BUSTECH 2014

The Fourth International Conference on Business Intelligence and Technology

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Foreword

The Fourth International Conference on Business Intelligence and Technology (BUSTECH 2014), held between May 25-29, 2014 in Venice, Italy, continued a series of events covering topics related to business process management and intelligence, integration and interoperability of different approaches, technology-oriented business solutions and specific features to be considered in business/technology development.

The term Business Intelligence (BI) covers a large spectrum of applications and technologies used to collect, store, interpret and decide on the information about company operations with the aim of helping corporate entities with a comprehensive status and knowledge on their business. BI is integrating with Warehouses (DWs), on-line analytic (OLAPS), corporate performance management (CPM), business process management (BPM), and other technology-oriented business solutions. Web technologies, semantics and ontology mechanisms are now used to mine, integrate and interpret distribute corporate data, either real-time or intermittent, by filtering noisy data, interpreting business data in context, enforcing trust and security in handling corporate data, and providing access to data from anywhere, at anytime, and via any media. The complexity, volume and intrinsic semantic of data needed for conducting business require a tailored IT infrastructure and advanced methodologies and technologies for timely building competitiveness by intelligent business decisions. With the large spectrum of emerging technologies, such as cloud computing, sensors environments, and mobility there is a need for specialized supporting tools and business/technology decisions to optimize the business process and business performance.

We take here the opportunity to warmly thank all the members of the BUSTECH 2014 Technical Program Committee, as well as all of the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to BUSTECH 2014. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the BUSTECH 2014 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that BUSTECH 2014 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the field of business intelligence and technology.

We are convinced that the participants found the event useful and communications very open. We hope that Venice, Italy, provided a pleasant environment during the conference and everyone saved some time to enjoy the charm of the city.

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Business Intelligence Trends and Challenges

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***Abstract*-There are several Business Intelligence (BI) tools and platforms available in the market to achieve BI solutions. Organizations are facing different challenges during the implementations of such tools related to various complexities, performance and security. Hence, there is a need to look forward and improve with the modern BI technologies and successful *implementations* for solutions for data mining, mobile BI, cloud BI, column-based approach, in-memory computing, managing structured and unstructured data with the improved performance, This way the business leads could see remarkable change in performance and visualization in order to have access to the related business growth by implementing such solutions. This paper refers to current challenges that companies are facing in BI with traditional approach and changing trends in technology. It would also provide forward approaches to overcome those problems by improved solutions with use of new technologies.**

Keywords-BI; BW; ETL; OLAP; SOA; APD; NLP.

I. INTRODUCTION

Large scale organizations are targeting advanced Business Intelligence (BI) systems to drive challenging revenue and market opportunities.

Fully integrated set of BI technologies can help companies reducing business complexity, organizing and distributing information, leading competitive advantages and better decisions for an improved intelligence bottom line.

Currently, most of BI projects and implementations are suffering due to the lack of right approaches and selection or combination of right tool and technology to meet short and long term BI targets with complex integrations [26].

The article is divided into three main portions. First portion covers BI demands and challenges. Middle portion covers advanced methods and changes in BI Technology and modifications required in existing tools. Last and third portion covers approaches to adopt for successful BI projects and implementations, along with the conclusion.

II. BI DEMANDS AND CHALLENGES

A. Industry Trends and Demand

Industry research shows increased demand for different types of industry sources all over the world, e.g., oil & gas industry is passing through significant changes and companies are doing mega mergers and associated consolidations for their deliverables and services to handle big projects with extreme level of collaboration in order to meet the industry demand.

There is a tough competition seen allover the market and the companies are now looking for the ways to reduce cost of their deliverables and services as organizations are making their plans for next 10 to 15 years to compete highly volatile market.

There are hundreds of inquiries to be answered by BI systems. For example, how to deliver cost effective engineering, procurement and plant construction projects? How to increase existing plant productivity? How to increase plant life for an oil & gas plant? Or, provide maintenance predictions by using innovative advancements in the technology for a large scale business.

B. Data Consolidation Challenges

It is time for data integration and consolidation, as fragments of different types of information is scattered by different applications and different sources including corporate level databases, internet and intranet data sources, specific social media sites and globally available services.

BI architecture needs to consider all the business processes in order to achieve final results reflecting all the information required for business and to make data available for detailed information examinations and on summarized level inspections.

There is a need to do data refresh from source systems into staging databases, and then, to transform to data targets in data warehouses in regular frequency of events using process chains and to make sure that no information is lost. It is also required to process original data using data transformation and mining tools in order to convert into useful information.

ETL (Extract, Transform, Load) tools are available in the market for data acquisition and transformation from different source systems to BI data targets and to load from one data target to another data target with data processing and filtrations.

Data warehouse platforms are available to design star schema and process chains and to make multi-dimensional cubes and data providers available for end users to do analysis based on facts and figures for interactive analysis. However, the research is going on to resolve integration problems between different platforms to achieve required collaboration.

C. Data Security Risks

Companies like are doing collaboration and coming up with shared BI application landscapes to meet extraordinary business demands to beat market competitions. As a result of change, organizations are forced to share BI applications and platform to delivery partners through Internet or intranet, which is becoming a concern to the companies for possible leakage of unwanted information [27]. PETROFAC International is one of the biggest oil and gas companies in

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the world where we are working on multibillion dollar oil and gas partnership projects with other companies and are sharing systems landscape with partners for sharing analytical information and to work in collaboration.

Object level, package level, analytical level and system level security privileges need to be implemented to secure BI system. Technology is improving providing resolutions and research is going on to provide high level confidence to business owners to provide them with secure place for sharing BI platforms to deliver and execute collaborative requirements [4].

D. BI Landscape challenges

Following are few of the challenging components in BI solution need scalability, accessibility, stability, security and improved performance.

TABLE I. BI LANDSCAPE.

BI Landscape
Infrastructure
• Required hardware and operating systems • Database environment • Application and Web servers • Technical security and systems performance • Network and middle ware • Storage and capacity planning • Desktop and browsers
Data Warehouse Environment
• ETL tools/methods for Data extraction, Data Transformation, Data Staging and Data Loading • Data Modeling, Data Quality, subject oriented and integrated data marts as Data Management • Management processes like Data Archiving and backups, Batch and Change management along with version control
Front End Applications
• Presentation tools like reporting, Portals, Dashboards, report distributions and alerts • OLAP Analysis, Data Mining, Predictive analysis and Web Analysis • Business Application and MS office Integrations, Performance management applications and Systems connectivity • Visualization • Data Discovery and exploration tools

BI landscape is facing major changes with new approach for implementation and new innovations in technology coming up in the market. Business application vendors are also coming up with data ware housing and ready-made BI contents as part of their product suits, so emerging further needs to come up with one competitive and complete BI and Business Warehouse (BW) solution on single platform including integration capabilities with ERP and legacy systems in addition to the common data ware housing engine along with ETL and intelligence capabilities.

E. Cost of Ownership

Cost of ownership is different for different BI platform vendors. It includes total license cost, total implementation cost, IT administration and business administration cost. We also consider aspects related to integration, product quality, ease of use for developers, single user implementation cost etc.

As BI technology is changing fast so it is important now to get ready with related investigations to acclimatize the change and to consider the value of services using BI Cloud, SOA (Service-Oriented Architecture), Column-based approach for performance, Mobility, etc.

When we do cost-benefit analysis and compare cost of ownership with respect to the Returns on Investment (ROI), many other thought-provoking things are there to consider during analysis.

F. Performance Bottleneck

Information needs to be reported, analyzed and distributed to a group of targeted people at the right time and in the right required format with the vision necessary to make better and faster decisions.

There are different scientific methods available listed below to overcome analytical performance,

- Query design for optimal performance
- Using variables and dropdown lists in front-end design
- General guidelines for optimization
- OLAP (Online Analytical Processing) caching techniques for optimal query performance [6]
- Using Aggregates and data manager techniques
- Complex result of queries and OLAP process to keep in cache.
- Least-Recently-Used-Algorithms [28] and Caching techniques
- Use of query monitors and cache monitors
- Delta caching [5]
- Parallel Processing techniques during Query Execution
- Calculations in database layer rather than application layer.
- Settings related to query drilldown with read modes like read all data or read data during navigation trade-off for number of DB accesses
- Using query runtime statistics, data load statistics, query monitor, trace tools, etc. in order to monitor, analyze and improve performance
- BI accelerators using special hardware to achieve faster performance [13]
- In-memory analytics [11][17]

G. Economic Challenges

By changing trends, business owners are keeping an eye on some of the below economic challenges to achieve ultimate BI solution and related change management for cost and scope management.

- Unpredictable Economy (BI is dead without business)
- Pricing is a huge obstacle for BI deployments
- Pricing for every user licenses (Inside organizations or when extending BI to other parties and partners)
- Organizations looking for quick-win technology projects

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- Large strategic projects becoming failures
- Diverse Justifications and business benefits
- Change control management and associated cost
- Like-for-Like comparisons for initiatives

III. BI ADVANCED METHODS

A. Move to Data Analytics

Many companies in the previous years have already adapted BI platform; it is time now for data analytics.

In recent years, companies were targeting to historical data to see business performance; but, today's Analytics is leading towards predictions and goes beyond insights to create business impact.

Predictive models and algorithms not only allow you to predict the most likely outcomes but also suggests for the best that could happen, So, predictive analysis is going to help business to make decisions based on facts rather than judgments and interpretations as business seeks forward-looking rather than back-ward looking.

Approximately 30% of the companies in 2014 will align analytics matrices completely with business drivers [9].

B. Data Mining Methods

Effective use of some of below data mining methods/algorithms for analytical business solutions could produce brilliant profitable BI results for organizations.

TABLE II. DATA MINING METHODS.

Data Mining Methods		
S No	**Category**	**Mining Methods**
1	Predictive Methods	Decision Tree Regression Analysis
2	Informative Methods	Clustering, Association Analysis, ABC Classification, Weighted Score Tables

Different BI platforms provides tools to implement these methods; for example, SAP provides Analysis Process Designer (APD) and Data mining workbench [8] to implement data mining methods in order to create related data mining models with customization settings to control related security and amount of detail generated during data execution.

SAP launched a new product "SAP Predictive Analysis" [21][23]. This tool is used to implement advanced business cases from data scientists, advanced business users and analysts to achieve data mining capabilities, statistical modeling & visualization.

C. Story-Telling Predictive Analysis

There are four types of dimensions which determine the type of story you are telling with available analytical data

TABLE III. STORY TELLING DIMENSIONS.

Story Telling Dimensions	
Type	**Description**
Time	Time dimension is to do data analytics about past, present and future. Stories about past are reporting stories , stories about present are to involve different forms of surveys data and stories about future are predictions
Focus	This dimension is to bring important factors from analytics like what happened, why something happened and how to address the issues
Depth	This involve in-depth analytical search to find solution to a complex problem
Method	These are the stories based on different analytical methods where we try to bring correlation stories and causation stories to determine how relationship of variables can cause rise and fall to outcomes. Data mining methods mentioned in section B would also help to achieve the outcomes.

How to condense data into a good story is an art and technique in BI. Instead of presenting data in tabular form to get predictive results for business leaders, companies are looking forward for the implementation of story-telling techniques of analytics where the information outcome is in demand after analyzing insight data in a descriptive form along with visualization.

There are some requirements to enhance BI analysis tools for creating BI stories.

TABLE IV: STORY TELLING CAPABILITIES TO ACHIEVE.

Story Telling Capabilities	
Capability	**Description**
Visual Aid	To draw attention on visualization data by arrows and by doing coloring, notating, highlighting, zooming etc. to support narration
BI Story Templates	BI stories would have some structure. There is a need to have templates with annotated dashboards.
Reusability	We need to have similar set of BI story templates for different set of data. It would be very easy in case the tools provide the facility to create reusable structure of stories.
Interactive Visualization	Shared reports need to be interactive and to be supported by storytelling tools by linking and brushing options
Transition	It is highly required to convert visualization into stories by some transition tools to save time and cost.

D. Artificial Intelligence and Computational Intelligence

There are many examples of latest Smart phones, like Google, with location support services; Google glass applications are providing information based on your present location.

These projects use natural language [22] to process questions or requests and you do not have to talk in code language to get the required answers. These applications can learn and adapt new words in any language from the user. This is an example of computational intelligence which is same as an artificial intelligence.

This technology would be extensively used to provide BI answers rather than presenting complex dashboards to the business owners.

BI analysts can do research on available business data and are required to do brainstorm to bring prediction by different available data mining methods with combination of story-telling art and intelligence to convert the results in speeches to answer business leaders. Outputs can be converted to perform some mechanical activity to achieve artificial intelligence.

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E. Mobile BI

Companies are now planning to move to mobile BI and stability and maturity is expected in this area in 2014 [4]. They want to take the full advantage of advanced technology to achieve insight into big data with the help of smart phones to get better information anytime anywhere and to analyze the data for faster decisions.

Using mobile technologies, information delivery from corporate data is not limited to desktops. It's time now to incorporate real time data available within the smart phones to take real time decisions.

There are large varieties of tools like Oracle Business Intelligence Mobile Application Designer to create mobile applications and to bring analytics. Many BI vendors in the market that are coming up with complete solution with security measures.

Exploration is still going on and improvements are required in Mobile BI in following areas

- Security
- Offline Support
- Authentication and authorization
- HTML5 versus Native applications

F. Cloud BI

Cloud computing is becoming populate now a days but adoption rate of cloud business intelligence is low. Business leaders are doing investigations in data integration and security on cloud. Query will be more accessible, as web services have given an innovative approach to marry cloud data with legacy application data sources, which are not available on cloud.

Some BI leaders provide faster and value added solutions to move implementation and maintenance for BI solutions with administration tasks to Cloud and ability to change analytics on the fly [10]. Research on technology is providing solutions to secure enterprise data on cloud. However, lack of awareness on security rules or business practices could cause very high impact on business and business owners are not getting decisive confidence as a result to move BI on cloud.

Enterprise Proof of Concept on different scenarios with pay-as-you-go [17] towards more integrated and complex scenario approach would provide solutions to problems and confidence level in BI cloud adoption.

G. Cloud BI Architecture

For example, SAP HANA Cloud application Platform [29] enables customers to initiate small BI projects for quick and running business solutions with massive data and provide continuous growth capabilities by adding new BI business cases with minimal IT investments.

SAP HANA Cloud platform is one of the examples and provides full set of developer application services including social and collaboration services, analytics, portal and mobile services. It also provides highly scalable database, transaction processing, real-time advanced predictive analytics and text mining capabilities.

Cloud-based implementations are now starting where cloud architecture is able to integrate with any technology, including SAP (ECC 6.0 and BW), Oracle, SQL Server and non-SAP systems.

Cloud architectures are providing best services for ETL tools. BOBJ data services are able to do data extraction from source systems to BI cloud. RFC connectors are used to extract data from SAP ECC 6.0 or from data warehouses. Data Services also supports different types of connections for data extraction supported by other database vendors.

H. Using BI Accelerator

Read performance of BI queries is greatly improved by the query drill down. Navigation requirements of the customer are complex and unpredictable. We are creating aggregates, but it is impractical to create an aggregate for every possible navigation scenario.

TABLE V. BI ACCELERATOR BENEFITS.

BI Accelerator Benefits			
No	**Benefits**	**Advantages**	
1	Very fast query response time	Performance Improvement by factor 10-100	Increased end user satisfaction
2	Stable query response time	Independent DB optimizer, aggregates	
3	High Scalability	One BIA instance can run on multiple blade servers	Significant reduction in cost of ownership
4	Low maintenance	No aggregates maintenance, minimized rollup/change run	

Tools like BI Accelerator (BIA) [13] with combination of special hardware are now providing business advantages to improve performance

I. SAP HANA

SAP HANA is a new solution and provides resolution for major BI problems [16].

TABLE VI. SAP HANA SOLUTIONS.

SAP HANA Solutions			
S No	**Problems**	**HANA Solutions**	**Additional Notes**
1	Speed (Proof Points)	3600x faster analysis, 460B data analyzed in less than a second.	21% average increase in revenue.
2	Flexibility	Real-time access to transactional data	Real-time data replication engine, Calculation Engine
3	Scalability	Ground breaking In-memory Innovations, Live cache, BW Accelerator	Solution with software and parallel procession of multi core CPU
4	Data Volume	41.9 GB of data in traditional DB comes in 6.6GB by data compression in HANA	
5	Query Run-time comparison	Query1: 2000 sec (6.1sec in HANA) Query2 1320 sec (5.1sec in HANA) Query3:1050 sec (3.2 sec in HANA)	
6	Classic Enterprise Data	To have corporate BI integrated with multiple ERP systems including SAP and non-SAP	

	warehouse	systems with new applications on HANA
7	Rapid delivery results	Fast Implementation methodology (Start, Deploy, Run)

J. Hadoop Big Data and SAP HANA

Big data raises many challenges. There are three main challenges which are common and are called as "Three Vs"

- Velocity
- Volume
- Variety

Hadoop low-cost commodity servers are able to handle data in petabyte and in Exabyte range, which is much higher than 100 TB ranges of data. SAP HANA and other RDBMS can typically handle less than this range. On the other hand, Producing Analytic solutions from Hadoop are much slower than SAP HANA.

