Big Data SE vs. SE of BD Systems

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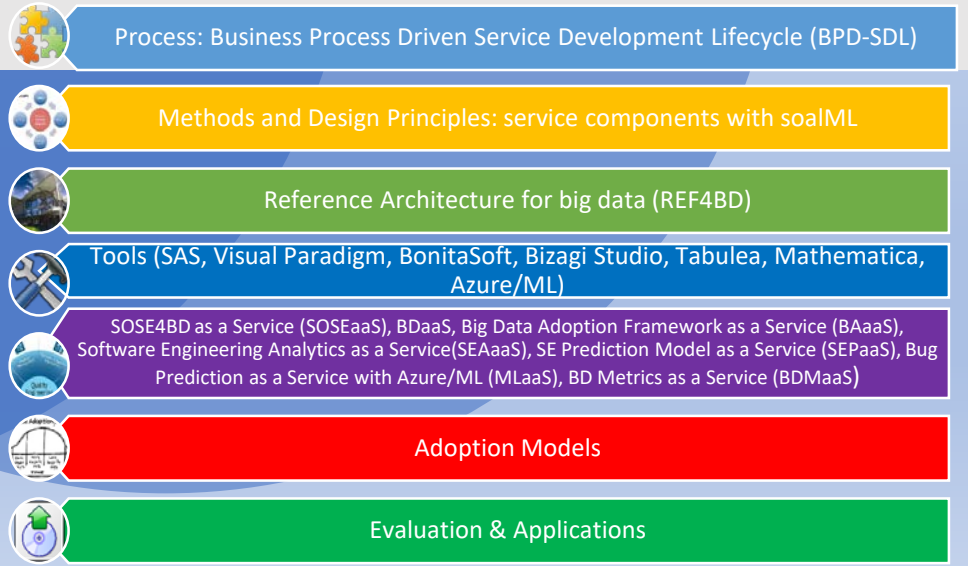


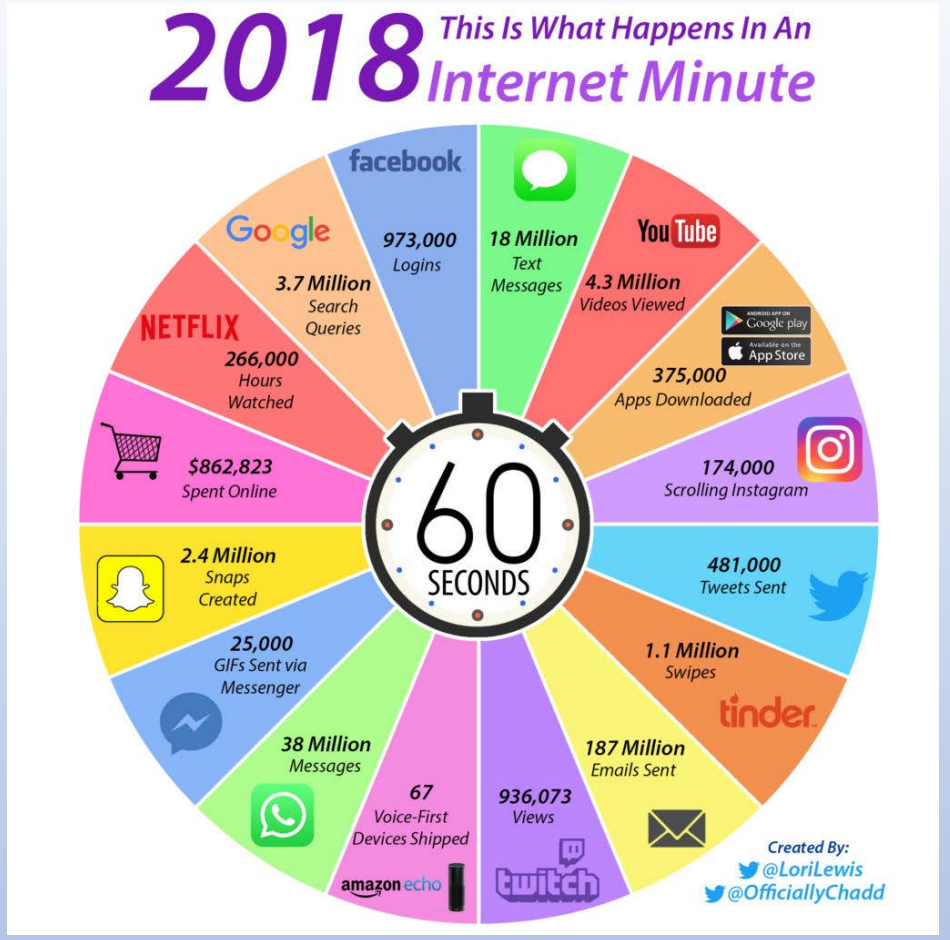
Research Motivation

- In this changing era of integrated IoT, Cloud, Real-time Big Data Stream (Social Media, Smart Cities, Smart Living, etc.) and services are to be Robust, Agile, Accessible and Available to its clients. For secured and guaranteed delivery of services, every big organization is shifting their service delivery model to Enterprise Service Bus (ESB). The following research questions are posed:
- How do we achieve Data Reuse, Reliability, Resiliency (3Rs) and Security, Accuracy and Availability (SAA)?
- How do we engineer a systematic approach to using and reusing software repositories, 50 years of software engineering knowledge and experience data for developing software and software as a service paradigm (**Big Data Software Engineering**)?
- How do we engineer a systematic approach with 50 years of software engineering approach to data science and to develop big data systems and services (**Software Engineering for Big Data**)?
- What are the design principles for a SOA driven reference architecture?
- What are services comprise reference architecture for big data systems?
- How to classify technologies and products/services of big data systems?
- How should software development teams integrate Data Analytics (Data Collection, Transformation, Analytics, and Improvement) into their software development process?
- What new roles, artifacts, and activities of BD process come into play?
- How do we integrate BD process of new roles, artifacts, and activities tie into existing agile or DevOps process?

BD Concepts

- Big data is characterized by 8V's: volume (large amounts of data), velocity (continuously processed data in real time), variety (unstructured, semi-structured or structured data in different formats and from multiple and diverse sources), veracity (uncertainty and trustworthiness of data), validity (relevance of data to the problem to solve), volatility (constant change of input data), and value (how data and its analysis adds value).
- Big data systems are software applications that process and potentially generate big data. Such applications receive and process data from various diverse (usually distributed) sources, such as sensors, devices, whole networks, social networks, mobile devices or devices in an Internet-of-Things. They process high workloads of data and handle high requests for data. The idea is to use large amounts of data strategically and efficiently to provide additional intelligence.

8Vs of big data



Velocity: BD requires real-time processing at varying intervals and may include stream as well as batch processing

Volume: BD provides a massive historical data over several time periods (years, months, weeks, days, etc)

Variety: The BD captured may be in variety of formats (multiple file files and multi-modal data) and may be structured and unstructured.

Veracity: The BD captured may contain unwanted data which requires extraction, transformation, and cleaning

Value: BD may contain very highly valuable data as well as not useful and it requires skilled data scientist to identify what to consider for analytical processing what to discard.

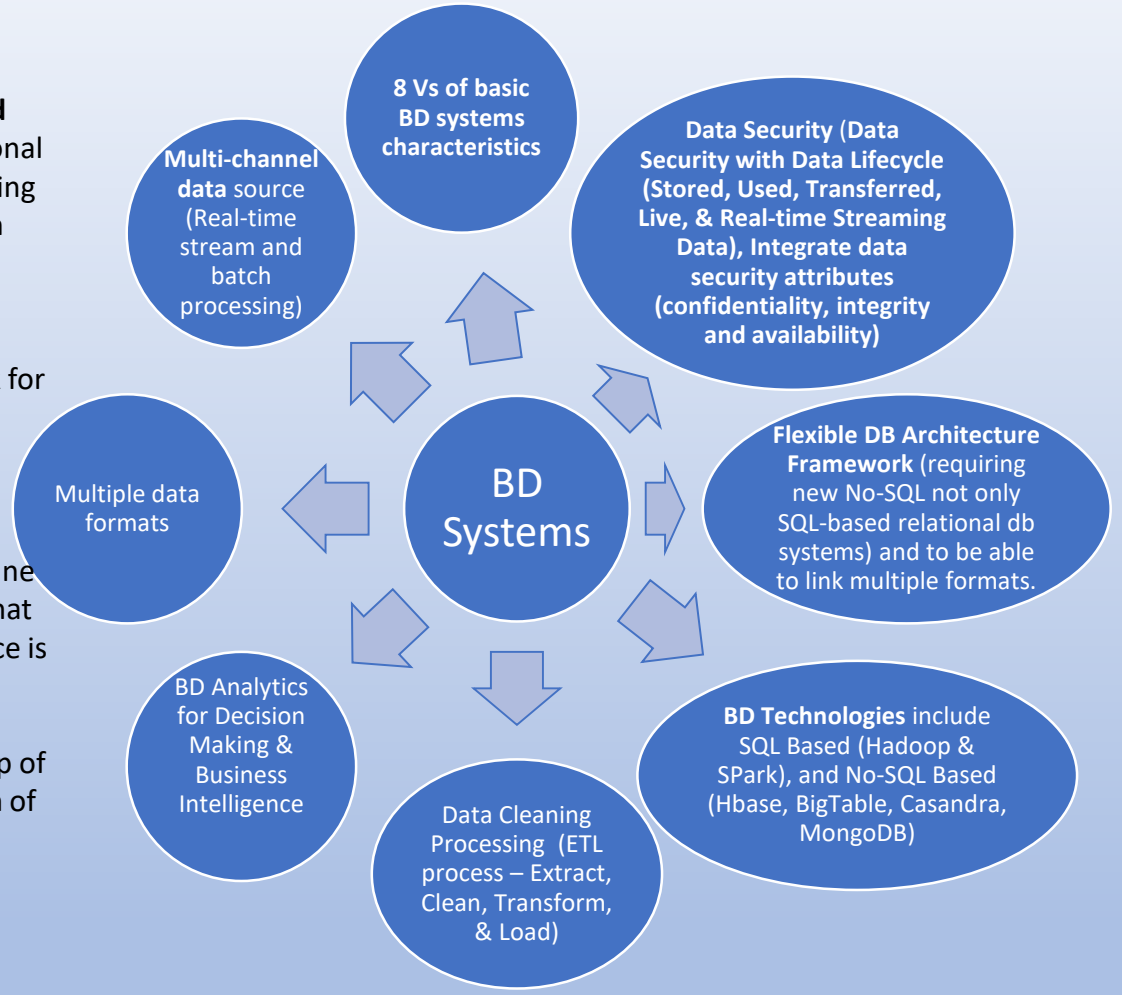
http://www.visualcapitalist.com/internet-minute-2018/

Characteristics of BD Systems Requirements

Spark is a cluster-computing framework, which means that it competes more with MapReduce than with the entire Hadoop ecosystem. For example, Spark doesn't have its own distributed filesystem, but can use HDFS. Spark SQL which integrates relational processing with the functional programming API of Spark. Querying data through SQL or the **Hive query language** is possible through Spark SQL. Spark SQL is a Spark module for structured data processing. It provides a programming abstraction called **DataFrames** and can also act as a distributed SQL query engine.
MongoDB is a NoSQL database, whereas Hadoop is a framework for storing & processing Big Data in a distributed environment. MongoDB is a document oriented NoSQL database. MongoDB stores data in flexible JSON like document format. You can easily map the documents to your applications.
Apache Cassandra is a NoSQL database ideal for high-speed, online transactional data, while Hadoop is a big data analytics system that focuses on data warehousing and data lake use cases. MapReduce is a programming paradigm for processing and handling large data sets.
Apache HBase is a column-oriented, NoSQL database built on top of Hadoop (HDFS, to be exact). It is an open source implementation of Google's Bigtable.

