are operating with encrypted data, and being able to interface with business intelligence products that are hosted in customers' local machines.

Research Direction 8 (*Integration of shared-nothing databases and traditional business intelligence products*): *Almost every organization has a type of database management system and business intelligence solution in their organization. Additional research needs to be done to explore the integration of customers' database and business intelligence tools with AaaS environment.*

Today's cloud supported analytic solutions should be able to produce continuous analytics results of real-time events, for monitoring oil & gas production, watching traffic status and detecting accident [11].

Research Direction 9 (*Continuous Analytics as a service*): *There are many research opportunities to investigate methods and models for continuous analytics as services for streaming data and analytics.*

The new methods should be able to integrate continuous stream data, information and analytics with stored data, and to analyze stream data chunk-by-chunk while maintaining the continuity of context, and to support efficient data staging and scalability.

Data- and-text mining is another very promising application of AaaS. Data mining is the process of discovering valid, novel, and potentially useful patterns (i.e., knowledge nuggets) in very large data sets by use of a variety of advanced analytical techniques [22]. If the data is textual in nature, then this discovery process is often called text mining. The value of the mined knowledge seems to be highly correlated with the richness (i.e., quality and the quantity) of data used in the discovery process. A key challenge that many data mining software has not been able to crack is how to extract knowledge from large and distributed data/text quickly and put it into the hands of managers to make better, more informed decisions. Although significant progress has been made over the last three decades by researchers in both software (i.e., database technology, statistics and machine learning to improve the techniques for efficiently detecting patterns in large data sets) and hardware (faster and cheaper processors and data storage mediums) fronts, the real use of data/text mining still requires an incredible amount of investment.

Processing large quantity of distributed data (often a combination of structures and unstructured data) requires high-performance hardware and software combinations, which for many organizations are still unjustifiable expensive. Once obtained, such high performance data/text mining systems can be designed to take advantage of powerful, but shared pools of computational resources. In such a system, data can be distributed to the processors, the communication among many components can be performed using a message passing type service architectures, the results can be gathered and synthesized, and the process can be repeated by moving new data to the processors until the desired results are obtained [25]. Because of the pooled resources, such an iterative process can be completed within a reasonable time frame.

An excellent example to such a high-powered analytics system is IBM's Watson. Watson is an advanced analytics based computer system (a combination of advanced hardware and software) designed to answer questions posed in natural human language [23]. It was developed in 2010 by an IBM research team as part of DeepQA project and was named after IBM's first president, Thomas J. Watson. In 2011, as a test of its abilities, Watson competed on the quiz show Jeopardy, which was the first ever human-versus-machine matchup for the show. In a two-game, combined-point match (broadcasted in three Jeopardy episodes in February 14–16, 2011) Watson beat Brad Rutter, the biggest all-time money winner on Jeopardy, and Ken Jennings, the record holder for the longest championship streak (75 days). In order to provide answers to questions in less than three seconds, Watson is built on massively parallel processors and innovative/proprietary algorithms and analytical services, all of which are running on Apache Hadoop framework [14]. Even though Watson shows the extend of what is achievable with advanced analytics, its multi-million dollar price tag makes it prohibitively expensive for the mainstream.

Research Direction 10 (*Affordable Analytics for Masses*): *There is a number of open-source, free-of-charge data/text mining algorithms/tools in the market* (e.g., *R*, *RapidMiner*, *Weka*, *GATE*, etc.). *Research need to take these tools to the cloud and make them efficient and affordable for discovering knowledge from very large data sets.*

The capabilities that a service-orientation (along with cloud computing, pooled resources and parallel processing) brings to the analytic world are not limited to data/text mining. It can also be used for large-scale optimization, highly-complex multi-criteria decision problems and distributed simulation models. These prescriptive analytics requires highly capable systems that can only be realized using service-based collaborative systems that can utilize large scale computational resources.

We also expect that there will be significant interest in conducting service science research on cloud computing in big data analysis. With Web 2.0, more than enough data has been collected by organizations. When we are entering to the "Petabyte age," and traditional data and analytics approaches begin to show their limits. Cloud analytics is an emerging alternative solution for large scale data analysis. Data oriented cloud systems include storage and computing in a distributed and virtualized environment. These solutions also come with many challenges, such as security, service level, data governance. Research is still limited in this area. As a result, there is ample opportunity to bring analytical, computational and conceptual modeling into the context of service science, service orientation and cloud intelligence.

5. Conclusion

In this section, we first summarize the main contributions of our work and then discuss the limitation and future research directions.

5.1. Contributions

Most organizations today are fundamentally dependent on their data and information handling services facilitated by their information technology [36] to collect, store, flow, manage and analyze data better. This paper provided a list of requirements for DSS in order to address today and tomorrow's needs. And then it proposed a conceptual framework for service-oriented DSS, evaluated the existing literature, the current applications and solutions, and proposed research directions. A unique contribution of this paper is its perspective on how to servitize the product oriented DSS environment, and demonstrate the opportunities and challenges of engineering DSS in cloud environment. When we define data, information and analytics we see that the traditional measurement mechanisms do not work efficiently. Organizations may care about service accuracy and quality in addition to the cost and delivery time. Service-oriented DSS (DSS in cloud) proposes scale, scope and speed economies. Basically, reduction in unit service costs due to increase in operational size (scale), reduction in unit service costs due to increase in number of services being developed and provided (scope) and reduction in unit costs due to increase in number of services put through supply/demand chain (speed).

5.2. Limitations and future work

There are additional and important theories and models that we have not fully addressed. For example, we did not discuss in detail how service orientation will impact the operations of DSS environment. How should we educate new DBAs, data engineers, data analysts and users for DSS in cloud?

Second, we have not analyzed the service provider's site of the research issues. Service providers need new approaches to be able to manage their capacity and pricing decisions efficiently. What will be the dynamics in service and price competition?

Third, it also will be beneficial if future research examines the challenges and opportunities for governments and international organizations. What will be the tax policies and procedures, when service providers are hosting their virtual data bases in different countries and providing services to different countries?

In this article, we had no intention to present an exhaustive survey of research articles, nor did we intend to offer a comprehensive reading on the research agenda for service-oriented DSS. We simply wanted to propose a new conceptual architecture for DSS in cloud, and identify research questions to fully realize this promising endeavor.

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