We can achieve very fast analytic solutions from really big data by using combination of capabilities provided by SAP HANA and Hadoop.

SAP HANA provides excellent OLAP, OLTP innovative capabilities with very fast data access and administration tools whereas Hadoop provides very slow data access and can support any data or file structure on the disk. It provides distributed and scalable architecture and does not provide OLTP and slow OLAP and few administration tools as compare to SAP HANA.

SAP is now providing full integrated support for Hadoop with SAP HANA platform, SAP Business Object & SAP Data Services to achieve complete sophisticated OLAP and OLTP technology solutions with both structured and unstructured data.

K. Cloud And Mobilily

Secured BI clouds are opening new opportunities for organizations that are able to get quality services at a low cost where users are also able to use different applications and web services and are using cloud data to make it available on mobile for business intelligence.

Now organizations are taking steps to bring all Business Objects, Web Intelligence reports and dashboards to make them available to mobile users with real-time data for operational use and business decision making.

L. Nosql in Future

Demand for NOSQL [24] is increasing along with the demand of Big Data [25] as combination of big data and NOSQL technology will set a new trend in 2014 in the form of high demand technology. Need for this technology is rising to improve performance for real-time analytics from large data sources, where traditional SQL is becoming a bottleneck for speed [30].

M. BW Capabilities

It is a good change coming in BI market for the implementation of Data warehouses on products like SAP HANA [16]. Companies were facing big hurdle in the way of BW adoption. It is now a breakthrough and companies would be able to think for BW capabilities [16] during 2014 to achieve the goals in an effective way and fast track. However, the need for BW platforms would still be required.

N. Embedded BI and SAP Netweaver CE

Now, people expect analytic information to be embedded in business processes. Embedded BI allows developer and business experts to embed BI components in applications and composites and to allow business users jump to reports, dashboards and BI tools within the business context and to make the information actionable.

Lightweight SAP composition environment provides integrated/embedded BI capabilities on top of common BI services layer.

SAP Net weaver Visual Composer [15] provides integrated key matrices from several heterogeneous systems into one user interface and one report without extensive and costly data modeling. It supports very quick Xcelsius dashboards style reporting [15], lightweight analytics and visualization.

O. Social Media Analytics

Social media analytics use advanced natural language processing engine to read, analyze, and normalize data by extracting customer's perceptions from terabytes of social media data in real-time and conclude not only sentiments but deeper insights for opinions and emotions.

Natural Language Processing (NLP) engine read each sentence and identify noun, verbs and adjectives and categorize them according to the required target opinion, emotions & behaviors. Later, NLP engine finally helps you understand what your customers feel about your product or service.

By SAP social media analytics you can get access to pre-analyzed data from social intelligence warehouses. Every hour these sources are updated with new entries and analyzed information. We can get real-time access from Twitter's complete data stream with more than 250 million tweets per day for our customized analysis.

By using the analysis tool, you can define filters, searches and produce drilldowns for analysis of customized categories like different products, topics, interest, feelings, and demographics. One can also export data and graphics into reports and presentations to examine individual comments for more detailed analysis.

P. Strategic Analytical Platform

To have a strategic analytical platform, you need to ensure that the solution we are planning should be able to access, integrate and process data for desired outputs taking from Cloud Data, Big Data, to local data and corporate data warehouse for all structured and unstructured data.

Q. Drives the New Data Warehouse

Data warehousing architectural design needs modifications in this current era towards more advanced state of art technology concepts like SOA, Big Data, social media analytics, mobility, Cloud, NOSQL and data visualization for more advanced BI solutions with advanced analytical and

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transaction processing capabilities with improved ways of implementations.

IV. BI PROJECTS

BI Leaders are considering the rapid change in BI trends and technology and are working on to overcome related challenges during initiating completely new BI projects, BI migration and integration projects. In addition, below are few areas to do tradeoff in order to bring effective BI systems and better project management.

- Produce all BI business cases
- Determine global integrated architecture
- Defining global implementation scope
- Prioritizing enterprise global scope
- Balancing top-down and bottom-up approach
- Follow and consider all aspects in six global dimensions
- To adjust 3-dimensions (Scope, time, cost)
- Project progress measurement procedure
- Document control & approval procedure
- Draw milestones for project linked with progress
- Monitor and control progress and risks
- Quality monitoring
- Produce global staffing plan
- Project Budgeting (How much and for how long)
- User acceptance group and UAT Plan
- Follow standards & steps during each phase including blueprinting, realization, Cutover and Go Live

V. BI IMPLEMENTATIONS

Most of implementations of any BI Technology are not successful and are becoming problem for companies in the completion of BI projects. Some of important things to consider for successful BI implementation are mentioned below

- Strategic Vision to succeed
- To draw short and long term BI strategies for short and long term benefits
- Platform/Technology and tools Selection
- Skilled staff and sub-optimal staff utilization
- Business analysis or standardization
- Business sponsors engagement
- Integration with Multiple Source Systems
- Organizational Collaboration (Disciplines, Departments, Business Units, Strategic Divisions, Global Locations)
- Cross Organizational Collaboration (Partners, Contractors, Subcontractors, Vendors, Customers, External Parties and Market conditions)
- Cross organizational collaborative culture
- Privacy Breaches and IT Security concerns
- Limit productivity VS Security Lapses
- Manage Islands of Information Systems
- Disparate data sources not designed to work together
- Elimination of Multiple Storage Towers
- Consistent Touch Points for all end users/Stakeholders
- Real-time data access to Stakeholders
- End user trainings
- Outsource model, Vendor & SLA management

VI. CONCLUSION

There is a need to maximize returns on BI investments and to overcome difficulties. Problems and new trends mentioned in this article and finding solutions by combination of advanced tools, techniques and methods would help readers in BI projects and implementations.

BI vendors are struggling and doing continuous effort to bring technical capabilities and to provide complete out of the box solution with set of tools and techniques.

In 2014, due to rapid change in BI maturity, BI teams are facing tough time to have infrastructure with less skilled resources. Consolidation and convergence is going on, market is coming up with wide range of new technologies. Still the ground is immature and in a state of rapid evolution.

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Business Continuity Opportunities in the Cloud

A Small to Medium Business Perspective

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***Abstract*—This research paper begins with a look at current work in business continuity as it relates to the cloud and Small to Medium Business (SMB). While cloud services are an emerging paradigm that is quickly making an impact on business, there has been no substantive research applied to SMB in disaster recovery efforts. Seeing this lapse, we have taken a fusion of continuity and cloud research with application to the SMB market. It is an initial reflection with base framework guidelines as a starting point for implementation. In this approach, our research ties together existing work and fills the gap with an SMB outlook.**

Keywords-business continuity; cloud services; medium size business; risk assessment; small business.

I. INTRODUCTION

Cloud services and related technologies are providing options to a proprietary, location based model that has dominated the industry for decades [1]. This has always been a challenging aspect for the Small to Medium Business (SMB) market. While this group is often one of the most important drivers in business activity, staffing is generally limited to operational functional units, most often this means a lack of dedicated technology personnel [2]. While this is by no means debilitating to normal operations as the SMB will hire staff for core functions as necessary, the situation has a distinct tendency to reflect limited or restricted technology resources.

The primary reason that cloud services can be a powerful differentiator for SMB's would be the "pay-as-you-go" model and only budgeting for the services you require [3]. Enterprise organizations are generally going to have complex infrastructure, staffing and potentially even continuity costs, which will fundamentally reduce the benefits of cloud services. In addition, the needs at the enterprise level will be greater along with associated costs. At the SMB level, it will generate additional costs but often will be a la carte so planning can be done, contracts put in place, and Service Level Agreements (SLA) signed which will assist in continuity preparedness. The primary reason this research is important and why it stands out is due to conventional wisdom dictating that enterprise solutions are applicable for all organizations, simply scaling down the implementation for the SMB. This is an erroneous assumption and dangerous to SMB technical operations and continuity planning.

This research took a look at conventional and enterprise level business continuity work that had been done previously [4][5]. After getting an understanding at that level, personal understanding of the SMB market has been utilized to interpret this information into a micro framework with flexibility to conform to the unique needs of the target organizations. While the result is not formally distinctive, which is the ultimate point of this work, the SMB businesses require a distinct overarching set of guidelines that can be applied to specific operational needs. The final output of this work is such a set of steps that can be used in a flexible manner yet have an open source aspect that can be customized to self-determined needs.

Rest of the paper is organized as follows: The second section will provide information about the cloud services and its usage. The third section provides background work on application of cloud services in disaster recovery / business continuity efforts. This is followed by the interpretation of how cloud computing takes a place in the SMB market. In Section 5, we will present a business continuity framework that can be used in SMB and the paper is finalized with a conclusion section.

II. ABOUT CLOUD SYSTEMS

A. Cloud Services

As covered by National Institute of Standards and Technology (NIST) (2009) [6], there are 4 types of cloud system consisting of public, private, hybrid and community as shown in Figure 1. The most popular and common one is the public cloud, though there are other alternatives as noted here if there are specific needs of an organization that cannot be met by a public option. This may come about from system needs or perhaps even from specific security needs. The primary scope of this research will center on the public cloud and the related potential offered by providers in this space.

Marston et al. [7] stated that accessing to a system independent of device and location represent a major shift in computing compared to all other previous techniques. There are some associated key advantages of this technology from lower cost to immediate access to hardware resources, while cloud resources potentially increase innovation with

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availability for enterprises to scale their operations along with others [7].

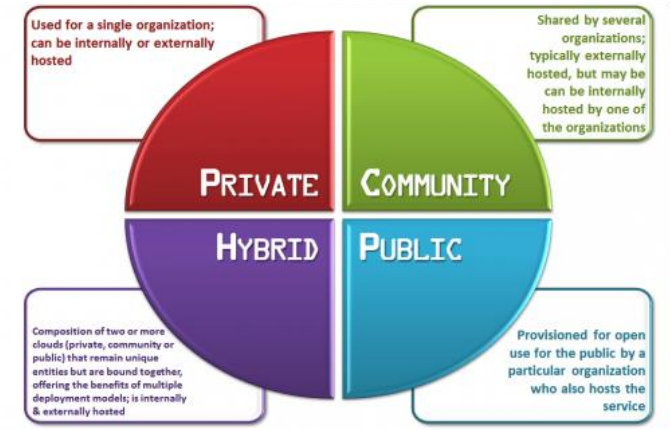

Figure 1. Types of Cloud Computing [3]

Some of the final elements of coverage on Cloud computing is the classification of services and applications. According to Lin and Chen [8], cloud services delivery models can be broadly categorized into four:

- Software as a Service (SaaS), in which applications are exposed as a service running on a cloud infrastructure.
- Platform as a Service (PaaS), programming platforms and tools (such as java [9], python [10], or .NET [11]) and/or building blocks and APIs for building cloud-based applications and services are made exposed as a capability.
- Network as a Service (NaaS) includes the provision of a virtual network service by the owners of the network infrastructure to a third party, and,
- Infrastructure as a Service (IaaS) resources (compute, storage, and network) are exposed as a capability.

Overall, cloud computing is the result of evolution and adoption of existing technologies and paradigms. So far, the descriptive information and the associated cost figures build up the fairly easily discernible benefits related to the cloud and stands out as a good potential structure to be used as IaaS in business continuity. That being said there are also security considerations to be assessed.

B. Challenges in the Cloud

There are challenges related to utilizing a framework that is so publicly available. A big part of the risk comes from having to access proprietary resources across a public WAN. While there will be established and implemented security protocols in place, with the escalating nefarious cyber activity, any additional exposure can be an increased risk.

Cloud computing inherently is affected by common and well-known Internet-based threats like Denial of Service (DoS) and SQL injections. Some of the security issues specifically related to Cloud computing [4] are:

- XML Signature Element Wrapping, renowned attack to web services
- Browser Security
- Cloud Malware Injection Attack, which tries to damage a spiteful service, application or virtual machine.
- Flooding Attacks, where the cloud is brazenly attacked
- Data protection
- Incomplete Data Deletion
- Locks in, affecting portability

C. Vulnerabilities

There are many potential vulnerabilities for cloud-based technologies and services, but they can be mitigated with an understanding of what types and categories are included. A place to start is the core cloud technologies, such as web based services, virtualized infrastructure as a service, and cryptography. Next essential characteristics are like services that are on demand, network access from anywhere, resource pooling and an elastic demand needs to be assessed. Within those areas is a further defined exploration of vulnerabilities along with security controls that can be implemented to provide mitigation [12]. The movement from proprietary infrastructures and technology provides a challenge in vulnerability assessment as it is difficult to define boundaries and responsibilities. This is where a solid review of the SLA comes in the picture.

It is not enough to be aware of options, risks and then just forge ahead hoping for the best. Even a small or medium sized business needs to stay viable, especially in a time of continuity threats. As the enterprise grows, being reliable and available can be some of the best tools in attaining and more importantly, retaining customer base goodwill.

Data and applications that are controlled and serviced internally can be readily assessed according to organizational protocols and security measures. Much like our customers trust us to be vigorous in protecting their data, housing assets in the Cloud implies an SLA. When it comes to the Cloud "the enterprise data is stored outside the enterprise in the most of Cloud Computing service model. Therefore, the Cloud Computing vendor is usually suggested to adopt additional security checks to prevent breaches [13]." The Cloud model implies a comprehensive enterprise model of availability and security. In order to rely on this model at a time of greatest need such as a continuity situation, there must be well established assurances. Ultimately, while the Cloud has revolutionized the computing environment there are a number of threats from the network to applications that need to be controlled. This will take effort from the enterprise utilizing the services through audits and to ensure that Cloud service providers are adhering to their SLA's [14]. In order to successfully leverage the cost and availability for a Small to Medium Enterprise, the security

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concerns will need to be explored and accounted for prior to establishing Cloud services as a continuity option.

III. LITERATURE REVIEW: CLOUD SERVICES IN DISASTER RECOVERY

Although cloud-based business process has been discussed widely and adopted by several companies, there is only a few study reflect the usability of cloud services for business continuity purposes.

Wood et al. [4] discussed about applicability of cloud in disaster recovery effort. Overall, the authors showed that warm backup sites can take the most advantage of the cloud's pay-as-you-go pricing model, since a hot backup site will be costlier. Their research also showed that cloud services can offer customers up to 85% cost reductions compared to company-owned equipment in business continuity.

According to Creeger [5], cloud services reduces the cost significantly. By enabling virtual machines to be sent to the cloud for access only when needed, virtualization becomes a cost-effective disaster recovery mechanism. Typical business continuity effort costs are twice the cost of the infrastructure. With a cloud-based model, true disaster recovery is available for an approximate of 5 percent extra cost for the company, a significant savings. Additionally, because external cloud service providers replicate their data, even the loss of one or two data centers will not result in lost data. Although the cost benefit is obvious, the authors stated most SMBs make no investment in disaster recovery via cloud.

As mentioned earlier, security within the cloud has been an issue because the business is giving up control of their data to an external entity. This issue is compounded by the fact that the data can be located in multiple locations making it very difficult to track. However, Alhazmi and Malaiya [15] suggested that there is some evidence with proper security protocols and policies that these issues can be addressed even if cloud is used for business continuity purposes. They also stated that with public cloud vendors, a higher security level can be achieved because they can employ more security personal that can monitor access of the data and if there is a breach, it has higher probability of being reported and stopped faster than a private cloud system.

As reflected from above, the work on cloud systems in disaster recovery efforts are limited and also the built frameworks are not considering the size of the company. Therefore, this work in using cloud services in business continuity from small size to medium size business will be unique in terms of what it proposes.

IV. SMB BUSINESS CONTINUITY AND THE CLOUD

A. SMB Market and Services

The challenge has always been greater for technology and related implementations in an SMB beyond even just plain economics. Staff levels are going to be limited to the levels of primary functional ability. There is not a scenario where there can be specific, targeted teams for assessment, testing or ultimately deployment on demand. Even though the SMB market is recognized to be a powerful driver of business activity on a macroeconomic level, anything other than enterprise organizations have often been overlooked. It is an exponential degree of greater difficulty to provide external services and consulting for the SMB market.