List of ETL Tools, https://www.etltool.com/list-of-etl-tools/

BD Analytics is the application of analysis, data, and systematic reasoning to make decisions, learn patterns of occurring to extract knowledge for improving process and business efficiency and cost. Analytics allows for summarising, filtering, modelling, and experimenting. **Tools and techniques include A/B testing, statistical modelling, machine learning, deep learning, natural language processing, and muti-linear subspace learning.**



Hadoop is an open-source software framework for storing data and running applications on clusters of commodity hardware. It provides massive storage for any kind of data, enormous processing power and the ability to handle virtually limitless concurrent tasks or jobs. The core of Apache Hadoop consists of a storage part, known as Hadoop Distributed File System (HDFS), and a processing part which is a MapReduce programming model. Hadoop splits files into large blocks and distributes them across nodes in a cluster.

Several research challenges of software engineering for developing big data systems

- Surveying the existing software engineering literature on applying software engineering principles into developing and supporting big data systems
- Identifying the fields of application for big data software systems
- Investigating the software engineering knowledge areas that have seen research related to big data systems
- Revealing the gaps in the knowledge areas that require more focus for big data systems development
- Determining the open research challenges in each software engineering knowledge area that need to be met
- **To be sustainable, we need an approach which is systematic, business-driven (supporting business-process and value driven), and based on established Software Engineering practices**

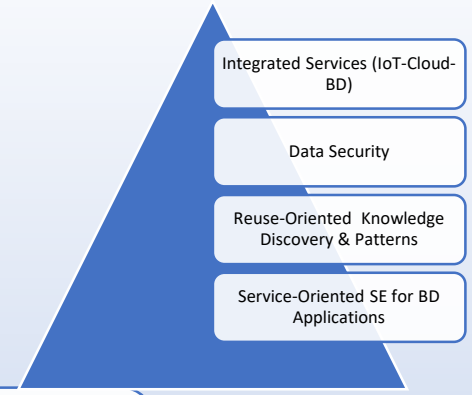
50 Years of SE

- 60 software development methodologies
- 50 static analysis tools
- 40 software design methods
- 37 benchmark organizations
- 25 size metrics
- 20 kinds of project management tools
- 22 kinds of testing and dozens of other tool variations.
- Minimum of 3000 programming languages software consisted, even though only 100 were frequently used. New programming languages are announced every 2 weeks, and new tools are out more than one in each month. Every 10 months new methodologies are discovered.
- Newly emerged **service computing paradigms (SOA, Web Services, Micro Services, Cloud SE, etc.) and established SE abstractions (Objects, classes, components, service components, virtualisation techniques, resource-oriented computing, and containers, etc.)**

Key Areas of Research Challenges

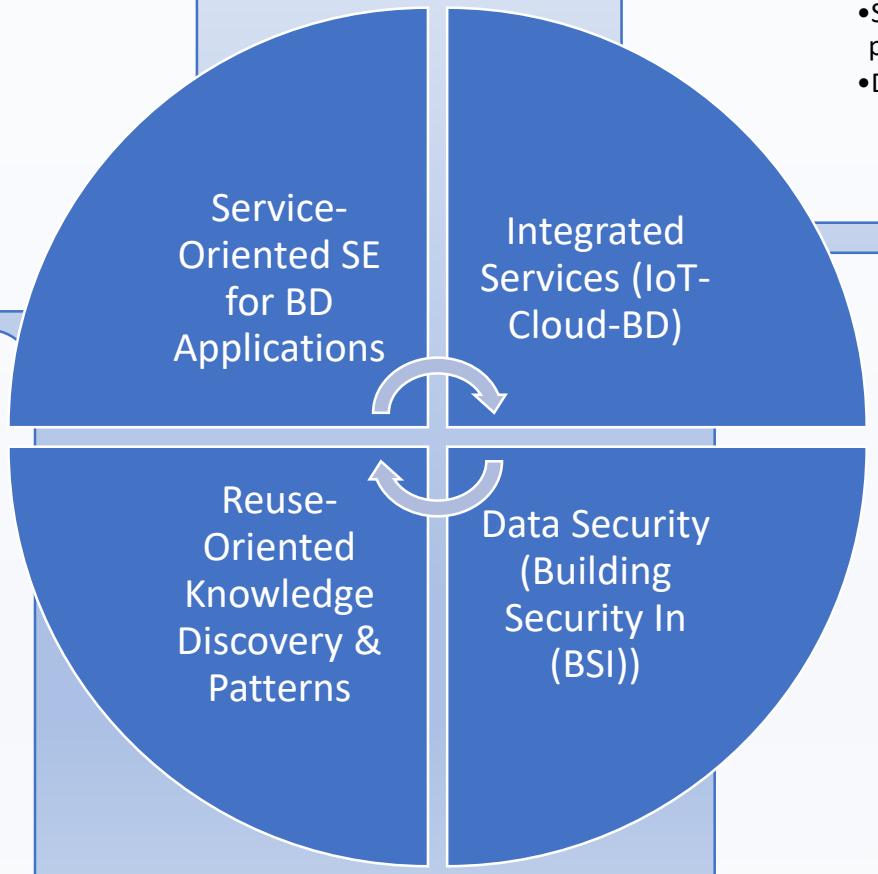
- **Software Engineering for Big Data** which can provide a systematic process for improving the development of big data systems. The process includes requirements gathering for BD, software architecture for BD, testing and debugging BD systems (performance, reliability, and security) where the logs of analysing 5V characteristics should be included, SE process for BD which could include CMMI, and finally Managing BD projects.
- **Big Data Software Engineering** is an area of research which should focus on utilising BD for the benefit of improving SE practices and to improve software production. The typical activities should include analytics for software engineering, data mining software repositories, visual analytics for software engineering, and self-adaptive systems which utilises data generated and self-learn.

Four Pillars of SE4BD Principles



- SOSE4BD
- Agile for BDSE
- Requirements Engineering for BD with BPMN Simulation
- Design for Data Service Reuse
- Design for Data Security (Achieving BSI)
- SOSE4BD Framework: Design methods based on soaML and service components, Process, Applications, and Evaluation

- Data Processing Architecture for Integrating IoT-Cloud-BD
- Support both stream & batch processing data
- Design for data complexity



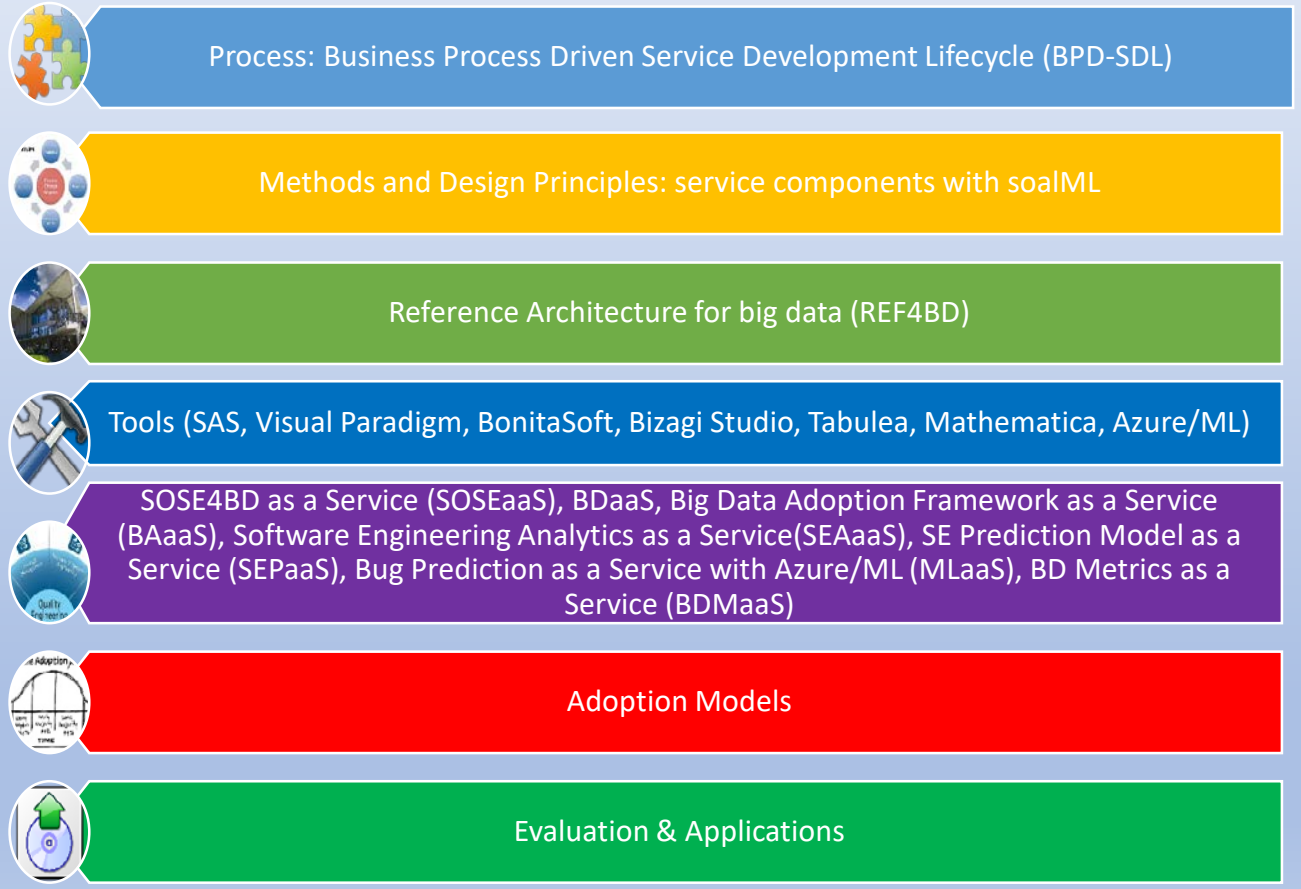
- Service Composition
- Autonomic Computing
- Knowledge Discovery, Extraction, & Patterns for Reuse
- Reuse by Analytics Patterns & Predictive Analytics Patterns
- BDSE Metrics with Data Points

- **Data Security with Data Lifecycle (Stored, Used, Transferred, Live, & Real-time Streaming Data), Integrate data security attributes (confidentiality, integrity and availability)** and apply Software Security Engineering Principles while Data Modelling for BD:
- Misuse and Abuse cases for service requirements
- Threat Modelling
- Secure SDLC