This exploration is specifically in the area of business continuity planning, but the challenges inherent to the scale of business for the SMB market are apparent in all level of functional aspects. As a whole, the potential market and revenue generation is rival to enterprise businesses, but the value has to be extracted in a dispersed and relatively scaled per business microeconomic manner. No million dollar consulting engagements to be had in this group.

There are services that have become available to the SMB market in recent times along the lines of the most readily apparent cloud services, but there are also innovative companies in industry that provide greatly needed and appropriately targeted consulting, such as HourlyNerd [16]. Taking advantage of an obvious business need and the glaring lack of services provided in this arena, HourlyNerd meets a need by providing affordably priced MBA guidance recruited from top business schools such as Harvard and Northwestern. Some of the obvious advantages of HourlyNerd are that the members are all from top 20 universities in the United States or elite international institutions, they have had their backgrounds thoroughly checked during the admissions process and have the requisite networks, resources and solutions.

B. Business Continuity

In the business continuity process, the SMB will not have the same resources to apply for planning, testing or ultimately application in time of need. Often there will be few, if any, specific technology resources available for any stage of the process. This is where an organization needs to be creative within the expanding boundaries of technology services that in practice actually have a greater impact on the bottom line for an SMB than for an enterprise scale business. Cloud technologies can provide a solid infrastructure and specific applications such as readily available Google Docs [17], technology can be leveraged in an extremely economical and flexible manner. The greatest hurdles would come from simple adoption arising from lack of understanding of available options. Accordingly, this is the point of the process where previously mentioned HourlyNerd could be instrumental in relatively priced enterprise scale planning and services at the SMB level.

C. Power of the Cloud

Some specific cloud-based and cloud-related technologies that can be powerful enablers for the SMB are not only the clearly defined cloud based services, but another organizational paradigm that can tie in to this movement and be leveraged for business continuity is Bring Your Own Device (BYOD). As the business stalwart PC

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sales continue to experience a precipitous fall, as consumers opt for the tablet and smartphone options, this trend is one that is favorable to the SMB market. In a continuity situation, communications are fundamental to any situation. Ready adoption of employee driven trends of BYOD and integration into operations can be a differentiator for smaller organizations without a dedicated technology budget or staff.

By having a policy that supports the adoption of mobile devices along with company-based reimbursement, an SMB could support adoption of business continuity ready devices and technologies without the requisite corporate investment or commitment of resources. Employees that embrace this trend are more likely to be self-trained and have a reliable and useful level of home based connectivity. Encouraging the adoption by providing company support, the investment can be compounded in potential benefit in times of need. This can help increasing the likelihood of employees having an understanding at least, and a level of comfort at best with the cloud based services that can make or break a continuity process at a SMB.

D. Security Concerns

Concerns are the same at this level as it is at any level and that is related to security, more specifically to cyber security. Cybercrimes and attacks are a very prevalent threat to business and government continuity. Verizon recently, released a report showcasing some disconcerting facts and figures on how small businesses are the easiest prey for cybercriminals [18]. "Of the 621 confirmed data breach incidents Verizon recorded in 2012, close to half occurred at companies with fewer than 1,000 employees, including 193 incidents at entities with fewer than 100 workers. A separate report from cyber security firm Symantec confirmed that trend [19]. It found cyber-attacks on small businesses with fewer than 250 employees increased 31% in 2012, after growing by 18% in the prior year." It is an ongoing continuity situation for the SMB market, building on previously mentioned factors such as lack of dedicated technology staff and funding. These elements need to be a part of the business continuity planning as it constitutes a threat to the organization

V. SOLUTION

Now, that we have explored the situational factors, concerns and how cloud services with related technologies can be solution facilitators, we need to look at a formalized exploration of a framework.

Three risk management methods EBIOS [20], NIST 800-39 [21], and IT-Grundschutz [22] are well-known and widely adopted techniques. Although these methods have been widely recognized, these methods fit for large scale businesses [23]. While implementation of the methods to smaller organizations is possible, it will introduce greater cost and a potential of information redundancy if viewed from "information-as-needed" point of view. By studying these methods, we derived that their processes are widely different and the quantity of sub-process/sub-steps may vary which adds to the complexity and cost to perform these steps for smaller organizations. Also, we observed that some of them possess useful processes that can be useful for smaller businesses or organizations while they may also lack in other parts of processes. For example, while EBIOS does not possess the concrete post-implementation monitoring strategy and evaluation, as showcased by NIST 800-39, it does, however, do initial study of existing security measures, which is not included in NIST 800-39.

Based on the analysis, as shown in Figure 2, a combination methods of Context Study from EBIOS, Knowledge catalogue concept from IT Grundchutz, and Continuous Risk monitoring and evaluation from NIST-800-39 can be combined to be used in Risk Management in Cloud computing for SMB business.

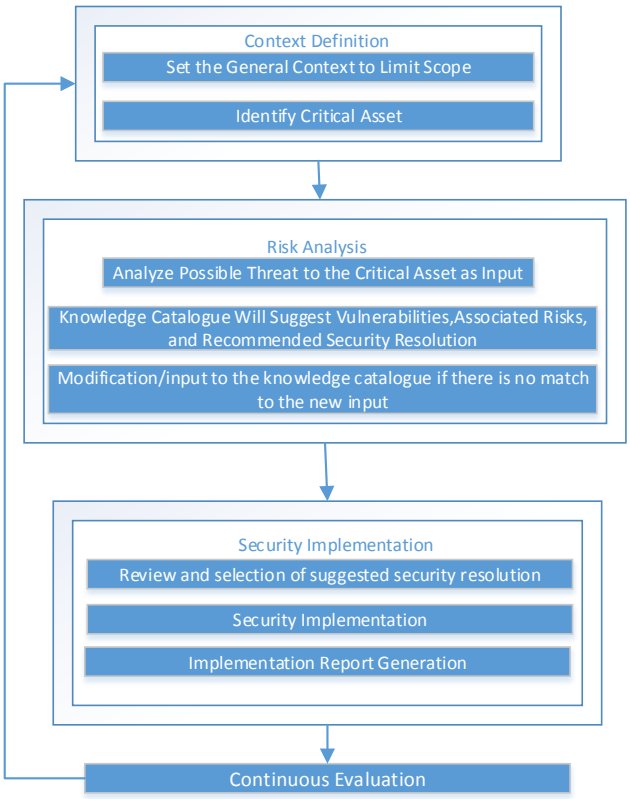

Figure 2. Proposed Risk Management Method Process

- Context Definition: First stage is the context definition. In this stage the person/team will define the context of the recovery plan to limit the scope. The other main activity will be the identification of critical assets of the business.
- Risk Analysis: Once the context definition is done, analysis of any possible threats to cloud that can affect the critical assets need to be listed as a list of inputs. These inputs are then compared to the knowledge catalogue to see if there are any existing similar threats from which can be derived its vulnerabilities, associated risks, and recommended

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security resolution/controls. If there are no matches of the inputs in the knowledge catalogue, further risk assessment will be done to define vulnerabilities, associated risks, and recommended security resolution/controls. This can become a basis for future risk analysis.

- Security Implementation: From the risk analysis, the risk assessment report will provide the list of risks and recommended security resolutions/controls in cloud. With the Cloud Controls Matrix (CCM) guideline available from Cloud Security Alliance (CSA) that is specifically designed to offer fundamental security principles in cloud [24], the stakeholder (usually business owner) can then decide which controls they want to be implemented and a report documenting the implementation along with the list of any risks that are not controlled due to acceptance from the stakeholder need to be generated.
- Continuous Evaluation: The cloud environment is one of ongoing change and to properly address a plan or potential implementation, there should be periodic assessments and monitoring on a regular basis. As understanding grows along with adoption of cloud based business practices and the associated risk assessment, an organization needs to treat this as a living process and revisit the framework, applying modifications as deemed necessary.

As shown in Figure 3, BYOD tied in to cloud services can provide communications, data, and applications capabilities. Besides cost advantages to the companies, BYOD can improve the agility and productivity of work practices amongst employees in an enterprise [25]. Prohibiting personal devices in a business recovery effort is risky, since employees may be forced to use their own devices because of lack of secured devices after a disaster. With the introduction of BYOD, the devices are owned by the individuals not by the companies. The device may be managed both by the company and the user as well. Accountability is not something that goes away for a user just because they personally own the device. At the end, the data belongs to the company.

The suitable defense in securing BYODs begins with the same requirements that are applied to devices that are already owned by the business. These security measures include:

- Enforcing strong passcodes on all devices. By password protecting the devices, a user acknowledges accountability and responsibility for protecting their data.
- Antivirus protection and data loss prevention (DLP)
- Full-disk encryption capability for cloud storage
- Mobile device management (MDM) to wipe important data when devices are lost or stolen
- Application control. The device should be able to perform other daily needed jobs when not in use for recovery efforts.

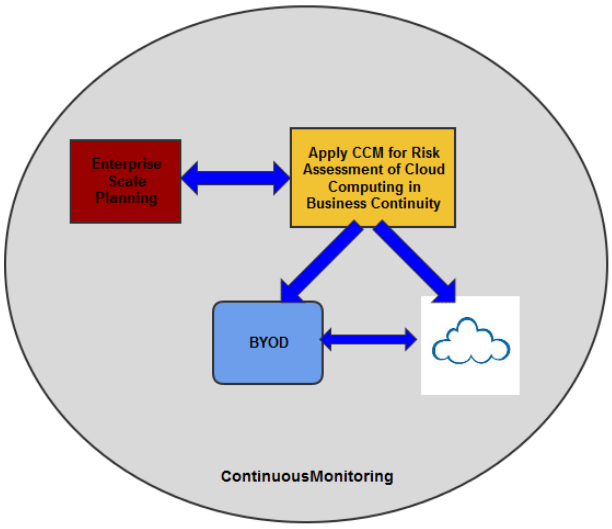

Figure 3. Framework for Business Continuity in Small Business

VI. CONCLUSION

There is great potential for the SMB market when it comes to cloud services. The challenge does not change but the impact of the solutions, and the related value of those solutions is much greater. A Small to Medium Business can have an as needed infrastructure that can be leveraged on an ongoing, day to day basis but beyond that can have an accessible infrastructure able to scale up or out in a time of distress. For this type of implementation, the costs of compliance often have a greater impact due to the smaller economies of scale, yet at the counterpoint cloud services offer a greater positive impact due to the scalable implementation and usage based pricing and services.

With some planning and a reasonable investment, an SMB can now achieve a level of risk assessment with associated mitigation by making the most of emerging offerings, such as the cloud, BYOD and companies like HourlyNerd. The current business environment is very challenging for everyone, at times debilitating to smaller enterprises and the ability to take advantage of these powerful, differentiating services and paradigms can give a SMB a good toolbox to build a future.

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Mobile Operators as Identity Brokers

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***Abstract* — In this paper, we discuss how a mobile communication service provider (Mobile Operator) can act as an intermediary between the end user and the digital service providers. This enables a more trustful relationship between the end user and service provider, and brings out compelling value. In addition to being a trusted broker, a mobile operator can also provide various value-added services to the end users and service providers.**

Keywords - Telecommunication; Digital Services Over the Top; Online Services; Identity Management; Identity Federation; Digital Identity Profile; Ease of Use; Security; Circle of Trust; E-commerce; M2M

I. INTRODUCTION

In a connected society, where a significant number of applications and services are available over the Internet, a user is faced with daunting challenges of maintaining multiple identities for various services. Usually, every application or service requires some authentication and establishing the identity of the appropriate user. It is done with an identity coupled with a password.

A user needs to maintain identities for each of the applications. However, there is a drawback in this approach. The end users tend to reuse the same identity and password across all services, which make them vulnerable to risks of identity thefts or identity pilferage.

In future, it is expected that the number of the services is going to grow exponentially [1]. It will be difficult for an end user to manage identities across all the services. In addition, the increasing number of devices associated with the user (for example, connected cars or home security systems) is also going to magnify these identity management problems.

Digital services like online banking or trading, require a secure identity establishment. However, digital services like e-mail or social networking need basic identity establishment.

For all the digital service providers, it is a big challenge to maintain and establish the identities of their users.

In this paper, we discuss how the mobile operator can act as an intermediary between the user and the service provider. It enables a more trustful relationship between the end user and the service provider. For example, it would be great for an end user to use single identity across mobile networks, Wi-Fi hot spots, broadband, utility, or cable TV. If mobile operators are able to provide an identity brokerage service between the end user and their service providers, it will help them monetize the brokerage services as well as increase the loyalty of their end users.

There are some initiatives ([2][3][4]), where mobile operators are playing a global identity provider role. This paper leverages on these initiatives, and presents how mobile operators can provide more compelling value to end users and service providers.

This paper talks about:

- The previous work done on identity management.
- The future requirements and actors in value chain.
- How mobile operator can provide identity broker services and other value added service.
- The challenges mobile operator's may have.
- How end users can be subscribed to the services provided by a mobile operator.
- The solution framework and its components.
- The case studies and the conclusion.

II. BACKGROUND

Many service providers allow subscriber authentication using popular service provider identities, for example, Facebook, LinkedIn, or Google account. This concept is known as Identity Federation. It enables end users to reuse their existing identities without registering to every service provider. There is a lot of work done towards standardization of the identity federation with protocols, such as, Security Assertion Markup Language (SAML) [5], Liberty Alliances [6], OAuth [7] gaining significance. Organizations like GSMA [8] are involved in driving these standardizations.

There are few success stories around this concept; however, they still need to achieve a mass adaptation. Also, mobile operators perceive this a potential revenue stream.

III. THE FUTURE NEED

The future need indicates that number of services is going to grow exponentially [1]. However, it also indicates the following points:

- It is a pain for end users to register and maintain their identities (including identities related to their devices) across multitudes of services. It also acts as a deterrent for the end users from trying out new services unless there is a need.

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- It is a pain for various service providers to maintain end users identity, authentication, and comply with local regulations.

Service providers have a strong requirement to differentiate between a genuine end user and a fraudulent end user.

An Identity Broker is required in the connected world, which can provide validated information of end users and service providers.

A secure identity establishment and identity exchange enables innovative use cases. For example:

- Digital voting
- Seamless access to connected devices
- Secured access to corporate Intranet or government portals

IV. ACTORS IN THE VALUE CHAIN

In the identity establishment and exchange flow, the following actors play an important role:

- End User: The subscriber of mobile operator and a digital service provider, whose identity is established before giving access to a service.
- Mobile Operator: The connectivity provider having the infrastructure available for securing the communication channel and also have detailed information about the end user.
- Digital Service Provider: The digital service provider to the end user over the Internet. It uses the connectivity provided by mobile operator to offer services.

Digital service providers need to partner with mobile operator to leverage on the assets which the operators have.

Operator's partners can be, for example, Over-the-Top (OTT) service providers, Wi-Fi hot spot providers, or Broadband providers.

V. OPERATORS AS A TRUSTED IDENTITY BROKERS AND MORE

The operators have unique position in a connected society. The operators have following capabilities:

- Verify customer information as per the local regulations.
- Contact/Billing addresses of the end user.
- Support for multiple communication interfaces like Unstructured Supplementary Service Data (USSD) [12], Short Message Service (SMS) [13], E-mail, and Voice.
- Self-care/Customer care
- Fraud management
- Established relationship with the end user.
- Charging and Billing infrastructure
- Extensive reach to the customers and dealer/agent network.
- Marketing infrastructure to enable service providers to get more end users.

The operator can leverage these capabilities:

- To act as an identity broker.
- To provide value added services to end users and service providers.
- To enable a low entry barrier for new service providers for offering their services to the end users.

It is not the identity brokerage service which is provided, but a complete bouquet of services made available to service providers enabling them to focus on best quality service delivery aspects.

The end users can enjoy a seamless and secure access to all the trusted partner services.

VI. THE CHALLENGES

The mobile operators have the following challenges:

- SIM-based Security: It is built in as part of the SIM [15] card or device, which has its pros and cons. There should be authentication mechanism for following scenarios:

Multiple devices per end user (including devices without SIM, for example, tablets, home security systems)

Shared family devices or accounts

- SIM tied to the operator: Here an end user might have multiple SIM cards from multiple operators. The challenge is how the identity brokering work is done when we have other services like Wi-Fi, fixed line, or broadband.
- Access Dependence: Connected devices may not be using operator's access network. For example, power line communications for a smart meter, home security solution over fixed Broadband, or Wi-Fi access over SIM less devices.

The proposal on how these challenges can be mitigated is discussed in the Proposed Solution Framework Section.

VII. GET END USERS SUBSCRIBED TO THE SERVICE

It is essential to get maximum number of end users subscribed to the service to enable mobile operator successfully monetize the identity brokerage service. However, there should be sufficient leverages for the end users to subscribe to the services. It will be difficult for the end users to subscribe to the services if there is no significant benefit for them.

The possible benefits which the mobile operator can provide to the end users are:

- Increased Security: No need to share personal information to multiple online services (about whom end users do not have sufficient trust level information). It protects the user from identity proliferation issues and associated threats.
- Partner Risk Score Information: Operator verifying the partner and providing a trust level score to the end user enables the end user to take good decision about the services.
- User Profile Sharing based on Partner's Risk Score and User Preferences: Risk scoring done by operator and recommending end user what to share and what not to share. User can use the trust level score and recommendations to decide his preferences for the service provider.

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- Special Tariffs and Quality of Services for Partners: Offer end users special tariffs (for example, no charge, quota usage, or higher speeds) for specific service providers, based on the mobile operator's agreement with the service provider. For example, online retail sites, giving higher speed and priority with discounted data tariffs.
- Allowing end user seamless access to various partner services. This is a unique selling point.
- Offering a digital signature to the end user, which can be used across critical services of service provider (for example, digitally signed financial transactions).
- Provide a generic loyalty point service for all partner service providers, which offers end user to use the loyalty points across service providers.
- A simplified mechanism allowing end user to opt-in and opt-out for this service anywhere and anytime is essential. For example, at a click of few buttons on the self-care App, end user should be able to register and create different digital identities and set preferences.
- The solution should be intelligent to understand the end user usage pattern, and quickly map various existing identities of the user to the centralized identity. For example, an end user of the service trying to log in to a partner's site (for example, Yahoo) should be offered an option of mapping his local identity (yahoo id) to his centralized identity with operator.
- Agreeing with service provider to allow end users subscription with their operator maintained identity. Since the end user's access request is coming from a trusted partner (through the mobile operator's network), the service provider can identify the end user using the security token inserted by the operator as part of the access request header. For example, an end user accessing a partner bank's URL on his smart phone is automatically identified by the bank.
- Mobile operator can also act as a seamless payment gateway. Service provider sites can provide an option to end user to pay via the mobile operator. Mobile operator may provide a wallet service to the end users. Another offer can be payment through prepaid account or a postpaid bill by the mobile operator.

VIII. Required Technical Capabilities

The required technical capabilities for this solution are described below:

- Secure token exchange for seamless identity exchange with service provider. Using intelligent URL inspection, service provider site identification, and exchanging the end user profile information in secure manner as part of the security token embedded in the HTTP header. For example, scenario of an end user accessing a bank's URL on his smart phone. Mobile operator identifies this service from a trusted source, and then embeds the configured security token in the request header. The secure token also includes the required end user profile as agreed by the end user and the bank. The bank's online service will check the presence of this token, parse and verify the token with the mobile operator's secure verification services and then allow the end user access to the bank's service.
  Advanced identity federation and security platform is required to maintain the end user's digital identity profiles to authenticate and authorize, and to share the required user profile towards service provider.

IX. The Proposed Solution Framework

A mobile operator needs a collaboration platform, which enables effective collaboration between digital service providers and operators.

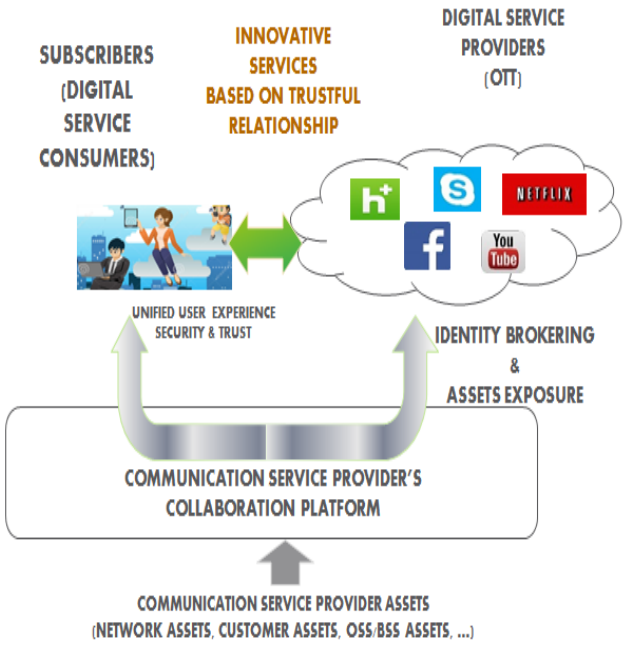

Figure 1: Enabling monetization via effective collaboration

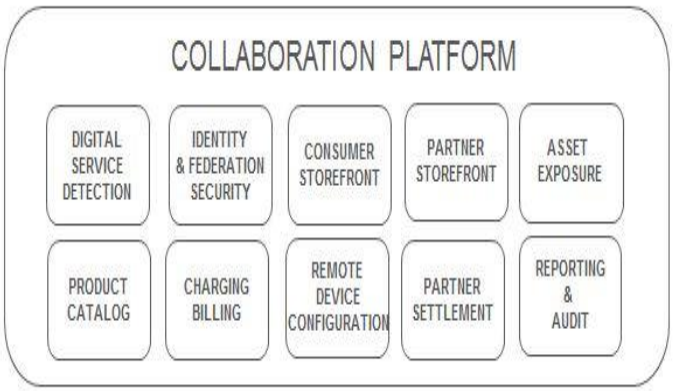

Figure 2: Collaboration Platform Functional Architecture

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Collaboration platform hosts capabilities for any digital service provider to self-register at the mobile operator's site and use of the mobile operator's assets and available capabilities.

The functional architecture of the collaboration platform is shown in Figure 2. The components of the architecture are described below:

- Partner Storefront: It enables digital service providers quickly register as partners. The partner lifecycle management including agreements is handled within this storefront.
- Consumer Storefront: It enables consumers quickly browse through available products from a mobile operator or a service provider.
- Identity Federation and Security: It enables the mobile operators act as a secure and trusted identity broker and federates the identities between end user and digital service providers. It enables secure exchange of customer information such as profile, preferences, and segmentation with the service provider.
- Service Detection: It is an intelligent service detection based on URL, packet intercept, and partner identification. Based on the partner identification, a secure channel can be established where the customer profile information can be shared with the digital service provider. The profile information exchange happens using a secure token to ensure that critical customer information is not compromised.
- Asset Exposure: It is a platform for exposing the mobile operator's assets (for example, authentication, location, or charging) in a secure manner as REST-based API's. This can be leveraged by service providers to build innovative services for the end users.
- Charging, Billing and Quality of Service Control: It enables differentiated charging and special Quality of Service (QoS) for the service provider's service usage session. A specialized charging & billing platform is required which in runtime can change the QoS parameters for the data session.
- Partner Settlement: It enables billing the service provider for a value added service session and exchanging settlement files/invoices with the service providers.
- Remote Device Configuration: It enables digital service providers and mobile operators to configure the end user devices (for example, mobile phones or any M2M device) to install a digital certificate or application.
- Reporting and Auditing: It enables analysis and reporting of Key Performance Indicators (KPI) for service providers. It allows mobile operators to determine their profitable service providers and provide more incentive to them.

X. CASE STUDY

Authentication services Mobile-ID are implemented in Estonia [2]. The Mobile-ID service is built and launched by mobile operator EMT [14], which in 2009 made its platform available to the other operators (Elisa and Tele2). This was recognized as key to driving scale among users and encouraging service providers to join the service. Mobile-ID service allows a client to use a mobile phone as a secure electronic ID. Just like an ID card, it can be used for accessing secure e-services and digitally signing documents. The private keys are stored on the SIM card with a small application for authentication and signing.

Turkcell's Mobillmza mobile signature solution was launched in 2007 in Turkey [3].

XI. CONCLUSION

There have been initiatives by the mobile operators across the world to offer Identity Provider Services to service providers and application developers. However, the success stories around it are still limited. If the operators have to achieve success from their Identity Brokerage Service, they need to provide more compelling value to service providers and their end users. With current assets and customer knowledge, operators are in a unique position to provide compelling values. The requirement is to build a collaboration platform which can package all the operator capabilities together and provide as services to the service providers and end users.

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Three Conceptual Modeling Patterns of Semantically Integrated Method

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***Abstract* — System modeling patterns are similar to workflow patterns, which were established with the purpose of delineating the requirements that arise during business process modeling on a recurring basis. Traditionally, only dynamic aspects are used for specification of modeling patterns leaving aside the static aspects of business processes. The paper presents three conceptual modeling patterns where integrity of totally different aspects can be analyzed. The advantage of such a modeling approach is that it enables visualization and integration of different modeling dimensions of information system specifications in a single diagram. Many graphical representations do not allow such a visualization and an integration of static and dynamic aspects.**

Keywords-Modeling patterns; service-oriented constructs; static and dynamic aspects; synchronization, selection and enclosing patterns.

I. INTRODUCTION

Analysis patterns are groups of concepts that represent a common construction in business modeling [7]. They are similar to workflow patterns that were originally established with the aim to define and visualize the fundamental requirements that arise during business process modeling on a recurring basis [19]. Workflow patterns are usually defined by using Business Process Modeling Notation, Unified Modeling Language (UML) Activity Diagram [16], or a Colored Petri-Net model [15]. All these notations are able to express process behavior but do not take into account the static aspects of business processes. They do not explicitly show what happens with the objects, which represent data, when some activity takes place. Integration of static and dynamic aspects is important for the control of semantic integrity among interactive, behavioral and structural aspects of a system [9]. Semantic integrity is critical to maintain a holistic representation of system specifications. To capture the holistic structure of the problem domain, it is necessary to understand how various components are interrelated. Analysis patterns presented in this paper are constructed using the principles of service orientation and they are called conceptual modeling patterns. These patterns are important for two major reasons. Firstly, they can be used for demonstration of the interplay among fundamental constructs that are used in system analysis and design process. Secondly, patterns are important for the evaluation of the expressive power of semantic modeling languages [18]. Comprehension and visual recognition of these patterns is necessary for building more specific pattern variations and composing them in different ways. Each modeling pattern language can be formally described using a set of modeling constructs and semantic rules.

Service-oriented modeling method [9] presented in this paper is based on the ontological principles [2] of the concept of service [6], and on a common understanding of the general structure of service, which is not influenced by any implementation decisions. The most fascinating idea about a service concept is that it can be applied equally well to organizational as well as technical settings. It means that conceptual representations of service define computation independent aspects of business processes. Business processes can be seen as service compositions, which are used to specify service architecture. Service architecture can be applied for specification of business processes in terms of organizational or technical services. Our assumption is that service-oriented representations can be communicated among business experts and system designers more effectively. Using service-oriented modeling, information systems can be structurally visualized as evolving conceptualizations of service architectures. The interplay between UML diagrams and service-oriented constructs can be also found there [10].

The concept of service in the area of information systems is mostly bound to the term of service-oriented architecture. According to Hagg and Cummings [12], Service-Oriented Architecture (SOA) is a software architectural perspective, where service is the same as component in component-based system development methodologies. It represents a set of guidelines and design principles, such as loose coupling, encapsulation, reuse and composability [5] [22], in which business processes can be effectively reorganized to support the business strategy [17]. From a business management perspective, SOA can provide the possibility to reach business flexibility. It enables business processes to be analyzed in terms of services. Conflicting views on the concept of service is one of the obstacles to the attempts to develop a new science of services [3] and new academic programs focusing on

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services [1]. This discipline takes a broader perspective of services as opposed to technical descriptions [20].

We use the concept of service as in the sense of service science. It *"can be understood as an action or a set of actions that are performed for some value"* [21]. In the context of enterprise modeling, it is necessary to have a broader understanding and interpretation of the service concept as the definition of service goes well beyond activities that are realized using software applications. The definition of service provided by Sheth [20] emphasizes a provider - client interaction that creates and captures value. It emphasizes a value exchange between two or more parties and a transformation received by a customer [3]. The concept of service facilitates a change of business data from one valid and consistent state to another. In the public sector it sometimes denotes organizational actions. According to Ferrario and Guarino [6], services are not transferable, because they are events, not objects. The main purpose of service orientation is to capture business-relevant functionality. Taking into account the nature of the service concept, which is based on interaction between different actors to create and capture value, a service-oriented way of thinking could be applied for a computation-neutral analysis and design of business processes as well as for creation of conceptual modeling patterns.

This paper is organized as follows. In the next section, static and dynamic aspects of service interaction are described. Three different modelling modeling patterns of an integrated method are presented in the third section. Finally, in the fourth section, concluding remarks are presented.

II. SERVICE AS AN INTERACTION

The action being goal-driven always results in some value to the actor. To get the result, which provides value on demand, four key elements are necessary: service requester, service request, service performer and service response. Interrelations among these elements construct an interaction loop which is necessary to represent service structure. Without one of these four elements, the concept of service loses its meaning. Service performers receive service requests and transform them into responses that are sent to the service requesters. Service can be characterized by an interaction loop that can be defined by a number of flows in two opposite directions. This idea is represented graphically by an elementary service interaction loop, which is delineated in Figure 1.

The main principle of service-oriented method is based on designing services as interactions among different enterprise actors. Service architecture can be represented by a composition of interaction loops. Actors in interaction loops can be seen as active elements. These elements can be organizational or technical subsystems. Organizational subsystems can be individuals, companies, divisions or roles, which denote groups of people. Technical subsystems can be represented as software or hardware components. Any coordination flow between actors [4] must be motivated by the resulting value flow. In such a way, any enterprise system can be represented and analyzed as a set of interacting loosely connected subsystems that form service architecture.

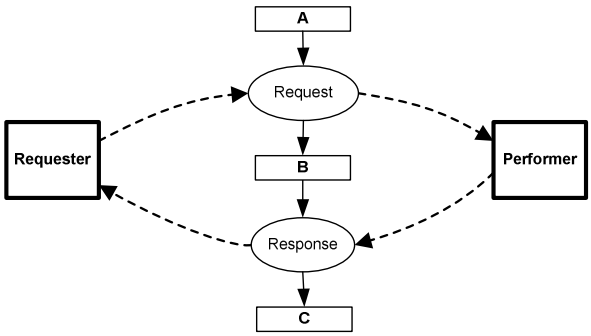

Figure 1. An elementary service interaction loop

A service cannot be defined without specifying the interaction, the result of which creates value to the actors [8] involved. Service is first of all a dynamic act of doing something to somebody. It means that there are more elements necessary to construct a concept of service than just the process of 'doing'. As there are always some actors involved in such process, it signifies that it is a communication act or an interaction between human, organizational or technical components. One is asking for something and another actor provides it. The purposeful action always takes place in a service. It prescribes responsibilities for the actors involved [1].

The dynamic aspect of service includes not just interaction (▪▪▪▪►) between actors, but also the resulting behavior among passive classes of objects when service actions are initiated. The transitions between passive classes of objects are resulting from interactions between active concepts. The internal behavior or so called objective perspective defines the dynamic aspect, which is expressed by object transitions between various classes of objects. Classes A, B, and C define the structural aspects of data. In such way, service modeling enables integration of business process and business data (see Figure 1).

There are two basic events for semantic modeling of service construct: creation and termination [9]. These two events are used for the definition of a reclassification event, which is considered as a generic modeling construct. A creation event is denoted by an outgoing transition arrow to a post-condition class. A termination event is represented by a transition dependency directed from a pre-condition object class. Before an object is terminated, it must be created. Since a future class makes no sense for a termination event, it is not included in a specification of action. Pre-condition class in a termination action can be understood as final during an object's life time. Reclassification of an object can be defined in terms of a communication action that is terminating an object in one class and creating it at the same time in another class. Sometimes, objects pass several classes, and then they are removed. A graphical notation of the reclassification action is presented in Figure 2.

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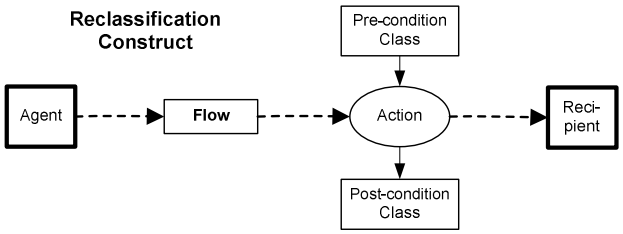

Figure.2. Graphical representation of a reclassification action

Fundamentally, three kinds of changes are possible during any transition (⟶). An action is either terminating or creating an object, or it can perform termination and creation at the same time. Pre-condition and post-condition classes typically define constraints on objects, which restrict the sending and receiving of communication flows between technical or business components. A reclassification action in a computerized system can be implemented either as a sequence of one or more object creation and termination operations. Request and response flows, together with created and terminated object classes, are crucial to understand the semantic aspects of service interactions. A pre-condition object class and the input flow should be sufficient for determining a post-condition object class.