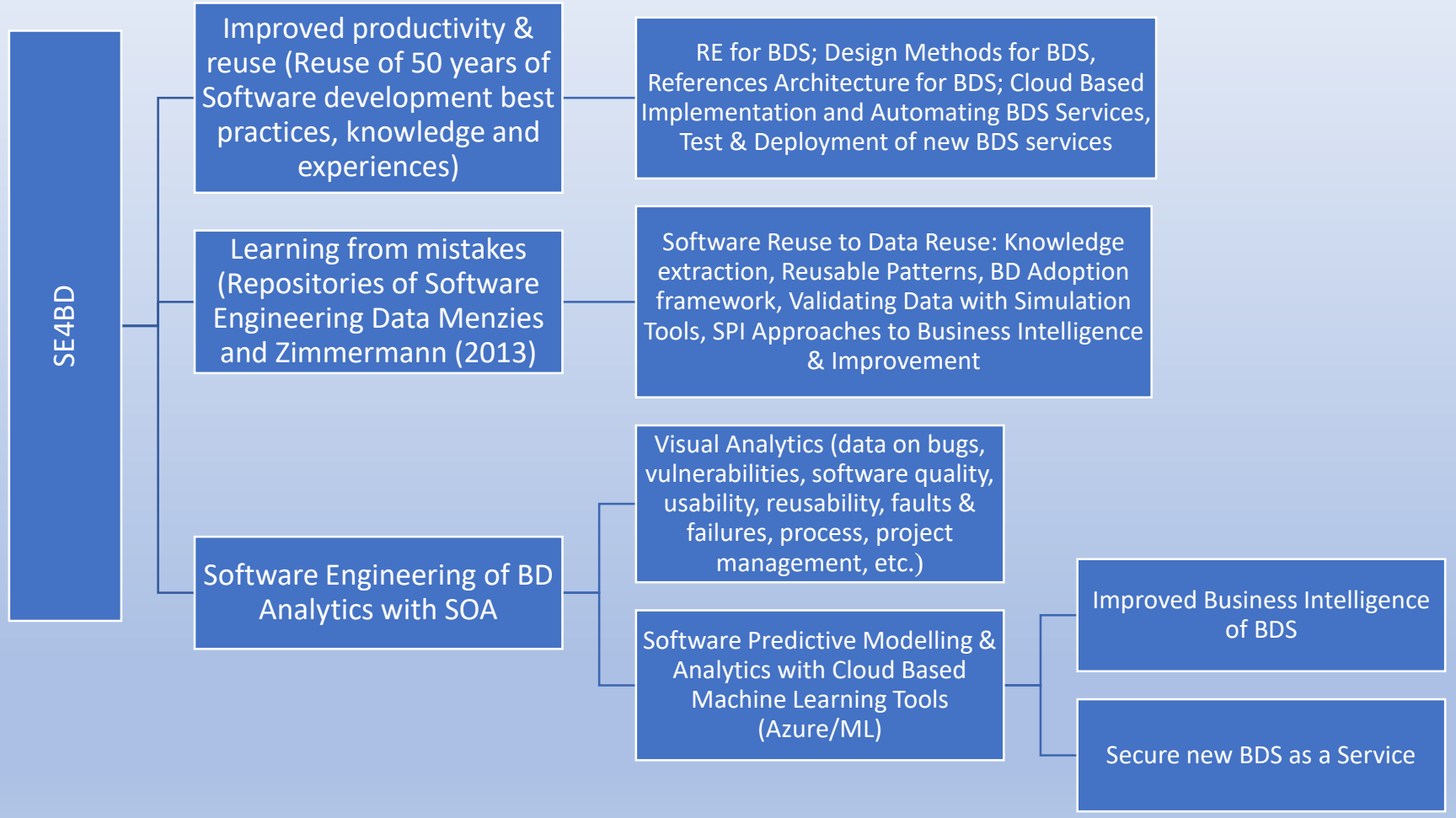
Software Engineering Framework for Big Data Systems (SE4BD) Framework: methods, process, reference architecture (REF4BD) applications, adoption and evaluation

SE4BD Framework

SE4BD is process-centric approach which provides process, Methods and design principles based on service components with soaML, reference architecture, tools, applications, adoption models, and evaluation

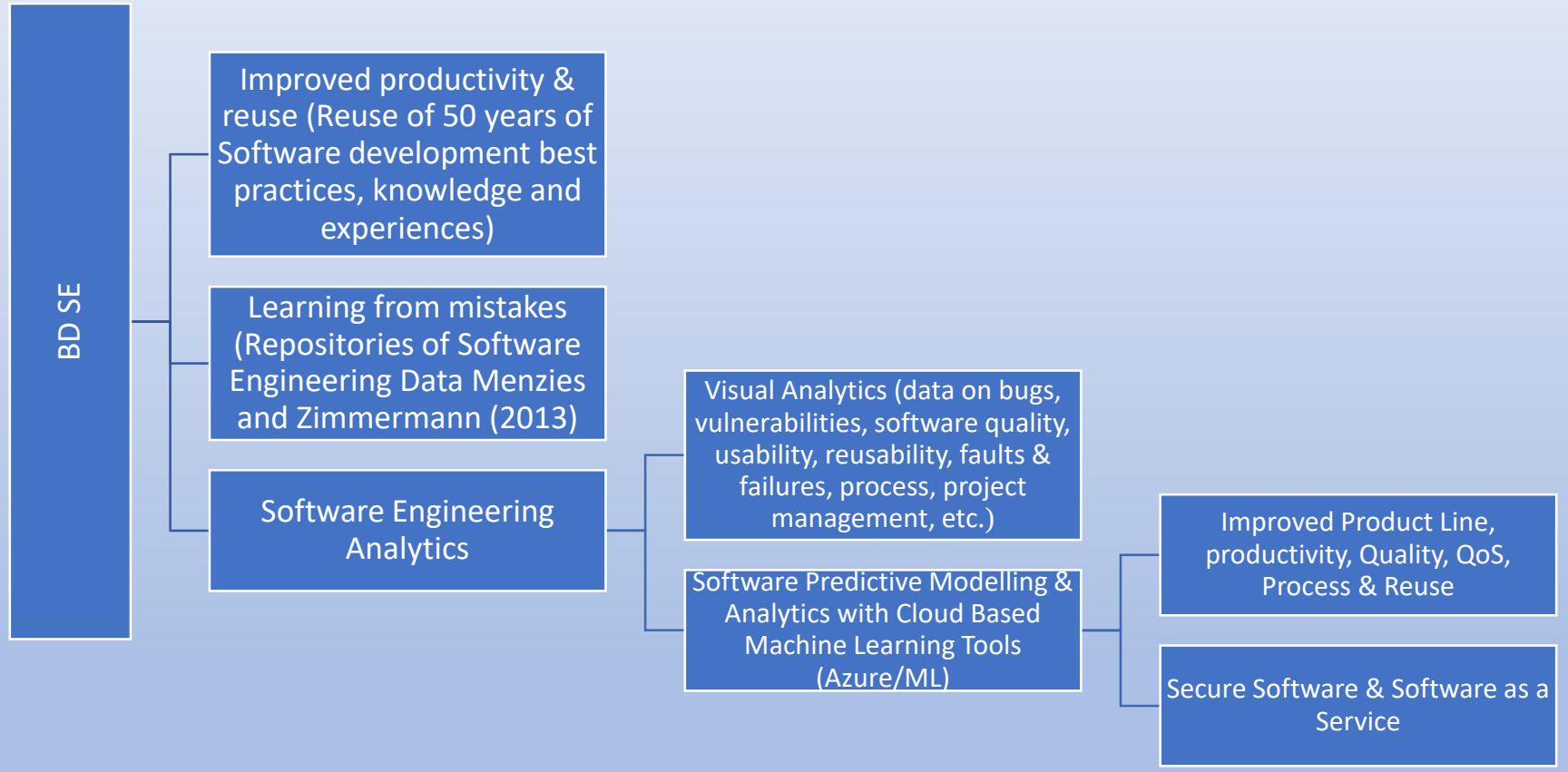


Benefits of SE Approach to BD Systems



Menzies, T and Zimmermann, T (2013) Software Analytics: So What?, IEEE Software, vol. 30, no. 4, 2013

Benefits of Big Data SE



Menzies, T and Zimmermann, T (2013) Software Analytics: So What?, IEEE Software, vol. 30, no. 4, 2013