The attribute dependencies are stemming from the traditional data models. Semantics of static dependencies in object-oriented approaches are defined by multiplicities. They represent a minimum and maximum number of objects in one class that can be associated to objects in another class. We use only mandatory static dependencies from at least one side of association. A graphical notation of the attribute dependencies and their cardinalities is represented in Figure 3.

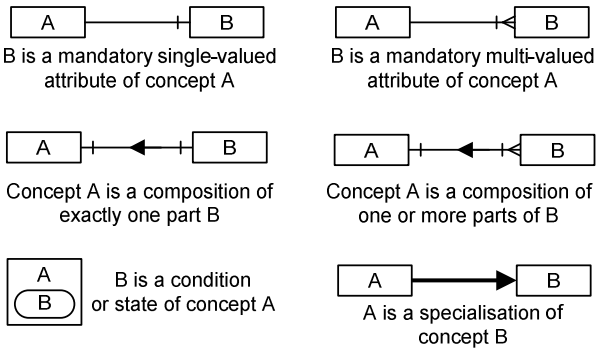

Figure.3. Graphical notation of the attribute dependencies

This notation corresponds to a classical way for representing associations between two entities [13]. One significant difference of this notation in service-oriented modeling method [9] from the traditional approaches is that the association ends are nameless. Dependencies are never used to represent association names or mappings between two sets of objects in two opposite directions. Any two concepts (in the same way as any two actors) can be linked by the attribute, inheritance or composition dependencies [9].

III. MODELING PATTERNS

Constructs based on service orientation were used for the design of three modeling patterns. A single diagram type helps to focus on modeling integration of static and dynamic aspects. Various combinations of dependencies are able to express the main workflow control patterns such as selection, synchronization and enclosing of transaction. Synchronization and enclosing patterns are presented the first time in this paper. Ignoring the static aspects of data in the pattern modeling research creates fundamental difficulties. If just dynamic aspects are taken into consideration, then the quantity of patterns increases and their usage for business process modeling becomes more complex. Comprehensibility and visual recognition of the fundamental patterns is necessary in constructing more specific pattern variations by composing them in various ways.

A. Synchronization pattern

A synchronization pattern is used when some activities must be performed concurrently. This pattern combines two parallel paths of activities. Both paths must be completed before the next process can take place. The primary interaction loop is composed of a more specific loop on a lower level of granularity. In this case, a service interaction loop on the lower layer of decomposition is viewed as an underlying interaction loop. The execution of the underlying loop must be synchronized with the primary interaction loop. The synchronization pattern is presented in Figure 4.

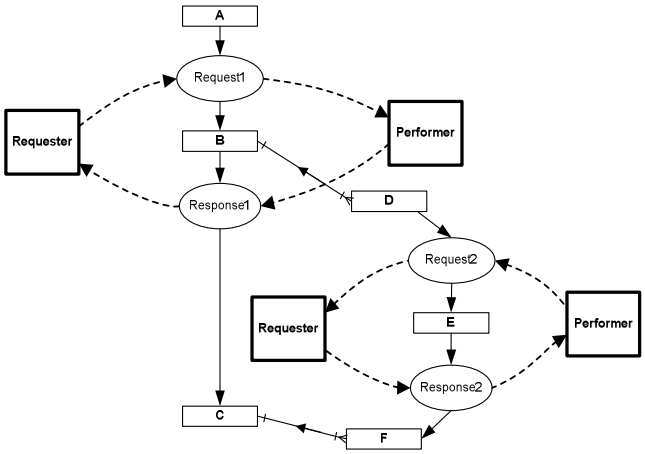

Figure 4. Synchronization pattern

This pattern illustrates that the action of Request1 creates a compositional object B, which consist of parts D. At least one part D must be created. Then object B is reclassified to C, object D must be also reclassified to E and then to F. If a compositional object is created, then the parts are created as well. If a compositional object is removed, then the parts are terminated at the same time. That is the reason why the

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action is propagated from a whole to a part according to the rule of class composition. The propagation of actions is a useful modeling quality. It allows a natural modeling of concurrency. Synchronization pattern is similar to concurrent activities (fork and merge of control) in an activity diagram [16].

The graphical example of synchronization is illustrated in Figure 5. In this example, the object reclassification effects represent the important semantic details of an unambiguous scenario in which three interaction loops are combined. Create Reservation action propagates to parts on the lower level of abstraction. Termination of *Hotel Reservation Request* requires termination of *Hotel Room*[*Desirable*]. Creation of *Hotel Reservation* requires creation of one or more *Hotel Room*[*Reserved*]. According to the presented diagram, the underlying interaction loop action *Select Room* can be reiterated more than once, because *Hotel Reservation* is defined as the composition of one or more *Hotel Room*[*Reserved*].

The underlying interaction loop describes a Customer's response to the Hotel Reservation System's request. If a customer expects to receive a Reservation flow from the Hotel Reservation System, it is necessary for him to get a reply in the underlying loop from the technical component. The request and reply of the second underlying loop is specified as follows:
If Offer Rooms (Hotel Reservation System ▪▪▪▶ Customer), then Select Room(Customer ▪▪▪▶ Hotel Reservation System).

The actions of the underlying loop are synchronized with the primary interaction loop. According to the presented description, Create Reservation is a reclassification action, which is composed of the Offer Rooms and Select Rooms actions on the lower granularity level. The Select Room action cannot be triggered prior to the Offer Rooms action. It can be performed several times for each *Hotel Room*[*Available*]. *Hotel Reservation* is a compositional object. When it is created, such parts as *Hotel Room*[*Reserved*] and *Customer*[*Logged-in*] must be created

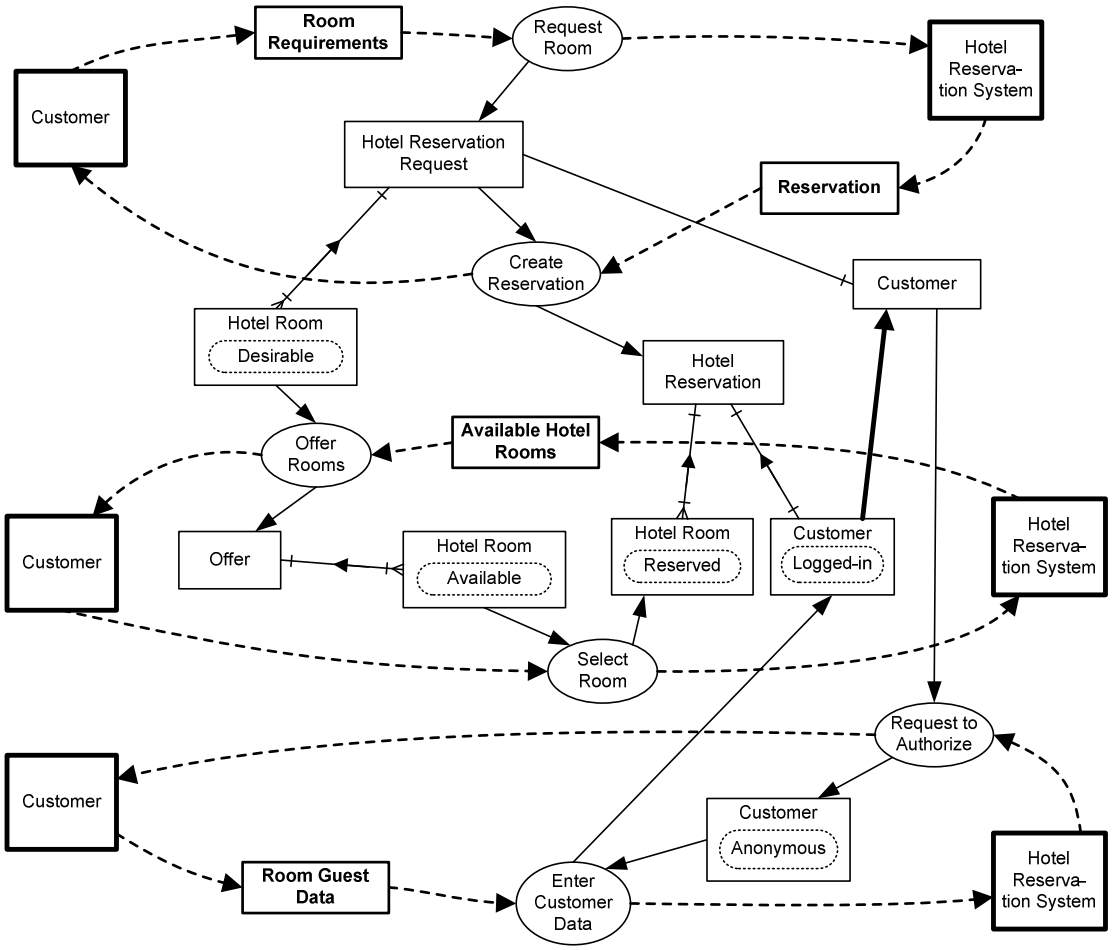

Figure 5. Example of a synchronization pattern

as well. The first underlying loop is necessary for offering available rooms and selecting of a desirable room. Creation of *Customer*[*Logged-in*] object requires to initiate Request to Authorize and Enter Customer Data actions that are represented by the second underlying loop.

B. Selection pattern

The *Selection* pattern can be expressed using a composition of two different sequences between the same two actors. It represents two alternative outcomes of a service request that can be selected by service provider. Two possible ways of replying by service provider are mutually exclusive. Only one type of response is expected by a service requester. If the first alternative is rejected, then the performer is trying to invoke the second alternative. The selection pattern was previously published and it can be found in [11]. It is similar to branches in UML [16]. The selection pattern is represented graphically in Figure 6.

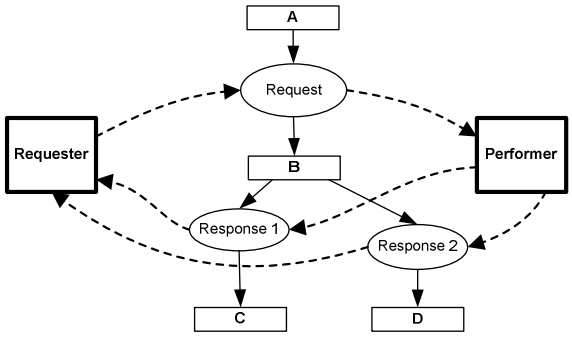

Figure 6. Selection pattern

Response 1 and Response 2 are two exclusive actions of a performer. If Response 1 is initiated, then a pre-condition class object B is removed and a post-condition class C is created. If Response 1 has failed, then Response 2 is triggered, which reclassifies object B to D. The example of selection pattern is represented in Figure 7.

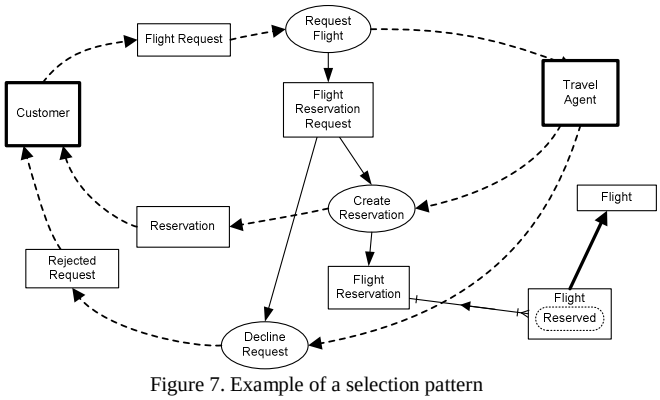

Figure 7. Example of a selection pattern

The selection pattern in the presented example can be explained as follows. The *Flight Reservation Request* is created and then it is reclassified into *Flight Reservation* in the *Create Reservation* action from the *Travel Agent*. If *Travel Agent* cannot create a *Flight Reservation*, then the alternative action of Decline Request is taking place. In this case, the *Flight Reservation Request* is terminated and a flow of Rejected Request is sent to the *Customer*. This action allows the *Customer* to reiterate the search again.

C. Enclosing pattern

An *enclosing pattern* is defined by a primary and a secondary interaction loop between requester and performer. In carrying out the work, a performer may play the role of requester in the secondary interaction loop by initiating further interactions. In this way, a network of loosely coupled actors with various roles comes into interplay to fulfill the original service request. Organizational systems may be composed of several interaction loops, which are delegated to more specific components. Enclosing pattern is similar to the enclosing of a transaction [4]. An enclosing pattern is represented graphically in Figure 8.

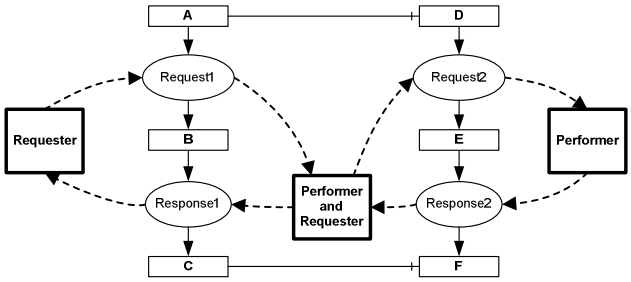

Figure 8. Enclosing pattern

The primary interaction loop consists of Request1 and Response1 actions. For the creation of object B in the primary loop, it is necessary to create its property E in the secondary loop. The reclassification of object B to C requires the removal of E and creation of F. So, the enclosing loop cannot be completed if the secondary loop is not finalized.

IV. CONCLUDING REMARKS

The goal of this paper was to demonstrate how the suggested service-oriented constructs can be used for the creation of three different modeling patterns. Traditionally, modeling patterns are constructed taking into account just dynamic aspects of business processes. The advantage of the suggested modeling constructs is that they allow integration of both static and dynamic aspects. One of the main contributions of this paper is the presentation of two new patterns such as synchronization and enclosing. The separation of static and dynamic details of the presented patterns creates fundamental difficulties for two major reasons:

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1) Since the static aspects must somehow be compensated by using dynamic constructs, the number of patterns becomes bigger than is really necessary. Sometimes, the pattern differences are difficult to understand and they are visually unrecognizable by business experts.
2) If static aspects are not taken into account, then patterns will become more complicated to use them for the purpose of blending enterprise and software engineering.

The semantics of service architecture can be defined by using one or more interaction loops. Each interaction loop is composed of creation, termination or reclassification actions. By matching the interaction dependencies from requesters to providers, one can explore opportunities that are available to different actors. The static dependencies define complementary semantic details, which are important for reasoning about service interactions. The examples of corresponding behavior are presented in this paper as well. The novelty of such a way of modeling is that it enables integration of static and dynamic aspects, which are important to maintain a holistic representation of information system specifications. Service-oriented way of modeling is computation-neutral. Diagrams follow the basic conceptualization principle in representing only computationally neutral aspects that are not influenced by any implementation solutions. Since computation-neutral representations are easier to comprehend for business experts as well as system designers, they facilitate understanding and can be used for bridging a communication gap among different types of stakeholders.

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A Case Study on E-marketplace Basic Functions

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***Abstract*—This paper conducts a case study to demonstrate that the success of EMPs corresponds to their basic functions. Through selected cases (Knowledgestorm.com, Dell.com, Taobao.com, Alibaba.com, Wire-and-cable.cn, E2open.com, Bolero.net, Tradecard.com, Ariba.com), this paper shows that the proposed basic function set will be able to increase, if not guaranteed, the success of future EMPs. The main contribution of this paper is that it has verified that there exists a basic function set of electronic marketplace such that the subset of the basic function set can be utilized to customize any particular type of electronic marketplace.**

Keywords—electronic marketplace;case study; interoperability.

I. INTRODUCTION

Electronic marketplace (EMP) [4][9][10] is a very important research area in the development of e-commerce technology. It is an inter-organizational market information system, or a common business information space that allows participants to do business through its provided functionalities [10]. Although EMPs becomes now more mature and stable, the increasing demand for online business calls for even higher interoperability between EMP participants and drives the need for more cost-effective EMPs [11]. To construct a higher interoperable EMP, the formula I = F/C proposed by Guo [11] offers an essential EMP theory such that business interoperability (I) between EMP participants can be computed as a ratio between the number of effective EMP functions (F) and the coordination costs (C) of providing EMP functions. This implies that, the quantity and quality of EMP functions is an important measure of EMP interoperability.

To understand the constituent of EMP functions for the existing EMPs, An and Guo [2] made a historical survey on EMP functions. This survey found there exists an EMP Basic Function Set (BFS) distributed in a suggested EMP functionality classification model [12]. Based on the finding, it is argued that all EMPs as a whole must present such a BFS.

This paper agrees that there exists a BFS for all EMPs as found in the work of [2]. However, it further assumes that any type of individual EMP is constructed by a subset of BFS and such a subset is dynamically changing. The goal of this paper is to verify these two assumptions through a method of case study.