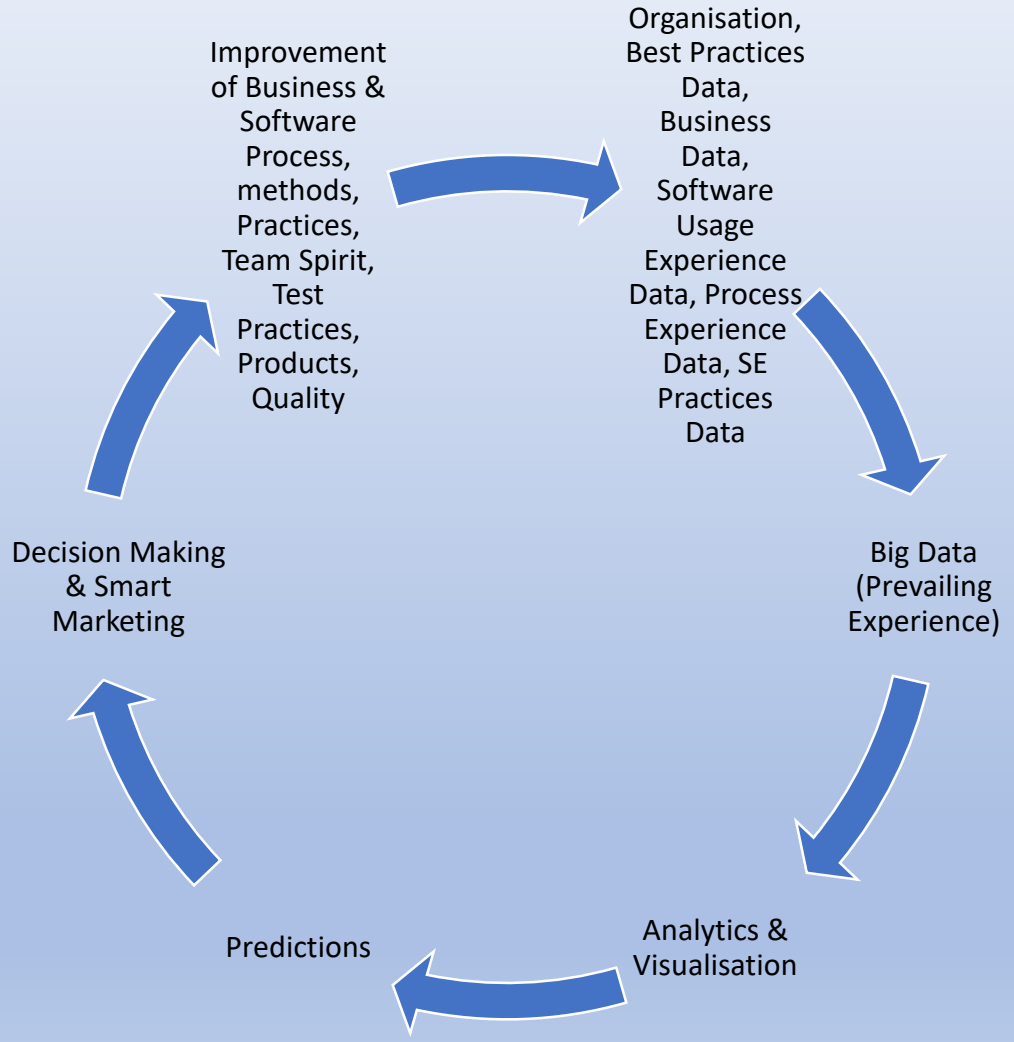
Software Engineering Analytics

Data Science for Software Engineering

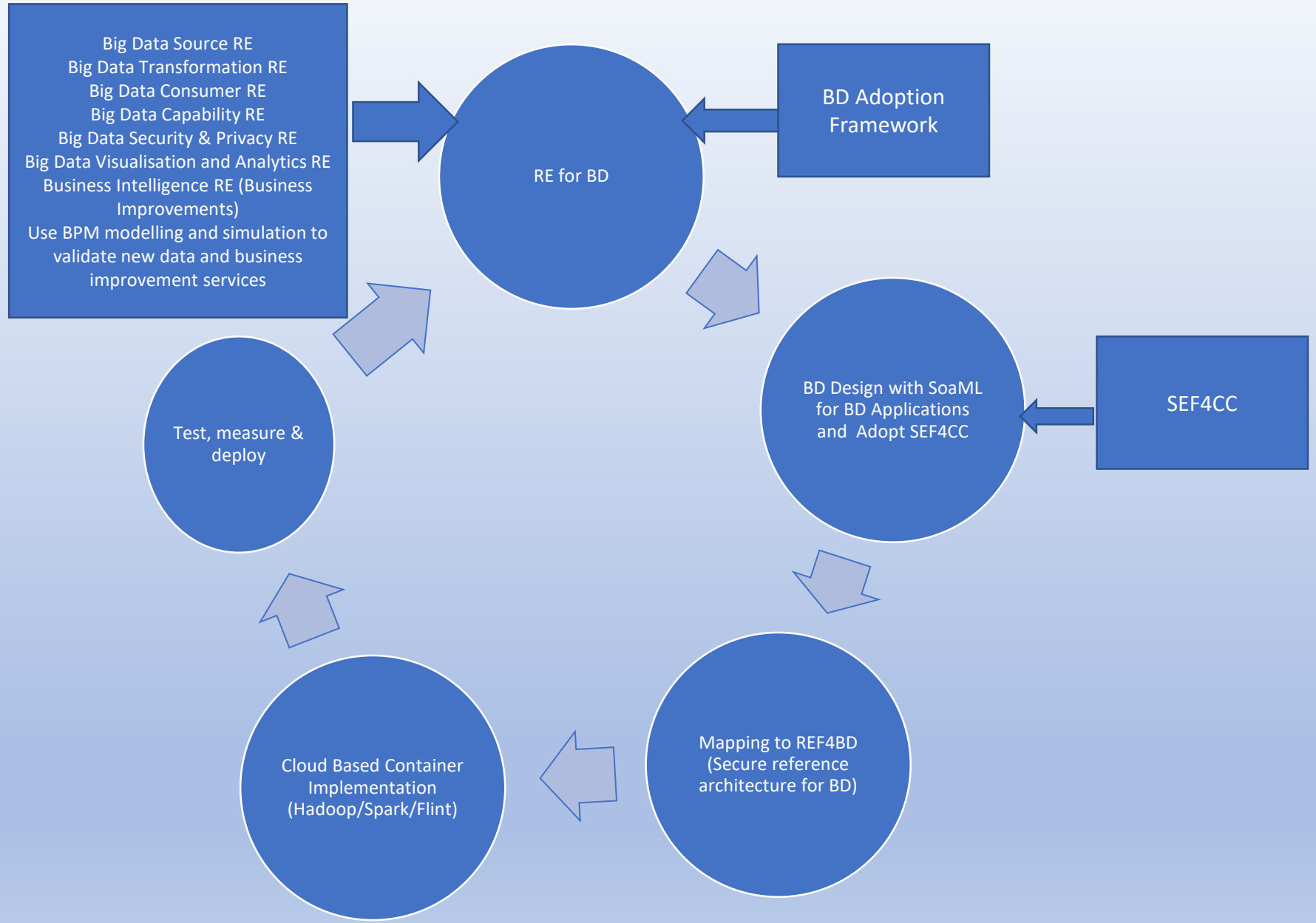
SE Analytics & Big Data SE

- Big data analytics, visualisation, and predictions has been useful and very popular research and applications in recent years. However, in the context of application of the big data practices to Software Engineering Analytics, there are some key questions need to be addressed:
  - How do we apply to software engineering analytics?
  - How do we collect and access SE experience data?
  - How do we apply them to decision making for business as well as the SE practices: process, methods, and technology?
  - How do we apply them for Software Process Improvement and Software Practices Improvement (SPI)
  - How do we apply them for software business process improvement?

SE for BD Analytics



SE4BD Lifecycle



Actionable SE Analytics Tools with SE Data Repositories

- Code coverage and visualisation tools
- Project Management & Monitoring Tools
- There are other tools to support management such as PROM, Hackystat which are capable of monitoring and to generate a statistical report of a software project. However, even after years of development, there is no major upgrade that can help predict management decisions (Zimmermann, 2013). Most of these tools were focused mostly more on collection rather than any critical analysis.
- Later, more tools were developed that realized the manger problems and created which focused data presentation rather than just collecting data. Tools like, Microsoft's Team Foundation Server and IBM' which keeps developers updated with modification, bugs and build results (Zimmermann, 2013). Other Project management tools such as Automated Project Office(APO) (Jones, 2017) also helps managers to come with the probable decision for the organization before or during the project.
- **Software Repositories**: As of late 2012, our Web searches show that Mozilla Firefox had 800,000 bug reports, and platforms such as Sourceforge.net and GitHub hosted 324,000 and 11.2 million projects, respectively.
- The PROMISE repository of software engineering data has grown to more than 100 projects and is just one of more than a dozen open source repositories that are readily available to industrial practitioners and researchers
- Jones, C 2018, Software Methodologies. [Electronic Resource] : A Quantitative Guide, n.p.: Boca Raton : CRC Press/Taylor & Francis
- Yang, Y. et al (2018) Actionable Analytics for Software Engineering, Actionable Analytics, Guest editors Introduction to Special Issue on Actionable Analytics for SE, IEEE Software, Jan/Feb 2018
- Menzies, T and Zimmermann, T (2013) Software Analytics: So What?," IEEE Software, vol. 30, no. 4, 2013
- Applications: Bug Data Prediction Models, ML for SPI, and Agile Methods

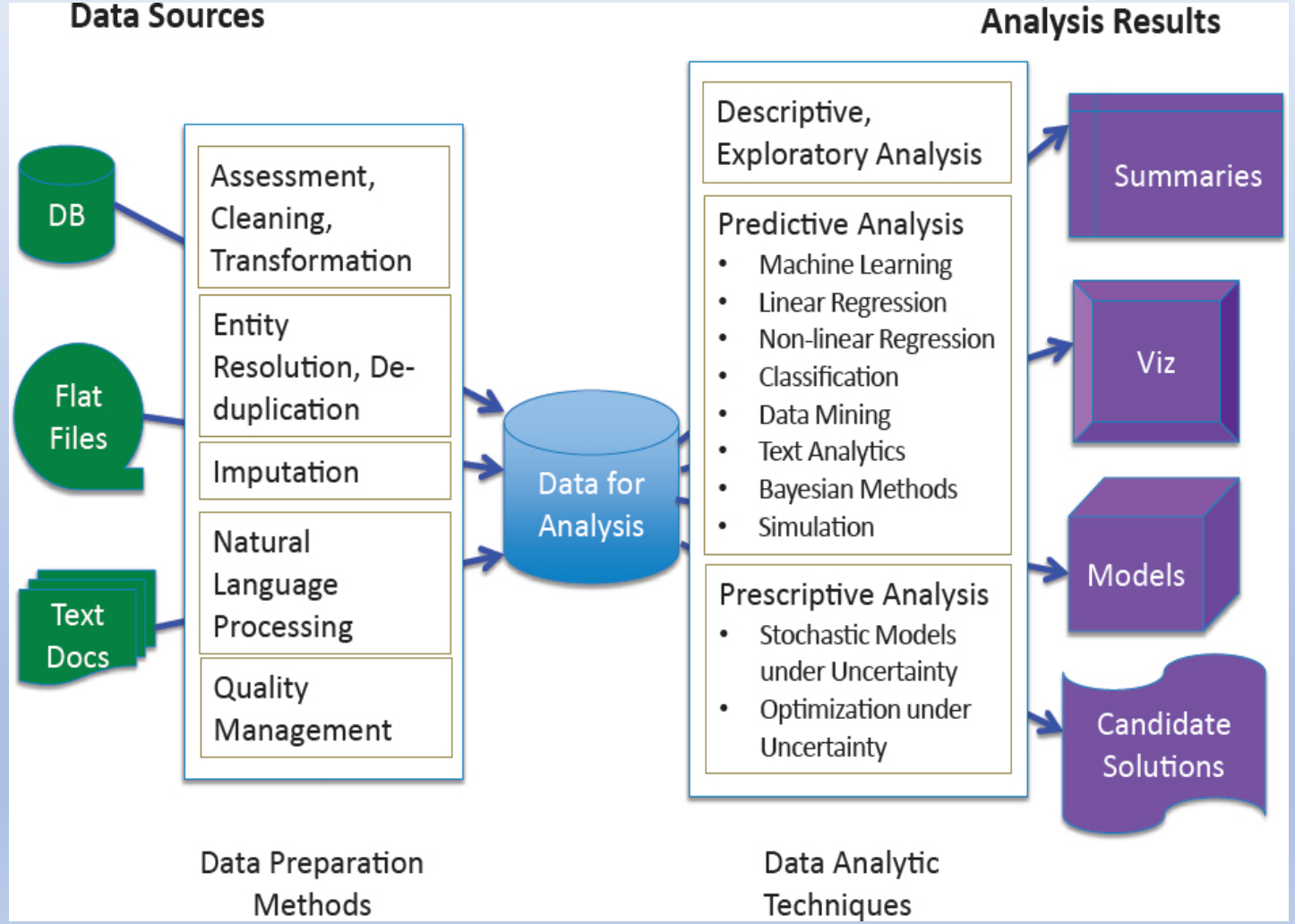
Repositories of software engineering data

Repository	URL
Bug Prediction Dataset	http://bug.inf.usi.ch
Eclipse Bug Data	www.st.cs.uni-saarland.de/softevo/bug-data/eclipse
FLOSSMetrics	http://flossmetrics.org
FLOSSMole	http://flossmole.org
International Software Benchmarking Standards Group (IBSBSG)	www.isbsg.org
ohloh	www.ohloh.net
PROMISE	http://promisedata.googlecode.com
Qualitas Corpus	http://qualitascorpus.com
Software Artifact Repository	http://sir.unl.edu
SourceForge Research Data	http://zerlot.cse.nd.edu
Sourcerer Project	http://sourcerer.ics.uci.edu
Tukutuku	www.metriq.biz/tukutuku
Ultimate Debian Database	http://udd.debian.org

Menzies, T and Zimmermann, T (2013) Software Analytics: So What?," IEEE Software, vol. 30, no. 4, 2013

Software Engineering Approaches for Data Science Applications

Data Science Process



Data Science Application 1: Bug Data Prediction Models using cloud based machine learning

https://app.box.com/s/b1g4jsp4k7f9cof90an6dg1qju0vv9uh

Application 2: Cloud Based Machine Learning Tool for Agile Method Decision Making

This tool is useful to know when making decision on choosing an Agile methods based on project size and constraints.