In the rest of this paper, Section II discusses the related work. Section III introduces the method of case study used in this paper. Section IV makes case studies along with the research result. Section V, validates and interprets the findings. In Section VI, the limitation of this research as well as some implications are presented. Finally, the paper is summarized and a conclusion is made such that a successful EMP construction will contain a subset of EMP BFS adapting to any dynamic context.

II. RELATED WORK

A. EMP Basic Function Set

The research in [2] found a basic function set (BFS) of EMP through a historical literature event methodology [11] by collecting required historical data about EMP functions to Guo's EMP functionality framework [12], which, in essence, is an EMP function classification. This BFS establishes an interrelationship between EMP basic functions and function published year as well as function counted quantity. In BFS, each function has its own tendency curve and vertically belongs to a higher leveled function category. The purpose of BFS research is to show that functions are the indispensable elements for EMP construction, and that the evolved basic functions of EMP are meeting the demand for more interoperable EMP requirement.

B. EMP Types

While there exists a BFS of EMP, how an individual EMP is clearly typed by allocating a subset of the basic functions out of BFS still remains unknown. In practice, observations are made that an EMP can often be typed based on Electronic Market (EM) business model, industry scope, ownership, and technical construction method.

1) EM business model

Early in 1998, Timmers defined an EM business model as an architecture for product, service and information flow [35]. It contains three components [1] of content (exchanged goods and information), structure (the links between transaction stakeholders), and governance of transactions (the control of the flows of goods, information and resources). Dai and Kauffman [7] thought an EM business model consists of three dimensions of market functions, management needs, and technological adaptation. Though different, EM business models are mostly devoted to providing more mature functions for online business [10]. To make distinctions, Chou [5] divides online business participants into individuals, corporations and governments. This

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enables to characterize EMPs based on transaction relationships between consumer, business and government [20]. For instance, EMP can be typed by the participant relationships of business-to-business (B2B) [14][22][25][27], business-to-consumer (B2C) [16][23][24][33], business-to-government (B2G) [5][8], and consumer-to-consumer (C2C) [21] [28].

2) Industry scope

EMPs can be classified as either horizontal or vertical [17] [29]. A horizontal EMP connects participants across industries. A vertical EMP serves the needs of a particular industry sector such as automotive, chemical, construction or textiles. Adopting a vertical EMP can reduce the cost and time along with a supply chain, thus enhancing working efficiency. According to [30][31], industries can be sorted as shown in Table I.

TABLE I. CLASSIFIED INDUSTRY WITH TYPICAL CASES

Industry Scope	**Typical Cases**
IT products and services	Intel, Dell, IBM, Ariba
Electronics industry	FastParts.com
Aviation	Exostar, Boeing
Transportation and logistics	PartsBase, Sailnet
Healthcare and pharmaceutical	Neoforma, Promedix
Agriculture	KDM International
Basic materials	DOW, Newmont
Construction and building	McCarthy
Education and knowledge	Wiley, McGraw-Hill
Financial services	Tradecard.com
Energy	ConocoPhillips, Shell
Hospitality	Ctrip
Forestry and wood	National lumber
Heavy manufacturing	BHP Steel
MRO/Office supplies	Qunaer
Industrial equipment and services	Qatarmark
Professional services	Delphion,Sportline
Retail/CPG/Wholesale	Alibaba ,taobao ,Sears
Government /Legal services	Go-business
Others	Google

3) Ownership

Unlike traditional market that is naturally existing, any EMP has its owners. The ownership of any EMP classifies existing EMP into private EMP, community (consortia) EMP and public EMP [6][11][18][19]. A private EMP is owned by a single legal person and is either buy-side or sell-side. A public EMP (also called an open EMP) is owned by an independent third-party other than buyers or sellers. A community EMP is owned by several key buyers or sellers or their established consortia, for example, Covisint, originally owned by three big automakers of Ford, GM and Daimler Chrysler.

4) Technical construction methods

An EMP is always technically constructed by a set of functions serving certain e-commerce purposes such that functions serve to satisfy a specific set of EM requirements. Function-based EMP construction has long been studied. Bakos [4] thought an EMP consisted of functions of matching of buyers and sellers, transaction facilitation, and institutional infrastructure. Wang and Archer [36] suggested that EMP functions are classified into market-oriented functions (aggregation and match-making) and collaboration-oriented functions (transactional and strategic). Researches of [3][6][32] stated that market-oriented functionalities construct a competitive markets while collaboration functionalities construct supply chains that support and streamline the business processes between business partners.

Recently, Guo et a. [13] proposed an EMP technical construction method. They thought that an EMP is a particular breakdown of a subset of EMP functions in BFS [2]. A particular subset of BFS is an EMP technical construction type. All types can be enumerated as specific EMP technical construction methods, which are: e-catalogue, e-shop, e-portal, e-hub, e-switch, e-integrator, and e-merger.

III. METHODOLOGY OF CASE STUDY

A. EMP case modelling

An EMP case can be modelled for study based on EMP types. EMP type classifications help model formation, where a case can be modelled as a multitude of EMP types from several angles. For example, Skjott-larsen et al. classified EMP into four categories: horizontal and vertical EMP; buyer-side, sell-side and neutral EMP; fixed pricing and variable pricing marketplace; open and closed EMP [34]. Ordanimi and Pol proposed a classification of relation structure, degree of diversification and transaction operating mechanisms [26]. Kaplan and Sawhney classified EMP based on what and how businesses buy [17]. These analytical methods are useful yet fail to provide us with mutually exclusive EMP function sets that formulate strongly typed EMPs. To provide a strongly typed EMP, this paper selects four classic variable factors (technical construction method, ownership, business model and industry scope) shown in the Fig. 1 to reconstruct to model an EMP – a four dimensional model.

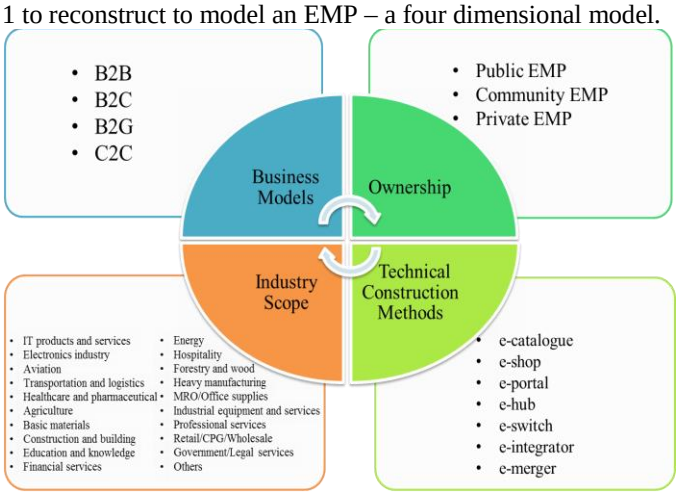

Fig. 1. EMP construction model

Based on the proposed EMP construction model, nine representative cases, shown in Table II, are selected.

TABLE II. TYPICAL CASES WITH FOUR MODEL VARIABLES

Construction Method (V_1)	Ownership (V_2)	Business Model (V_3)	Industry (V_4)	**Typical case** (URL)
e-portal	Public	B2B	IT products and services	knowledgestorm.com
e-portal	Private	B2B	IT products and services	dell.com
e-portal	Public	C2C	Retail/CPG/Wholesale	taobao.com
e-portal	Public	B2B	Retail/CPG/Wholesale	alibaba.com
e-portal	Public	B2B	Industrial equipment and services	wire-and-cable.cn
e-hub	Public	B2B	IT products and services	e2open.com
e-switch	Public	B2B	IT products and services	bolero.net
e-integrator	Public	B2B	IT products and services	tradecard.com
e-merger	Public	B2B	IT products and services	ariba.com

B. Method to case analysis

Two concepts are introduced to express the relationships between collected functions in the nine studied cases and BFS.

1) Union of functions (U): The union of all the functions from the nine cases.

2) Intersection of functions (I): The intersection of all the functions from the nine cases.

If U and I both belong to BFS between 1986 and 2012 [2], then it is concluded that BFS is a complete function set for any EMP to customize its construction. To find the functions historically appeared in nine cases, Wayback Machine [46] is adopted as the history web archival website, where all functions from 1986 to 2012 are collected. Since the history of EMP is as short as Web history, the most recorded Web pages at [46] are pretty robust in recording Web history and sufficient to represent the whole EMP development [11][13].

IV. CASE STUDY AND ANALYSIS

A. Case study

The nine cases, shown in Table II, are studied. They are all well-known and representative for EMP construction modelling as illustrated in Fig. 1. To analyze them, the nine cases are divided into two control groups. Control group one consists of three comparative samples, shown in Tables III, IV and V, with the same V_1 (e-portal) but different V_2, V_3, and V_4. Control group two, shown in Table VI, consists of different V_1, but same V_2, V_3, and V_4.

TABLE III. FIRST SAMPLE IN CONTROL GROUP ONE

V_1	**V_2**	**V_3**	**V_4**	**Cases**
e-portal	Public	B2B	IT products and services	Knowledge storm.com
e-portal	Private	B2B	IT products and services	Dell.com

TABLE IV. SECOND SAMPLE IN CONTROL GROUP ONE

V_1	**V_2**	**V_3**	**V_4**	**Cases**
e-portal	Public	B2B	Retail/CPG/Wholesale	Alibaba.com
e-portal	Public	C2C	Retail/CPG/Wholesale	Taobao.com

TABLE V. THIRD SAMPLE IN CONTROL GROUP ONE

V_1	**V_2**	**V_3**	**V_4**	**Cases**
e-portal	Public	B2B	Retail/CPG/Wholesale	Alibaba.com
e-portal	Public	B2B	Industrial equipment and services	Wire-and-cable.cn

TABLE VI. CONTROL GROUP TWO

V_1	**V_2**	**V_3**	**V_4**	**Cases**
e-hub	Public	B2B	IT products and services	E2open.com
e-switch	Public	B2B	IT products and services	Bolero.net
e-integrator	Public	B2B	IT products and services	Tradecard.com
e-merger	Public	B2B	IT products and services	Ariba.com

B. Analytical Results

The cases of control group one (see Knowledgestorm [37], Dell [38], Wire-and-cable [39], Taobao [40] and Alibaba [41]) shows that (1) if the technical construction method is the same (e.g., e-portal in control group one), the EMP function set adopted has commonality for all EMPs even if they have different variables of business model, industry scope and ownership; and (2) Some functions appear not belonging to the e-portal EMP type and belonging to e-integrator type, which means that e-portal is evolving to a more sophisticated EMP type.

The cases control group two are selected with different technical construction methods, shown in E2open [42], Bolero [43], Tradecard [44] and Ariba [45]. The analytical result shows that different technical construction methods have different subsets of BFS for EMP despite of the same business model, industry scope and ownership. This verifies that each EMP technical construction method has its own subset of BFS for EMP construction.

V. VALIDATION, INTERPRETATION AND IMPLICATION

With the validation from the two control groups, functions are proven to be the indispensable elements for EMP construction. Furthermore, when compared with other three EMP construction classifications, technical construction methods based on functions have their own superiorities.

In order to meet the demand for highly interoperable and cost-effective EMP, Attentions should be more paid to basic functions. According to the studied cases, a best fit (least squares) linear regression is used to predict the tendency of all functions till the year of 2020.

FORECAST (x, known_y's, known_x's) (1)

The parameter x shown in (1) must have a numeric value, known_y's and known_x's must be arrays or cell ranges that contain equal numbers of numeric data values. It shows clearly different results in Table VII separately in 2014, 2017 and 2020. Specifically, the function of license agreement will be the most popular one (11.81) in 2014. However, social network system (marketing) will replace license agreement as the top function (13.90 and 18.40) in both 2017 and 2020. With SPSS forecast results of the two basic functions shown in Fig.2, we can further validate this prediction.

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TABLE VII. FORECAST RESULTS

Function	2014	2017	2020	Function	2014	2017	2020	Function	2014	2017	2020
Catalogue(marketing)	10.30	11.61	12.92	Billing	5.19	5.79	6.39	Credit Management	5.19	5.88	6.56
Advertising	11.54	13.10	14.65	Information Standardization	4.95	5.42	5.89	Availability	10.00	11.29	12.57
Social Networking Systems(marketing)	9.40	13.90	18.40	Social Networking Systems(sourcing)	5.10	6.20	7.30	Demand and Supply Forecast	3.16	3.96	4.76
Product Recommendation	8.76	9.90	11.05	Currency Exchange	1.13	1.15	1.17	Integrity	11.04	12.48	13.91
Search	10.51	11.95	13.39	Warehousing	1.00	1.00	1.00	Confidentiality	11.32	12.88	14.44
Catalogue(sourcing)	10.42	11.87	13.31	Transportation	3.85	4.30	4.75	E-police	3.55	4.00	4.45
Product Channel Analysis	10.02	11.71	13.40	Tracking	3.85	4.30	4.75	Privacy Protection	11.75	13.27	14.80
Financing	6.55	7.56	8.57	Customs Clearance	3.90	4.47	5.04	Intellectual Properties	8.43	9.62	10.81
Supplier Comparison	7.19	8.29	9.39	Quality Inspection	4.98	5.67	6.37	Duties and Taxation	5.13	5.75	6.37
Price Comparison	3.63	4.25	4.87	Insurance	5.00	5.58	6.16	Consumer Protection	10.12	11.44	12.76
Product Comparison	6.31	7.17	8.02	Order Management	6.67	7.56	8.45	License Agreement	11.81	13.38	14.94
Supplier Credit Management	4.68	5.57	6.46	Call Center	2.35	2.62	2.88	Cybercrime	9.79	11.59	13.38
Online Robot(helpability)	3.36	4.43	5.50	Online Robot(after sales services)	5.00	8.00	11.00	Jurisdiction	8.46	10.08	11.69
Help	11.79	13.47	15.16	FAQ	8.92	10.19	11.45	Trademark Protection	11.49	13.05	14.61
Product Review	11.64	13.24	14.84	Instant Message	2.37	2.36	2.35	Repair	1.00	1.00	1.00
Marketplace-made Regulations	11.75	13.27	14.80	Social Networking Systems(after sales service)	2.60	3.50	4.40	Other Laws and Regulations	10.96	12.23	13.51
Selling Products and Services	5.15	5.76	6.37	Digital Copyright Declaration	10.41	11.78	13.16	Payment	5.19	5.79	6.39
Buying Products and Services	3.65	4.04	4.42	Business Process Integration	3.71	4.08	4.46	Systems Integration	2.72	3.02	3.32
Value-added Services	3.86	4.38	4.90	Return	2.43	2.73	3.03	Application Integration	3.71	4.08	4.46
Auction	2.46	2.73	2.99	Claim	3.72	4.23	4.75	Service Integration	3.19	3.29	3.38
Inquiry	3.36	3.57	3.77	Customer Tracking	6.08	6.84	7.60	Replacement	3.80	4.40	5.00
Offer	3.36	3.57	3.77	Customer Behavior Analysis	6.28	7.18	8.08	Document Integration	3.48	3.72	3.96
Counteroffer	2.33	2.51	2.69	Marketing Channel Analysis	7.24	8.43	9.62	Vocabulary Integration	3.34	3.51	3.69
Acceptance	3.86	4.29	4.73	Supplier Analysis	7.17	8.07	8.97	Collaborative Design	3.13	3.75	4.37
Contracting	2.33	2.51	2.69	Product Comparison Analysis	7.09	8.06	9.02	Product Sharing Information	6.54	8.03	9.53
Tendering(Inc. RFQ)	1.00	1.00	1.00	Product Review Analysis	9.18	10.54	11.90				

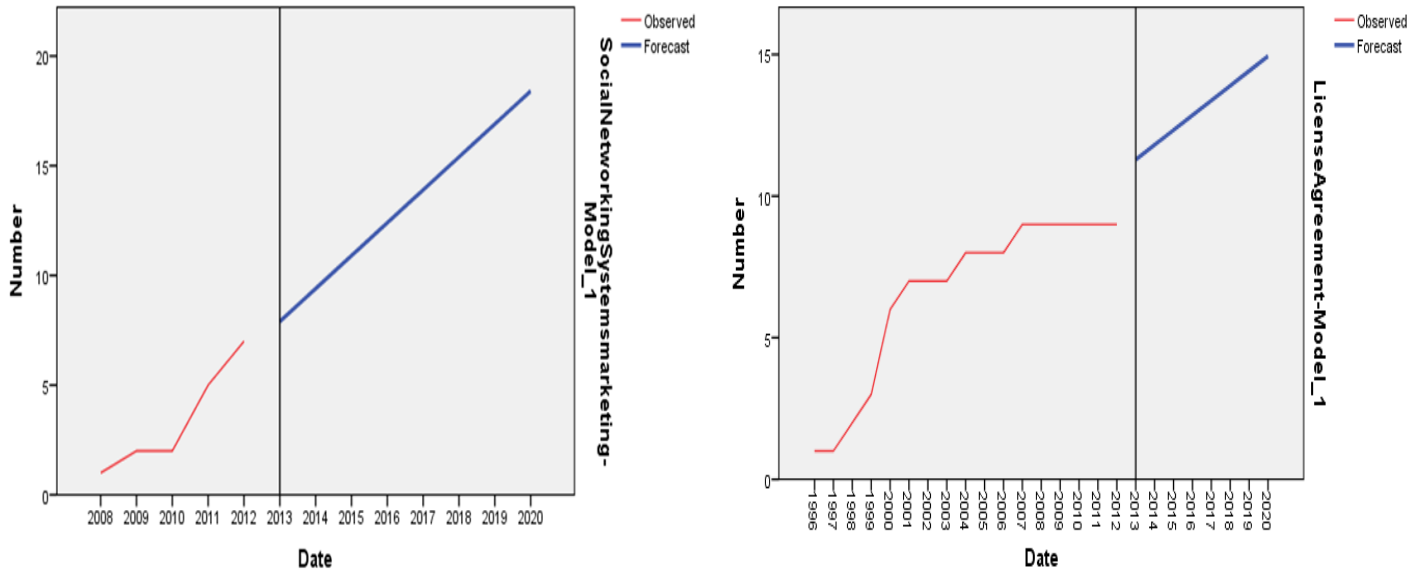

Fig.2 .Social network system (marketing) and license agreement SPSS forecast results

VI. LIMITATIONS AND IMPLICATIONS

Nowadays, smartphones and computers are intimately connected, and this new relationship will perhaps reveal some limitations of our study, because the functions we covered in this study are primarily based on official websites not mobile applications. For instance, take the case of Alibaba; QR Codes function is not included in our study. Moreover, in the case of Taobao, the emerging Taobao University is also an important function, which produces a great number of e-commerce specialists. Similarly, Ariba University is able to help the participants with the skills and practices that will allow them to take advantage of all the benefits of the Ariba EMP solutions. Nonetheless, given the scope of this paper, the nine selected cases are very representative.