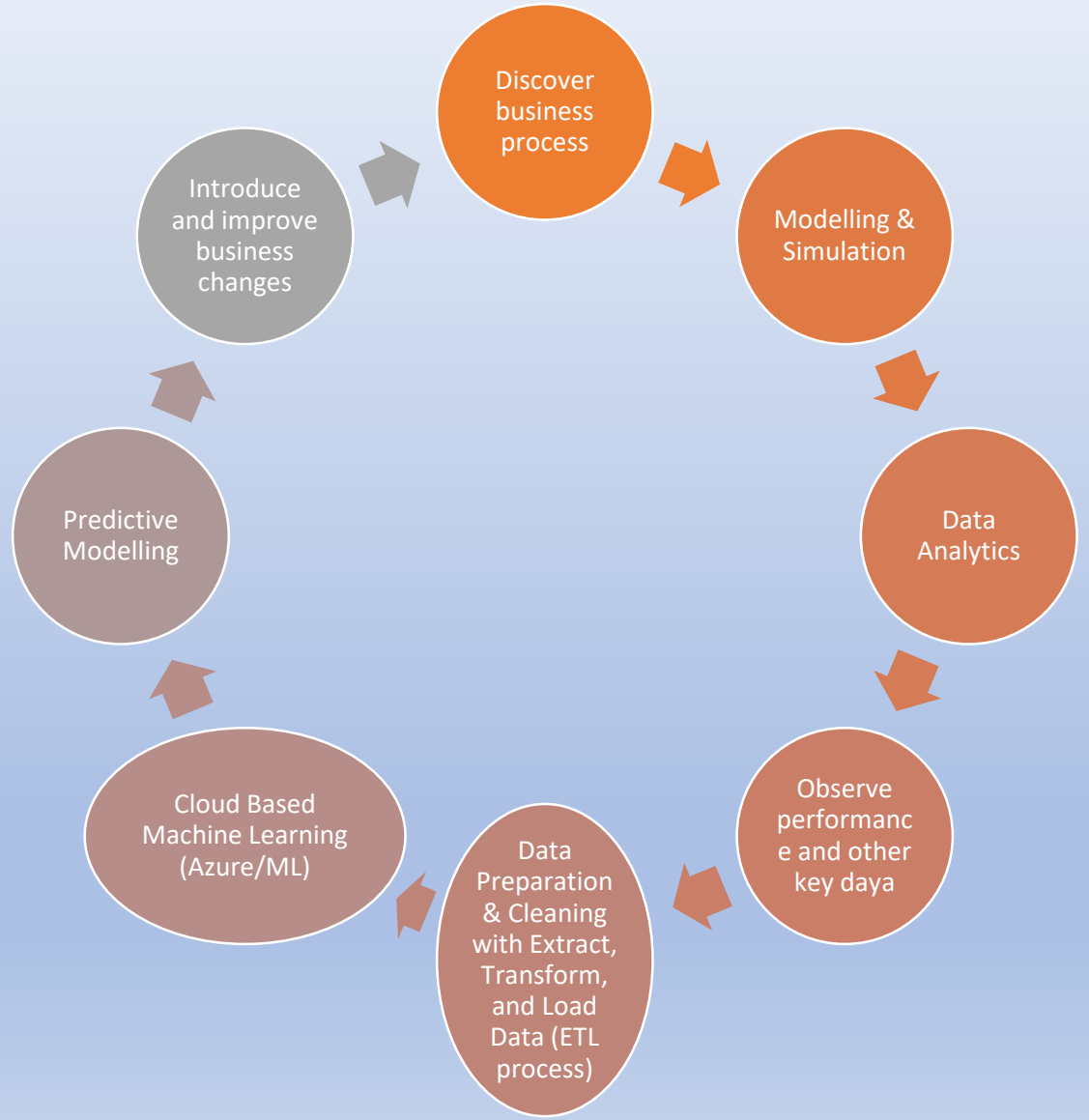
https://app.box.com/s/7q8sjo0zf36qpsahoqvv5ai28forv0vn

Application 3: Cloud Based Machine Learning for Software Process Improvement

https://app.box.com/s/6gd4zgimtz11014eavu3wv2c8cc1do6h

Application 4: Process Mining and Business Intelligence for Predictive Modelling

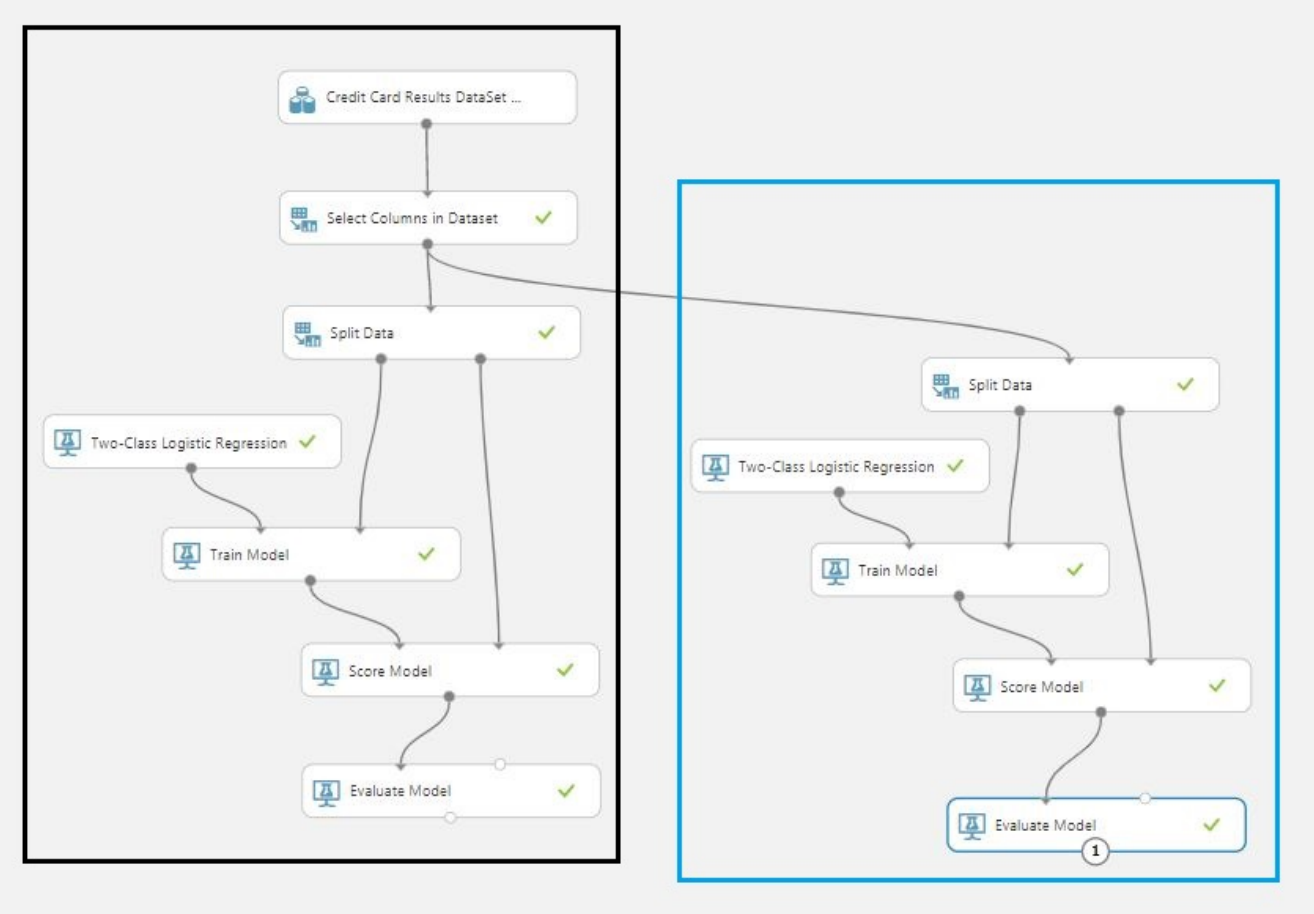
Process Mining and Business Intelligence with Machine Learning

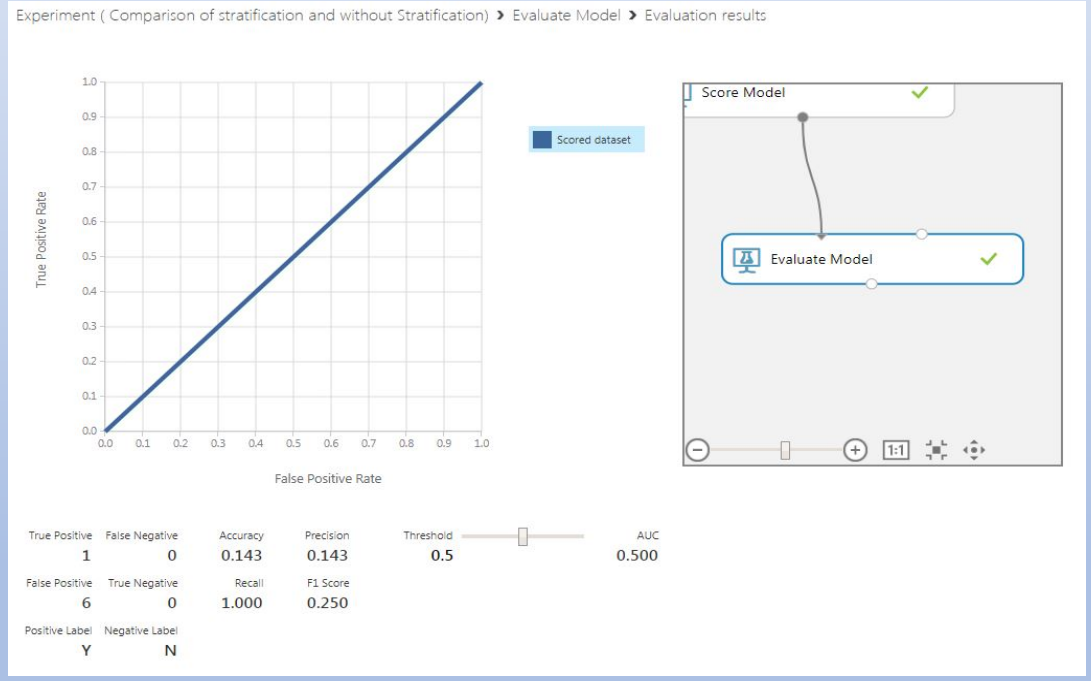


Benefits of Process Mining with Machine Learning

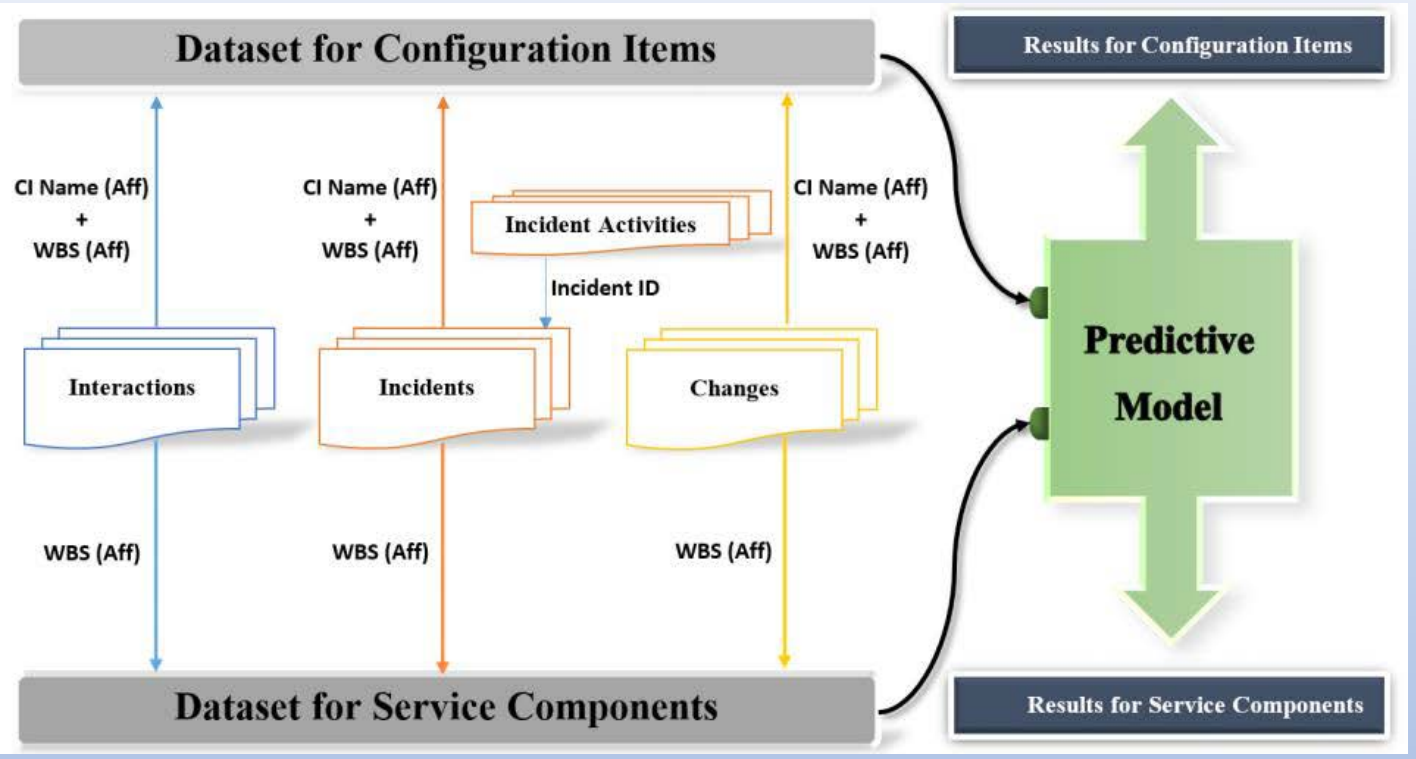
- Live data from the business services (event logs and performance data) to study the impact patterns
- Useful to study business and service patterns
- Useful to study business and service improvements
- Useful to improve change management process
- Reuse of services and data
- Improved QoS
- Predictive modelling for efficiency and QoS