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This paper has several important implications for the future development of EMPs. First, finding and updating the known EMP (BFS) is important. Second, mastering technical construction methods is a key to simplify the building of various types of EMP. Third, the EMP construction model has provided a guideline of customizing a particular EMP based on the given BFS and the forecasted functions.

VII. CONCLUSIONS AND FUTURE WORK

In a nutshell, the case study done in this paper has validated the EMP BFS proposed in the previous research [2] and also predicted the future development of each function until the year of 2020. Employing the methodology of EMP construction model proposed in this paper and the notions of union and intersection, all functions have been collected from the nine cases and have been found in the BFS. This research is a more comprehensive study, which has been combined with the previous literature-based research [2], to reflect the typical customer requirements and inherent functionalities for a successful EMP. It aims at higher interoperability and cost-effectiveness that meet the demand of a successful EMP. In future, the EMP construction customization will be studied based on the given BFS.

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Bringing Flexibility into Dynamic Process Change

The Process Re-execution Approach

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***Abstract*—The business process must reflect changes in the environment, therefore, the adaptation of the process model or the particular process instance is essential. The state compliance criterion has been introduced to check that dynamic process change is correct and does not lead to soundness problems or run-time errors. In some cases, however, the process instance must immediately be migrated to the changed model or updated itself. Hence, the strategy of coping with the non-compliant process instance must be chosen. This paper presents the process re-execution approach which effectively implements the state compliance test. The re-execution algorithm makes it possible to defer the suitable activities and use them later, thus offering a flexible solution for treating the non-compliant process instances. Moreover, a custom strategy of treating can be used based on the full context of the activity that caused the inconsistency. In many cases, the process re-execution approach enables to treat the non-compliant process instance automatically and thus the total number of instances that are successfully migrated is increased.**

Keywords-flexibility; process change; process evolution; state compliance; re-execution.

I. INTRODUCTION

Quick reaction to changes in the environment (like new technologies, new laws and new market requirements) is one of the crucial abilities of every enterprise. Different business goals, modifications of organizational structure, or legacy changes have influence on procedures and activities within the enterprise. Business processes, which are modeling these procedures and capturing the way that particular goals are achieved, must reflect these changes and adapt to them. As a result, Process-Aware Information Systems (PAIS) must offer tools for such adaptations and ensure that the dynamic changes are applied correctly [1].

We can distinguish different ways of the process change. During long-running processes it is sometimes necessary to deviate from the pre-specified process model and thus the correct behavior of one specific process. In contrast, the evolution of the whole process model may be required in order to accommodate changes or refine the model quality. Changes can be focused on the control logic of the process. For example, some of the process activities are added or deleted. Changes can also affect the data flow of the process by deleting some data edges or inserting new data variables. Control flow adaptation may also be connected with data changes.

In all these cases, the challenge is to avoid errors and inconsistencies caused by dynamic change. Approaches which guarantee a sound and correct process model after adaptation are presented in [1][2][3][4][8]. One well-known criterion used by many approaches is state compliance [4]. If the process instance is non-compliant, it cannot be migrated to the new model (for the case of model evolution). The ad hoc change of specific non-compliant process instance cannot be applied either. One possible solution for the evolution is to leave the non-compliant process instance continuing its execution on the original model. However, this means that the process instance cannot benefit from future model changes. For this reason, it is necessary to find strategies [3][6] to cope with the non-compliant instances.

The goal of this paper is to present a different approach of process execution that efficiently implements the essential state compliance testing, on the one hand, and offers better flexibility in treating non-compliant process instances, on the other hand. The approach is based on the idea that the process instance is always re-executed from the beginning in order to perform the next activity pre-specified in the model. This is useful in the situation in which the process model is changed because the process instance is executed on the adapted model, thus making it possible to verify whether instance migration is possible. Moreover, the first activity causing the process instance to be non-compliant can be found. The activity data collected by the run of the process can be taken into account when choosing a strategy for treating the process instance.

The paper is organized as follows. According to literature, Section 2 includes the state compliance definition as well as an overview of strategies for dealing with non-compliant instances. Section 3 introduces the process re-execution approach that we have developed during our research. The contribution of re-execution approach can be found in Section 4. Section 5 contains our experience with the re-execution approach in practice. Related work is described in Section 6 and Section 7 concludes this paper with a summary and outlook.

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II. ENSURING THE CORRECTNESS OF PROCESS CHANGE

A. State compliance

The basic requirement for the process dynamic change is to ensure the soundness property of the changed process model. This can be achieved by the application of reachability analysis on the process model represented by workflow net as described by Weske [2].

If we want to decide whether the process instance can be correctly relinked to the changed model, we must establish a correctness notion. We can distinguish two groups of correctness criteria [1]. The first group includes criteria based on graph equivalence. One example might be the inheritance relation criterion used in WorkFlow nets [11]. The second group contains criteria founded on process execution trace equivalence. One of the well-known criteria from this group is state compliance. For further consideration, we chose this criterion because our approach is based on replaying the process execution trace.

In [8], state compliance is defined as follows. Let $I = (M, \delta)$ be a process instance running on sound model M with execution trace δ. Assume M' is another sound model and M is transformed into M' by the change Δ. Then, I is state compliant with M' if δ is producible on M'. State compliance is based only on a process instance execution trace and presumes no specific process modeling language.

Assume, for example, process model M which defines a sequence of two activities A and B. We change this model into model M' by inserting activity X between activity A and B. Further, we have two process instances I_1 and I_2 based on model M. In instance I_1 activity A is running, thus I_1 is state compliant with model M' because its execution has not entered the changed region yet. In contrast, in instance I_2 activity B is running. However, model M' pre-specified that new activity X must run before B and thus the execution trace of I_2 cannot be produced on M'.

According to the Rinderle-Ma et al. [3], traditional state compliance is too restrictive in connection with loop structures, thus relaxed state compliance is established in order to increase the number of process instances which can be migrated to a changed model. The approach is based on the idea that we logically hide information about activities from previous loop iteration and the modified loop-purged trace of process instance is then used to check state compliance. The approach is also applicable to nested loops [3].

We also need to ensure the correctness of data flow after model adaptation. Compliance conditions for data flow change are defined by Rinderle-Ma [9].

B. Strategies for non-compliant process instances

The state compliance check can uncover process instances which have already progressed too far and their relinking to the changed model must be prohibited because of possible soundness violations or data flow errors. In some cases immediate on-fly migration may be requested, therefore, a solution for the non-compliant process instance must be found. Consider, for example, legacy changes or unexpected situations while treating a patient.

There are three widespread strategies described by Reichert and Weber [8].

1) The partial rollback: This strategy is based on the idea that necessary activities are undone and the process instance is reset into the compliant state. This strategy is closely connected with the execution of compensation activities [4]. Consider, for example, that activity *book a trip to the sea* was completed. The travel agency, however, decided to cancel the trip due to lack of interest. As a consequence, the compensation activity in order to cancel the respective booking is performed.

2) Delayed migration: This strategy assumes that the non-compliant process instance becomes compliant again after a certain time. Consider the changes related to a loop body. Although the current iterration of a loop progresses too far, the next iteration fulfills the state compliance. Hence, the migration will finally be successful.

3) Adjusting change operations: The idea of this strategy is to adjust the intended change itself instead of reseting the process instance state. Consider the insertion of activity A. If we adjust the position of A without violating the data flow correctness or the other semantic constraints defined by the process model, the number of migratable instances is increased.

III. PROCESS RE-EXECUTION APROACH

A. Process re-exectuion algorithm

First, we define an abstract machine which simulates the execution of particular process instance I running on the given process model M and then we describe the way that the process re-execution is performed.

Let A be a set of unique activity labels. Further, let F denote a set of unique activity flow labels which are used to model a situation in which the execution is split into more parallel branches. The flow can be also described as a token in the terminology of Petri nets [14]. Let V be a set of data variable names and D denote a set of possible values of these data variables.

Next, the machine has a memory tape on which data about already performed activities are stored. This tape represents the partial execution trace of simulated process instance I. The tape has one head which can be used both for reading and writing and the current position of the head denotes the data of performed activity which can be used to support re-execution. We define the tape as the sequence $\delta_I = <pa_1, pa_2, \ldots, pa_k>$ where the performed activity is defined as $pa_i = (f, a, DI, DO)$, $f \in F$, $a \in A$, $DI \subseteq V \times D$, $DO \subseteq V \times D$ and $i = 1, \ldots, k$, $k \in N$. DI stands for data inputs and DO denotes data outputs of the performed activity.

The established abstract machine works in two modes of execution. The *real mode* is defined as follows. The machine reads the activity that is pre-specified in process model M and creates a respective work item. A source is chosen and then the activity is performed. The data about current flow, activity label, data inputs and outputs are stored on the machine tape at the position where the head is situated.

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The *silent mode*, in contrast, is used during the re-execution of the process instance. The abstract machine reads the activity label from model *M*, although no work item is created. Instead of this, a subsequent test is performed. Assume that the machine is executing activity *a*, the current flow label is *f* and we have a set of current data input variables *di*. If the machine head reads quadruple *(f, a, di, do)* from the tape, the activity data output *do* is used as a result of the activity being executed. This is why we say that activity has been performed "silently".

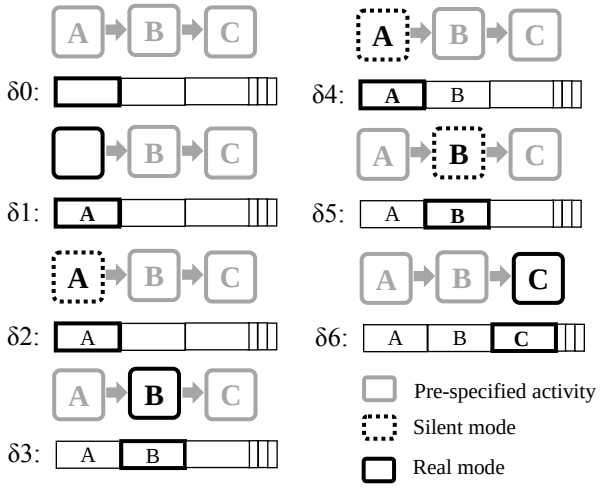

Figure 1. A scheme of the process re-execution.

Finally, we can define the process re-execution algorithm, which is illustrated in Figure 1. At the beginning of process instance execution, the abstract machine is in *real mode* and has an empty tape. Firstly, the machine reads activity *A* according to process model *M*. Once *A* is completed, the machine stores the appropriate data on the end of the tape. The next step of process execution, however, does not focus on the following pre-specified activity *B*. Instead, the process instance re-execution is started. The abstract machine switches into the *silent mode*, the tape is rewound and the execution starts from the beginning again.

The machine acts according to *silent mode* definition. The result of the simulated activity is taken from the current field on the tape and then the head is shifted forward. The machine continues with the next pre-specified activity *B*. We have, however, an empty field under the head. Therefore, the *silent mode* is toggled to the *real mode*. The change of the execution mode means that we re-executed the first performed activity and are now proceeding with the "real" execution. After the completion of activity *B*, the re-execution is repeated. It is important to highlight that the state of the process instance is not held throughout the execution. Instead of this, it is always reconstructed after finishing each individual activity.

B. Process re-exectuion on a changed process model

We will now investigate the process re-execution approach in the context of a changed model. Assume that process model *M* is transformed into model M' and instance *I*, which ran on M, is now relinked to changed model *M'*. Our abstract machine enters *silent mode* and begins to simulate the activities of *I* according to data stored on the tape. The machine detects a difference between the pre-specified activity and its inputs, on the one hand, and the performed activity on the current position of tape, on the other hand. We have already detected that process instance is not compliant with modified model M'. To flexibly cope with this inconsistency, the abstract machine interrupts execution and triggers the event which can be handled in order to treat process instance *I*.

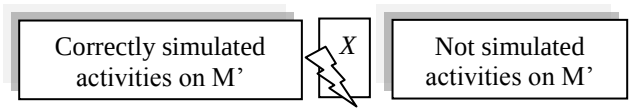

Figure 2. The tape content during interrupted execution.

We can divide the tape into three segments as depicted in Figure 2. The first segment of the tape contains performed activities which are correct in the context of modified model *M'*. The second segment includes activity *X* which caused the inconsistency; the third segment comprises the rest of the performed activities that have not been simulated but may be potentially reused in sequel. The state machine removes the second and third segments from the tape and attaches them to the interruption event. The interruption event is a data structure that contains all the information about the interruption. If there is no treatment specified, the machine can choose a default strategy, or the event is sent to the system administrator to warn that the process migration has failed. Due to the triggered event, we get the full context of the inconsistency and, together with the knowledge about the semantics of the performed model change, are able to flexibly solve this situation.

In some cases, it is helpful to defer suitable activities from the third segment of the tape and use them later, because we can reduce unnecessary loss of work. For this reason, we designed the Store of Deferred Activities (SoDA). The SoDA can be used for these purposes:

- We can search deferred activity and use it during custom-process instance treatment.
- The machine itself may match suitable deferred activity and fill the current empty field on the tape in order to continue in silent mode execution. In other words, the deferred activity may be automatically used later.
- To dynamically modify the result of the activity that has already been completed to perform dynamic data flow change.

Further, we define the SoDA formally. Let PA_I be a set of activities that have already been performed. UA_I denotes a set of performed activities whose outputs have been adjusted by the process participant and DA_I stands for a set of *deferred activities* and $DA_I \subseteq PA_I \cup UA_I$. Then, the SoDA can be defined as triple $S_I = (DA_I, <, m)$ where $<$ is the partial order relation on DA_I and m is a matching function. The matching criteria must be unique, thus the activity label,

flow label and also data inputs of performed activity are taken into account when matching function *m* is scanning the *SoDA*. If deferred activity *ad* is found, the predecessor test is performed. If and only if there is no deferred activity *ad'* < *ad*, then *ad* is matched and returned from function *m*.

We actually need to change the re-execution algorithm in order to integrate the established SoDA as follows. At first, the abstract machine looks into the SoDA and with the help of matching function *m* tries to find suitable deferred activity. If no such deferred activity exists, the machine acts according to the *silent mode* definition. If matching function *m* succeeds and the current tape value is empty, the deferred activity is moved from SoDA to a current position on the tape and the *silent mode* proceeds normally. Finally, if matching function *m* is successful and the head of our machine reads the data that vary from the matched deferred activity in output data only, then the machine triggers the interruption event and the detected data change can thus be handled properly. Moreover, if no handler is provided, the default handler is chosen which moves the found activity from the SoDA to the current field of the tape and the *silent mode* continues.

TABLE I. THE ABSTRACT MACHINE STATES

The abstract machine				
Meaning	***Tape***	***SoDA***	***Event***	***Performed action***
Real mode	Empty	Not found	No	Do activity
Silent mode	(A,i,o)	Not found	No	Use *o*
Activity reuse	Empty	(A, i, o)	No	Use *o*
Data change	(A, i, o)	(A, i, **x**)	Yes	Custom Use **x**
Data change consequence	(A, **x**, o)	Not found	Yes	Custom Search A Do A
Newly added/deleted activity	Not found	Not found	Yes	

Table I clearly shows the possible states of the abstract machine, the meaning of these states and the corresponding action that can be performed. Note that the flow label is omitted because of the place.

As we can see, the first four rows of the table were previously described. The data change consequence (the fifth row) is characterized by the partial compliance on the activity label. However, the values of input data variables differ; therefore, the interruption event is triggered and we can handle it in three different ways:

- It is possible to define a custom handler.
- We can try to find the suitable deferred activity in the SoDA.
- We may allow the activity to perform in the *real mode*.

The last row of the table describes the abstract machine state in the situation where the newly added or deleted activity is detected. Note that to identify whether it is insertion or deletion of the activity, we must know the semantics of the change, because we are only able to find out that there is an inconsistency.

Now, we demonstrate the re-execution approach by means of an example. Assume process model M_2 as depicted in Figure 3 and process instance *I*, which is currently running on M_2. Activities *A, B* and *C* successfully finished.

Further, we will change model M_2 to M_2' by inserting two activities, *X* and *Y*, and one data binding between them. The abstract machine starts re-execution on adapted model M_2' and according to the re-execution algorithm switches into *silent mode*. Activity *A* is found on the tape and that appropriate stored output data are used. Then, we shift to the next newly added activity *X*. The SoDA is empty and the abstract machine detects inconsistency. According to the model, activity *X* should be performed. However, the machine head reads activity *B*. As a result, the abstract machine triggers the interruption event to allow the handling of the unexpected situation.

The re-execution algorithm has actually performed a state compliance check and has detected that process instance *I* is not compliant with adapted model M_2'. Moreover, we have the full context of this situation. The performed activities from the past are on the machine tape. The event contains activity *X*, which caused interruption, as well as the rest of the activities which have been performed and can potentially

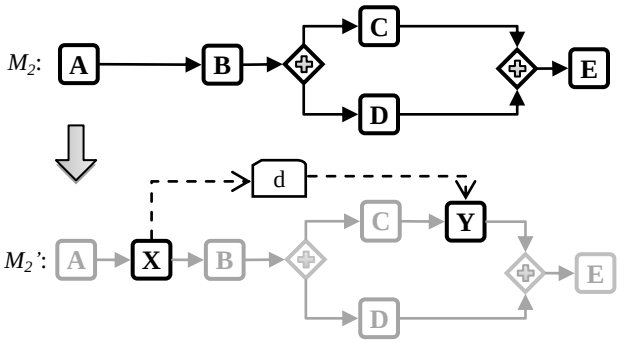

Figure 3. The adaptation of model M_2.

be used to treat non-compliant process instance *I*.

Assume that we have no special strategy to cope with this situation and put the list of already performed activities into the SoDA. Then, we let activity *X* perform in the *real mode*. The respective data are stored on the tape. Then, the abstract machine toggles back to *silent mode* because the current field on the tape is empty. In the next step, activity *B* is matched in the SoDA, therefore, the current content on the tape is filled by a deferred activity item and output data of this activity are used. Activities *C* and *D* are executed in the same way. Then, the abstract machine reads activity *Y*. Activity *X*, which writes the necessary data for *Y*, has been performed as a result of the instance re-execution on the updated model M_2'. Activity *Y* is thus performed successfully and we can proceed to the next activity. Instance *I* can be migrated to adapted model M_2'. In [8], the same example is discussed with the result that *I* cannot be migrated due to the possible deadlock or run-time errors.

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The situation described above is an example of the change, including the modification of both control and data flow. Now, we will focus on pure data change, which may also lead to errors [9]. Consider process model M_3 (Figure 4). Process instance *I* has already finished activity *C* which is data-dependent on activity *A*. However, the data output of

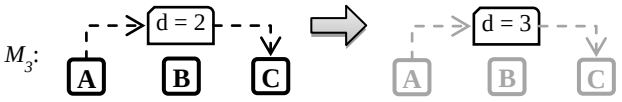

Figure 4. Model M_3 including the data dependency.

activity *A* has to be changed (the value of data variable *d* is 3 instead of 2). This requirement is simulated by inserting a new user activity item into the SoDA which includes the updated value of output variable *d*. This can be practically accomplished by offering form with current data of activity to process participant. After submitting a new value, the corresponding content is added to the SoDA.

Further, the re-execution starts and matching function *m* finds an item for activity *A* in the SoDA. The machine head also reads performed activity *A*, but with different output data, therefore, the interruption event is triggered. Consider that no custom handler is specified. Hence, the default handler to cope with this situation is used. The current content of the tape is replaced with the item found in the SoDA. As a consequence, the output of activity *A* is changed. The next activity *B* is simulated without a problem. However, activity *C* has different input (variable *d* now has a value of 3); thus, the abstract machine triggers the interruption event. A custom strategy to solve this situation takes place. We have the result of the last performance of *C* and under certain situations it may be possible to accept the result of *C*, or we can perform a rollback of this activity and then repeat *C*. It is important to say that we do not needlessly roll back activity *B*.

IV. The Contribution of the Process Re-execution Approach

The main goal of the re-execution approach is to bring more flexibility into process change. The essential requirement is to effectively implement a state compliance test in order to avoid run-time errors [1]. We presume state compliance as a basic corrections notion. The re-execution algorithm satisfied this requirement because re-execution itself always checks whether or not the changed process model or data modifications are correct and the process instance may proceed further. State compliance is also correctly checked regardless of whether there are arbitrary loop constructs in the model. Moreover, the first activity which may cause possible violation is automatically detected.

The second advantage of the re-execution approach is the fact that the process state is always properly reconstructed. Assume, for example, a non-compliant process instance which includes more activities that must be compensated. Additionally, these activities are in a loop body and we need to revert the process state into the second iteration, for example. Performing such partial rollback may be difficult because it is essential to revert all the necessary data variables to their correct values, including the loop control variables. The re-execution algorithm, however, helps us with this complicated situation because the execution is always performed from the beginning. Hence, all data variables (including the loop control variables) are evaluated again and have the correct values.

Partial rollback is not always possible; therefore, we need to choose a different strategy in order to cope with a non-compliant process instance. Some of the previously described strategies can be used. However, in some cases a custom solution according to the semantics of change is necessary. The re-execution approach brings all the essential information for implementing such a custom strategy, because we have the full context of activity which caused inconsistency during execution. The data on the machine tape as well as the content of SoDA can be taken into account to flexibly treat a non-compliant process instance.

Due to the store of deferred activities, we can reuse activities that have already been performed. This is important because the rollback of activities is connected with loss of work which is usually not acceptable for users [3].

V. The Re-execution Approach in Practice

During our research, we developed a prototype of the workflow engine which is based on the re-execution algorithm presented in this paper and successfully interpreted several processes from the area of human resources (the emergence of a new employee, correction of bonus distribution and traveling command).

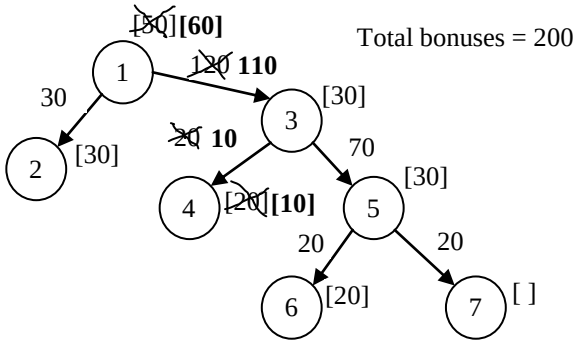

Figure 5. The bonus distribution.

Now, we demonstrate the re-execution approach on the real business process which models the correction of bonus distribution in the enterprise. The bonuses are distributed through the hierarchical organizational structure depicted in Figure 5, where the circles represent the enterprise departments. The number inside the circle identifies the department and indicates the order in which the distribution is made. We define the activity *Divide Bonuses* (*DB*), which has two input parameters – the identification of the department and the total amount of bonus to divide. The result of the activity includes the bonuses for employees within the processed department (the number in square

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brackets in the figure) and the value of bonuses for all subordinate departments (the value of the edges leading from the respective department).

Assume that activity *DB* for department 6 is finished and bonuses for department 7 have not been divided yet. Further, department 1 needs more bonuses for its own employees and thus the manager of this department changes the benefits for subordinate department 3. The data output change is shown in Figure 5. The input of *DB* for department 3 has changed to 110. If we apply the extended state compliance test, including the data inputs and outputs of activities described by Rinderle-Ma [9], then the process instance is not state compliant because the input of activity for department 3 has changed. The bonuses for department 4, 5 and 6 have already been divided; thus we must perform rollback of the respective activities to get the process instance into the compliant state.

Assume, further, that the bonuses for subordinate department 4 will be changed from 20 to 10 and bonuses for department 5 will stay the same (70). In this case, the rollback of the activity for department 5 and 6 is useless and the activity *DB* for these departments has to be repeated. In practice, the process participants were informed that the division of bonuses had been cancelled and then they had to repeat activity *DB* with the same value of bonuses.

Now, we investigate the application of the re-execution approach on the presented business process. The re-execution algorithm detects the changed input of activity *DB* for department 3 and interrupts the execution. Activities for departments 4, 5 and 6 are deferred into SoDA. The new division of bonuses for department 3 has to be made again and thus rollback of the particular activity is essential. The activity for department 4 has also changed the input and we use the same strategy as for department 3. The activities for department 5 and 6 are, however, matched in SoDA and thus the rollback is not performed. The algorithm automatically recognized that the new results of *DB* for department 3 do not affect *DB* for department 5 or, consequently, for department 6. Finally, the division for department 7 is performed.

We focused on different kinds of changes related to the process model, such as the insertion, deletion or movement of activity. This tested our ability to cope with process instances which had progressed too far. The result of this test confirmed our expectation that the re-execution approach significantly increases the flexibility of treating such instances. This is because if we know a semantic of the change and use the information from the re-execution algorithm, we can create really customized strategy, thus increasing the probability that the process instance will be successfully relinked to the adapted model.

The limitations of the presented approach lie in the expectation that we assume that the activity acts as a pure function which transforms its inputs to outputs without any side-effects and that the usage of external data must always be encapsulated by the activities. Reference to an outside data structure or data taken from a foreign database, which are used directly in the process model, may be potentially changed during execution, thus, possibly causing inconsistency leading to unexpected results. This limitation does not mean that the process must be run in a completely isolated data environment. We can allow the data output modification of some activity as was described in model M_3 (Figure 4). However, the decision about whether we use the stored result or a new value must be controlled by the particular activity.

Our research also focused on the memory complexity of the re-execution approach. We need to store all relevant activity inputs and outputs, which leads to higher memory consumption. However, it is important to note that we need this data in order to present process instance execution to workflow participants as well as to support administrator intervention, if necessary. Moreover, the content of the tape can be used for further analysis and process mining [10]. In comparison with the approach presented by Rinderle-Ma [9], we do not need to store the complete state of the process instance, because many supporting data variables and conditions are automatically evaluated during re-execution. For large data structure changes, an approach based on saving the differences can be used.

We analyze the time complexity of the re-execution algorithm. The time complexity is defined as the number of steps which the re-execution algorithm must perform in order to execute the process instance. If we have n activities and every activity is performed n-times during re-execution, then the time complexity is quadratic (n^2). Although this may be a potential drawback, we should consider that the overall time spent doing particular asynchronous activities is significantly longer than the total time it takes the re-execution algorithm itself. For example, a manager must read the complete report and other related documents to authorize a decision. As such, the time needed to perform the respective activity in the process can take hours or maybe days. A forward evaluation of process instance is in some cases less time-consuming than a complicated rewind of the process state in order to perform a partial rollback.

We also discovered that the idea of process re-execution enables us to use a common high level programming language. If we create a process model as a program, which is capturing the way that the process is executed, then we must solve the problem with the simulation of long-running processes, because the code of the program finishes immediately. The re-execution approach, however, successfully solves this problem. We can simulate step-by-step the instructions of the program that represent the activities of the process model, therefore, also the asynchronous activities can be executed properly.

The usage of universal high level programming language instead of specialized process modeling language has many advantages. We can easily reuse and extend existing process models and modeling tools. The concepts of object-oriented programming, including encapsulation, inheritance and exceptions, may be applied. We can also use the standard development environment for process modeling, debugging and testing, thus improving the maintenance and flexibility of the created process models.

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VI. RELATED WORK

There are many approaches dealing with the correctness of dynamic process change. A detailed description of these approaches and their comparison can be found in [1]. The strict version of state compliance is used by WIDE Graphs [4]. ADEPT WSM-Nets [12] use the relaxed version of state compliance, which is loop-tolerant. The different classes of relaxed state compliance are presented in [3]. On the other hand, WorkFlow Nets [11] are based on the graph equivalence approach. $WASA_2$ Activity Nets use the instance information described in the form of the purged instance graph [13]. The description of other existing frameworks for process flexibility can be found in [7].

Now, we can compare the re-execution approach with given approaches on the basis of the ability to solve typical problems connected with dynamic change. We investigate these problems, which are given in [1]:

1) Changing the Past: If the change affects the region of the process model which has been passed by the process instance, then some control or data inconsistencies may arise. The re-execution algorithm is able to tackle such situations because the activities that have already been performed are deferred, as was presented in several examples. WIDE completely prohibits the changes of the past, as do ADEPT and $WASA_2$. The inheritance transformaiton rules in WF nets enable the changing of the past.

2) Loop Tolerance: Loop constructions can cause that the application of too strict correctness criteria excludes the process instance from migration, although the instance is compliant with the changed model. Re-execution is always performed from the beginning and thus the state of the process instance is properly reconstructed, including the states of the loops. WIDE uses a strict compliance criterion and thus it is not loop-tolerant. $WASA_2$ is also not loop-tolerant due to the usage of acyclic graphs. ADEPT and WF nets are loop-tolerant.

3) Dangling States: If the approach does not distinguish between activated and started activities, the deletion of some activity may be forbidden in some cases, or, conversely, the already running activity is deleted. This is a weakness of the re-execution approach because the state of the activity is not provided for the treatment of the process instance. The problem with dangling states is present for WIDE because its history logs contain only activity entries. The activity state is not contained in WF nets. ADEPT stores information about the state of the activity; $WASA_2$ distinguishes between started and non-started activities.

4) Order Changing: This problem is connected with the swapping of activities, or with the sequentialization/ parallelization of activities. The re-execution approach detects the swapped activity correctly and offers the necessary information to cope with this problem. The putting activity in parallel or removing the parallel branch can also be handled because we store the information about the flow. However, the detailed description of how the matching function works in this situation is beyond the scope of this paper. WIDE avoids this type of problem; ADEPT handles the change of activity order by migration conditions. However, WF nets exclude order changing; $WASA_2$ criteria do not allow order changing.

5) Parallel Insertion: The insertion of a new parallel branch into the process model will be the subject of our future research. WIDE, ADEPT and $WASA_2$ allow parallel insertion. WF nets enable parallel insertion by adding new control tokens to avoid deadlocks.

In [8], the strategies for treating the non-compliant process instance are described. The state compliance graphs are used to return the process instance into the compliant state [5]. The partial rollback of the process instance and the compensation activities are also discussed by Sadiq et al. [5]. More advanced strategies for process migration are given in [6].

VII. CONCLUSION AND FUTURE WORK

In this paper, the process re-execution approach was presented to support better flexibility when coping with problems related to dynamic process change. We showed how this approach efficiently implements the essential state compliance test in order to uncover process instances which cannot be relinked to the new process model. The re-execution algorithm always ensures proper reconstruction of the process state, thus the necessary partial rollback of some activities can be performed safely. If there is inconsistency both in control or data flow caused by the adaptation of the process model, the re-execution approach brings us all the possible information needed to implement a custom strategy for handling a non-compliant process instance. The re-execution approach also makes it possible to use high level programming language to create a flexible and well maintainable process model. We implemented the presented approach as a prototype of the workflow engine and tested all the described features.

In future work, we will focus on the transformation of activity signatures in order to solve problems with different count and types of input and output activity parameters after the application of dynamic change. The model version will also be taken into account during transformation. We will further investigate the possibilities of using high level programming language for process modeling.

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