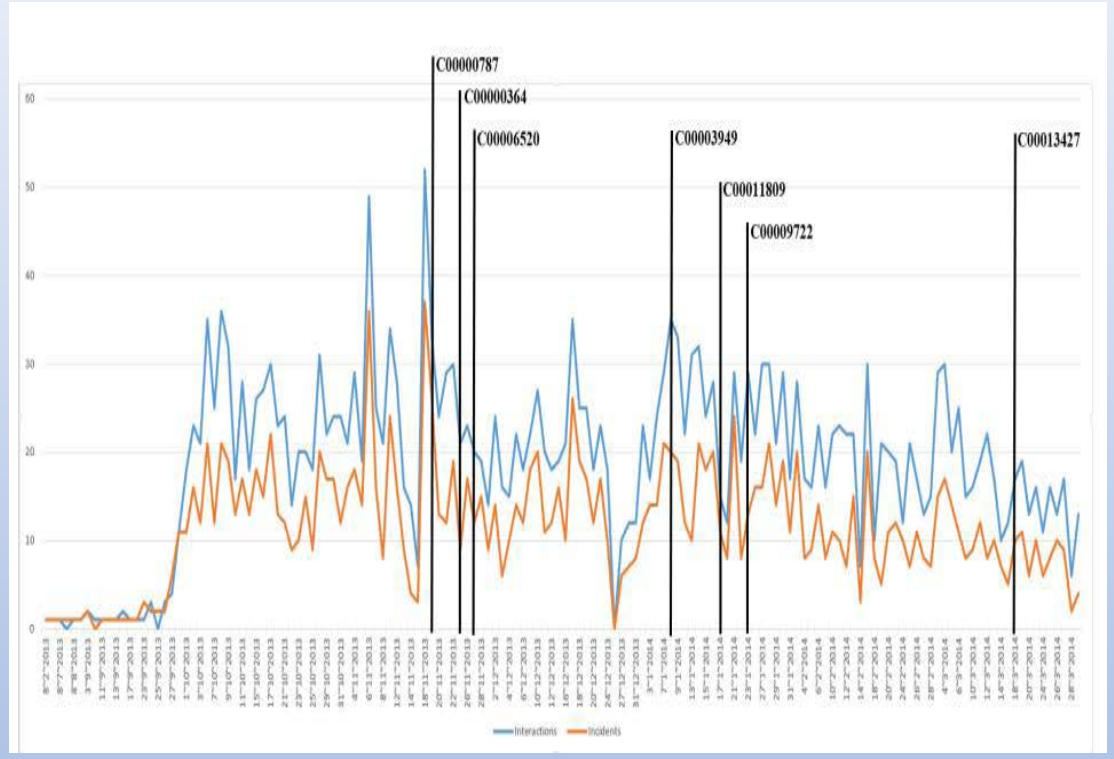
Predictive Modelling for Loan Business Processes





Predictive Modelling for Service Desk Application





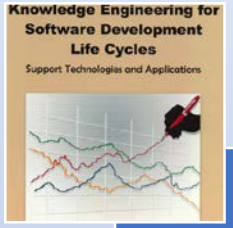
Occurrence of Interactions (blue) and Incidents (orange) in time with marked Changes (black) for Configuration Item "SBA000607" related to Service Component "WBS000263"

Suchy, J and Suchy, M (2012) Predictive Model for supporting ITIL Business Change Management Processes, BI 2012

Software Engineering Framework for Service and Cloud Computing (SEF-SCC) for Developing Data Science Applications

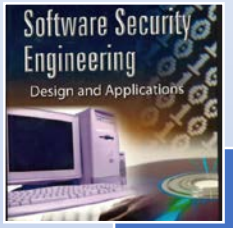
SEF-SCC Framework Poster,
https://app.box.com/s/u5fcktx687fy6qv2nhgzp93e5n9i7r8p

SEF-SCC: Service-Security-Reuse – A Three Integrated Service Engineering Framework



Service Development

- **Accuracy, Correctness & QoS Design Principles**
- Service RE with BPMN and Simulation
- Service Design with Service Components (SoaML)
- Service Development (any platform)
- Service Testing & Deployment & Continuous Delivery



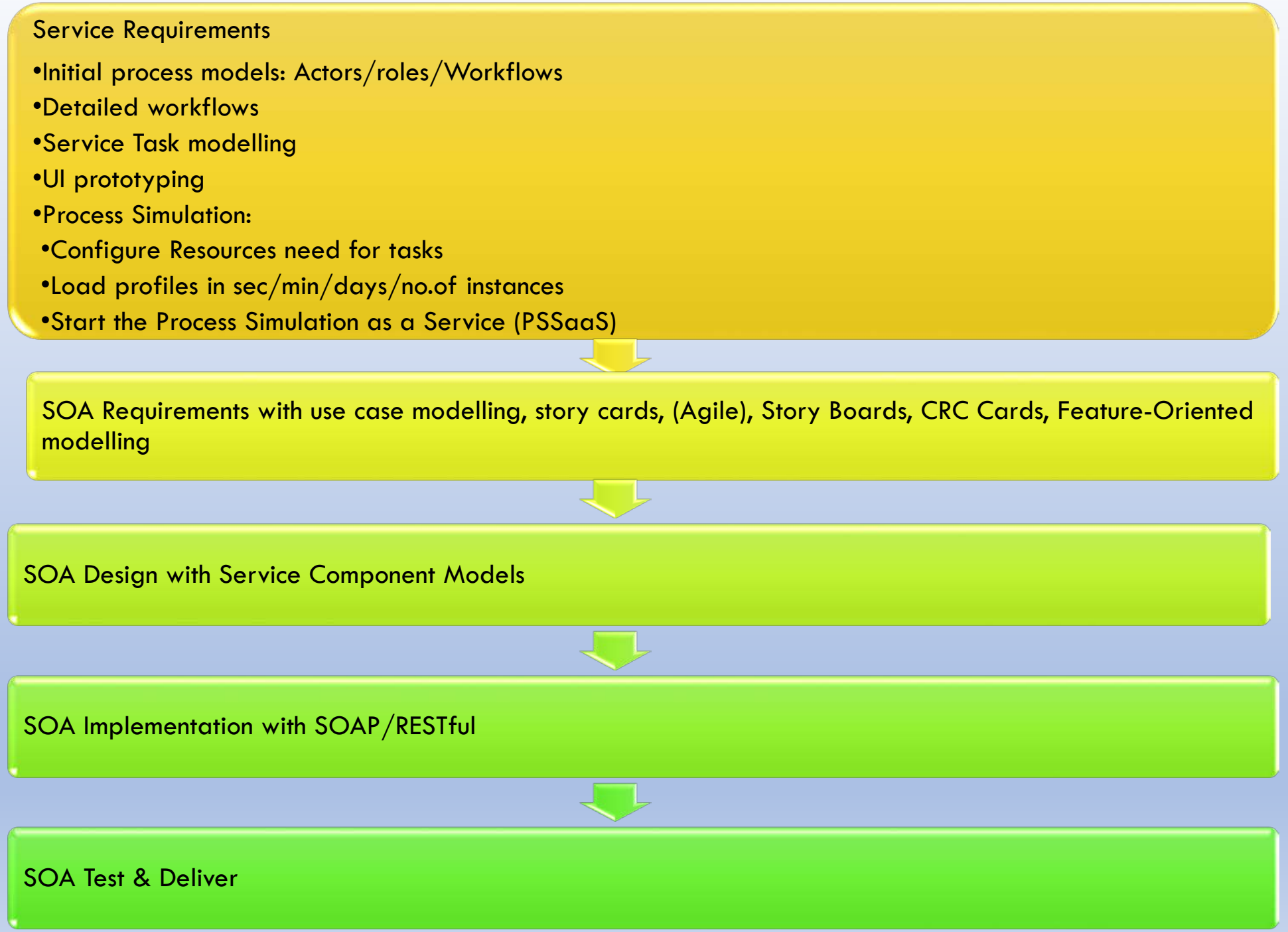
Software Security Engineering

- **Building Security In (BSI), Resiliency, Fault-Tolerance Design Principles**
- Service Security RE with Misuse & Abuse Use cases for all identified services
- Threat Modelling
- Design for Security
- Building Security In & Resiliency, Fault-tolerance,
- Software security testing

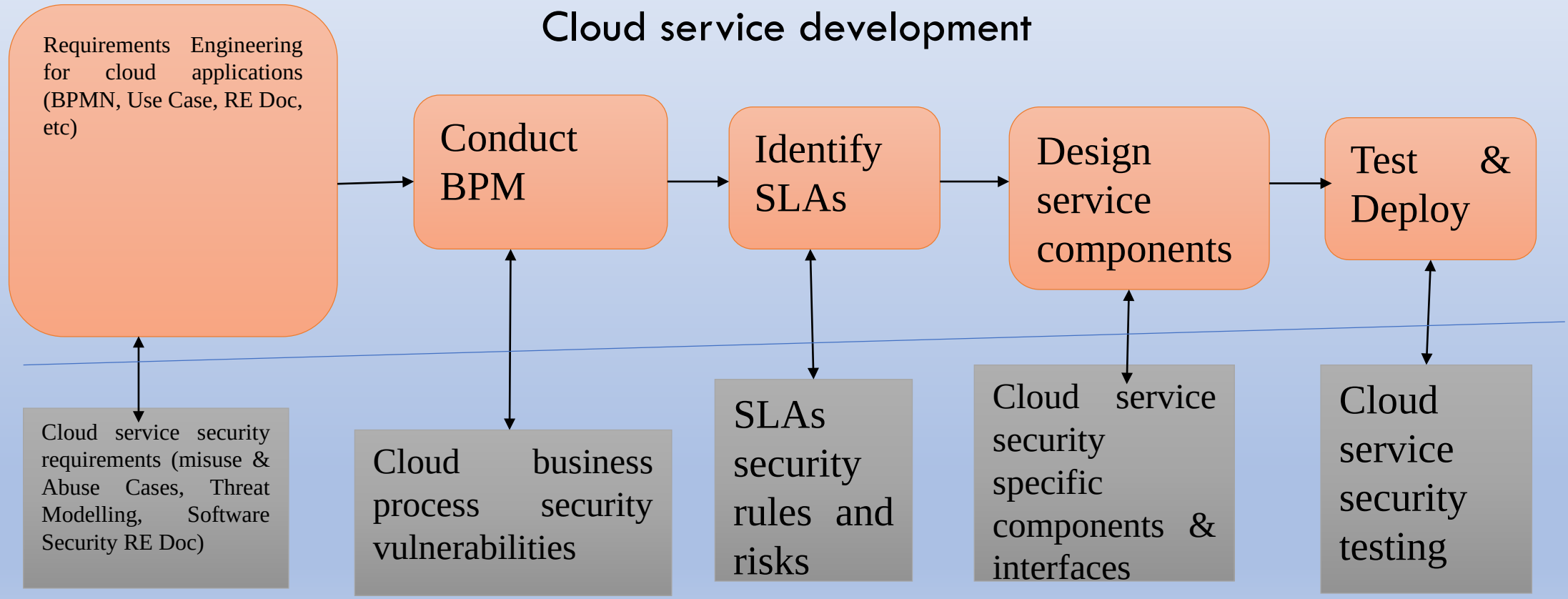
Service Reuse Engineering

- **Design for Reuse & Design with Reuse, Composable, Scalable Design Principles**
- Reuse RE (Commonality & Variability Analysis of secured requirements on selected BPMN & Secured use cases)
- Design for reuse approaches
- Reuse Development (Implementing composable services)
- Testing for reuse, composition & integration testing strategies

Software Engineering Lifecycle for Service and Cloud Computing (SEL4SCC)

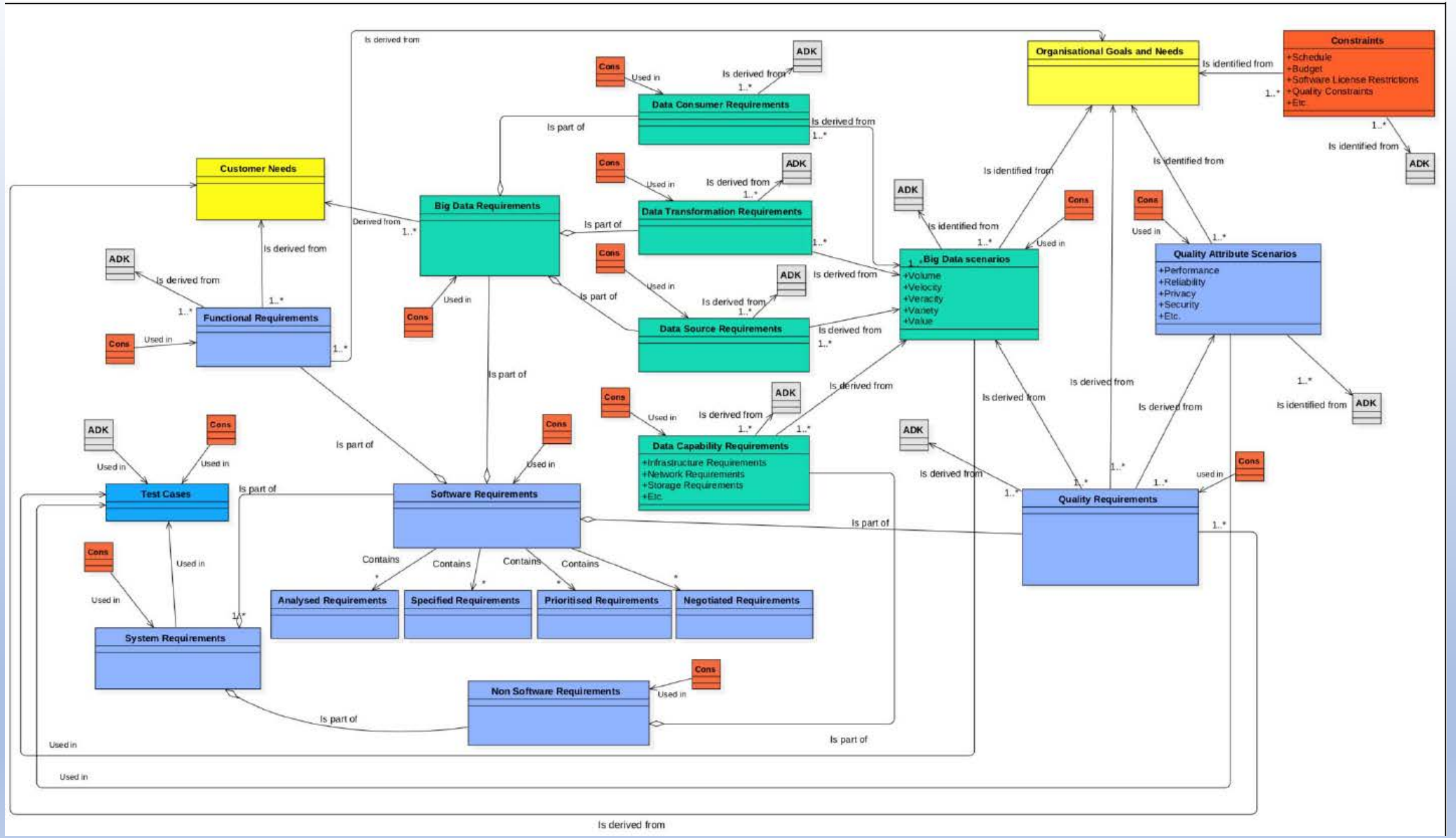


Cloud service security development process with Building Security In (BSI) – Our Systematic Approach to developing secure services



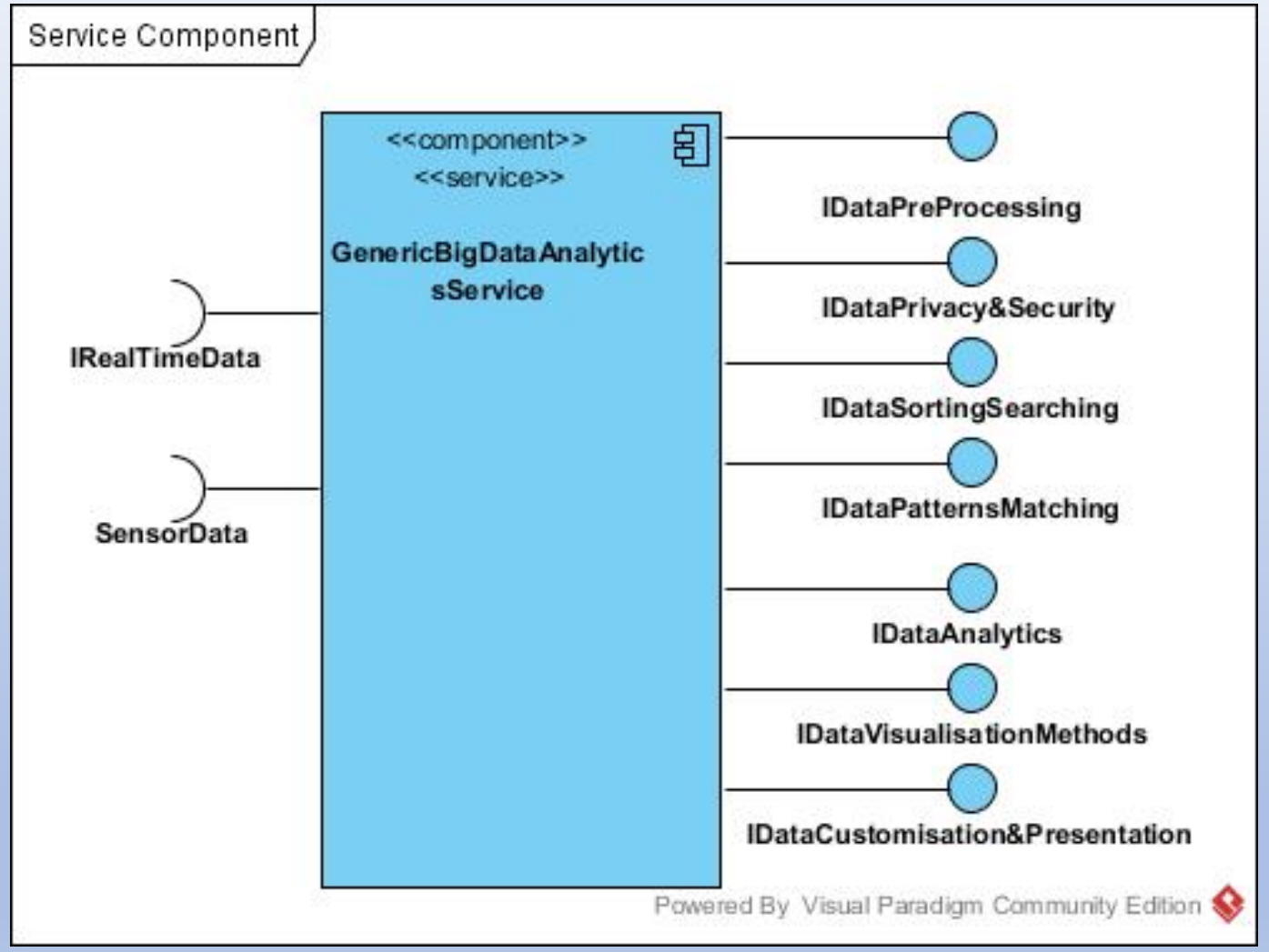
Build-In Security (BSI) – Cloud service development with build-in security

RE for BD

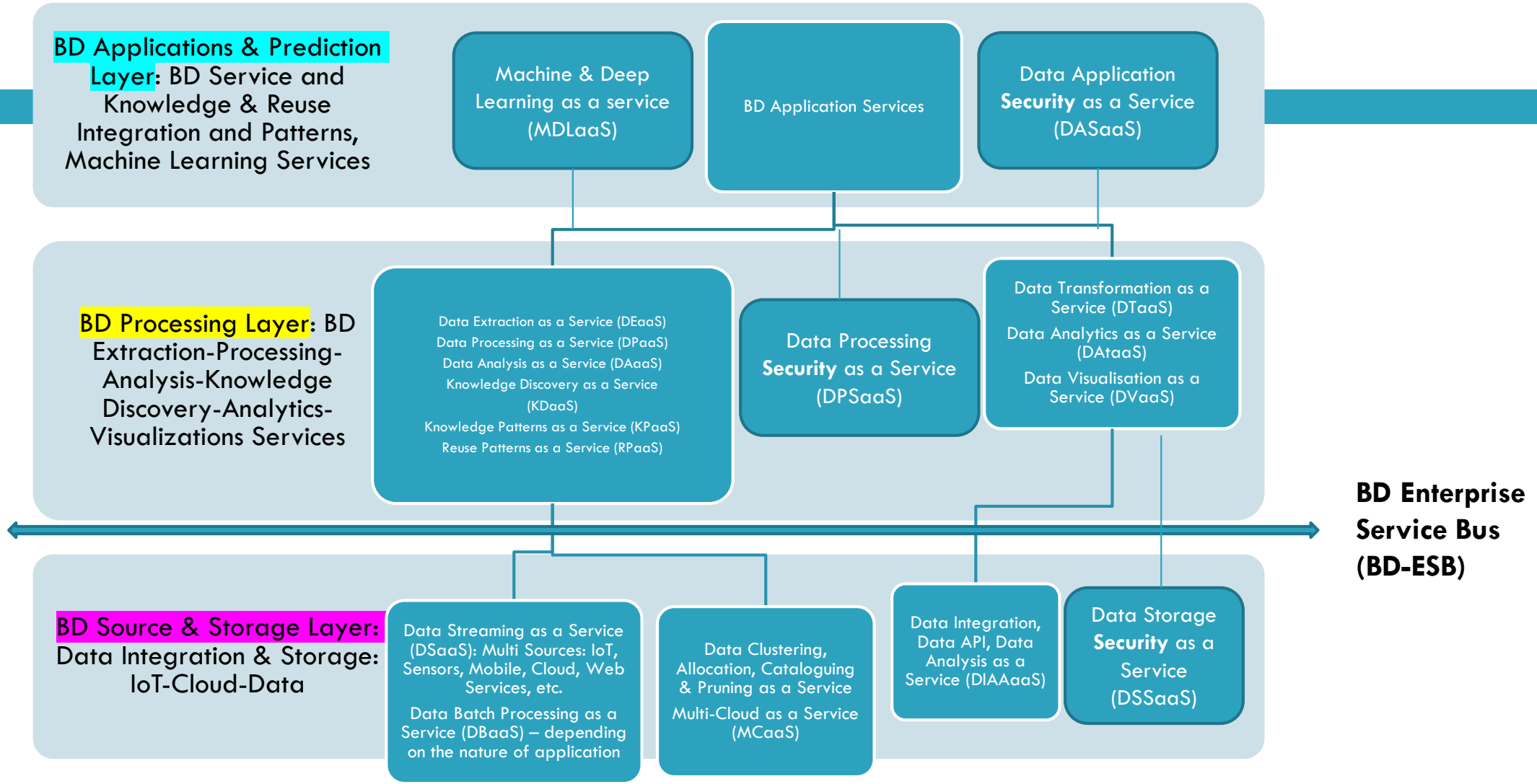


Arruda D., and Madhavji, N.H. (2017) Towards a Big Data Requirements Engineering Artefact Model in the Context of Big Data Software Development Projects, 2017 IEEE International Conference on Big Data (BIGDATA)

BD Service Component Model: Data Processing layer

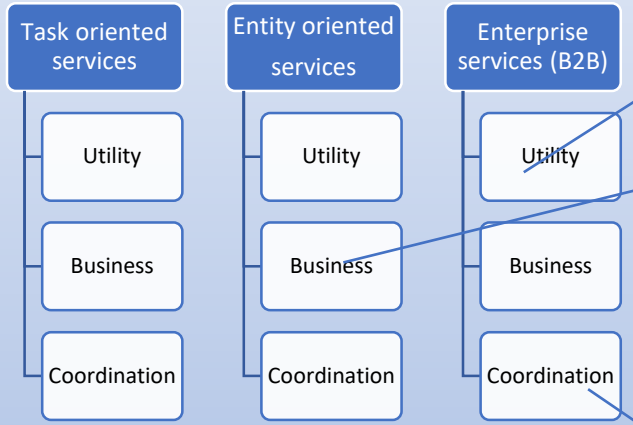


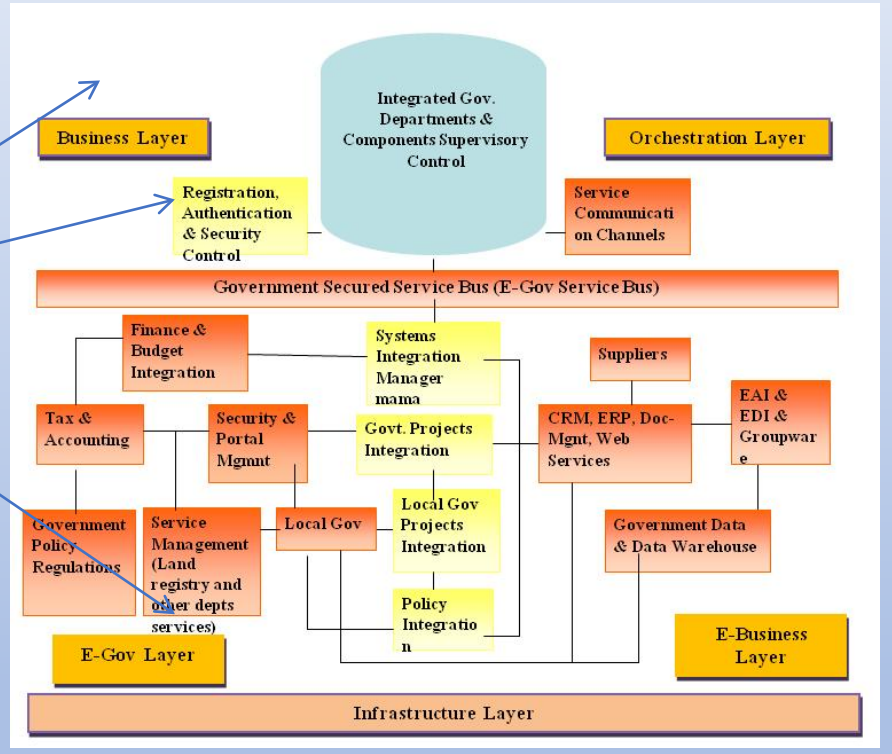
SEF4BD Reference Architecture for Big Data: Secure Service-Oriented SE for BD



Pääkkönen, P and Pakkala, D (2015) Reference Architecture and Classification of Technologies, Products and Services for Big Data Systems, Big Data Research, Elsevier, http://dx.doi.org/10.1016/j.bdr.2015.01.001

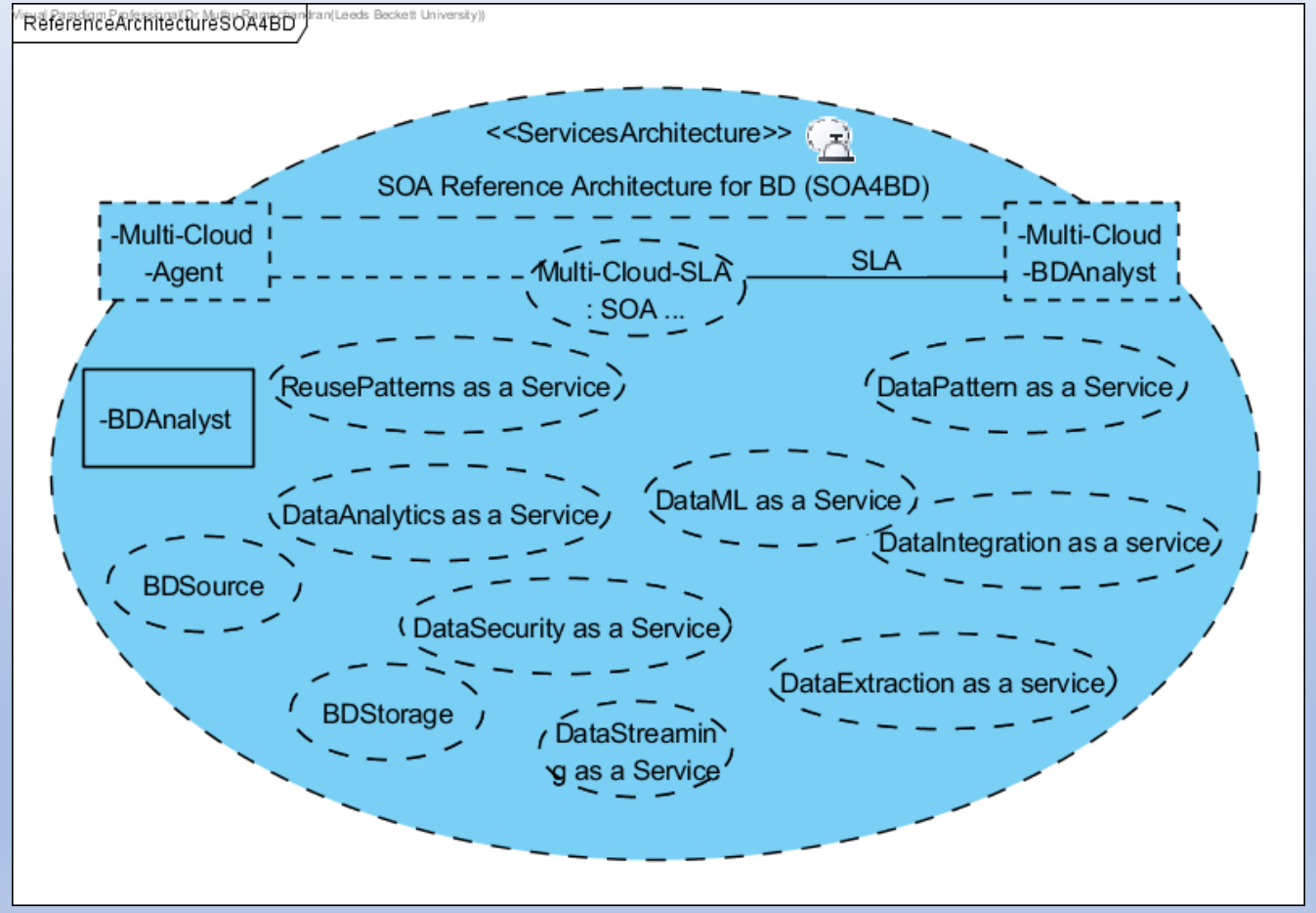
Mapping Services to SOA Design





As an Architect, you will need to categorise services therefore you will be able to place them in the appropriate architecture layers on the right

SOA Architecture (soaML design) for SEF4BD with REF4BD (Reference Architecture)

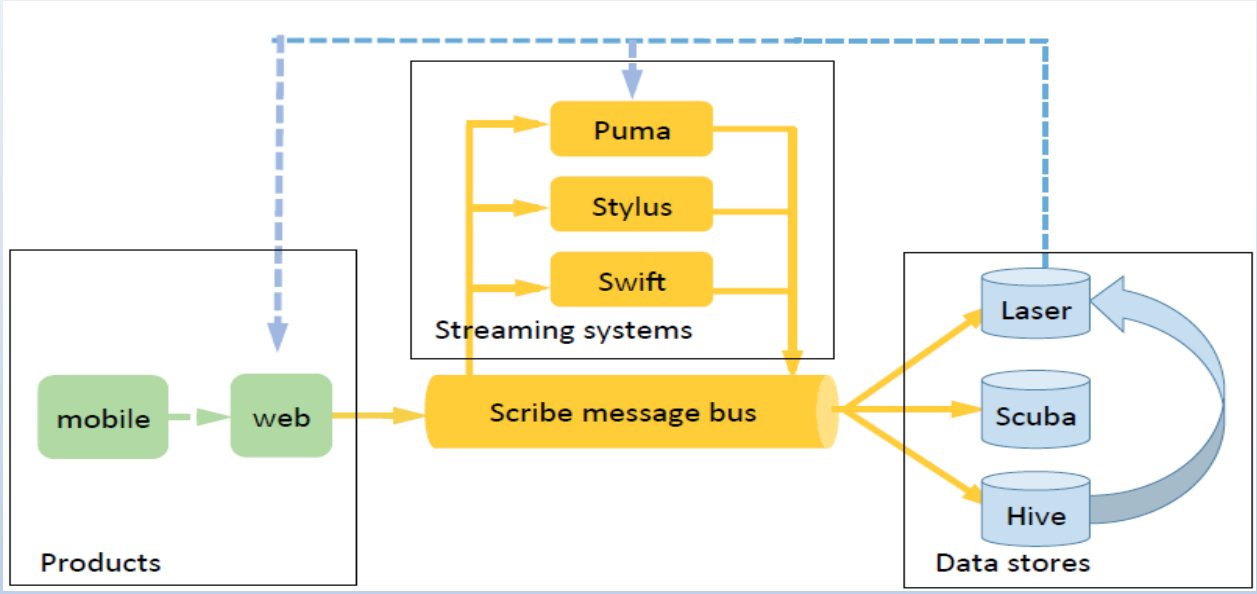


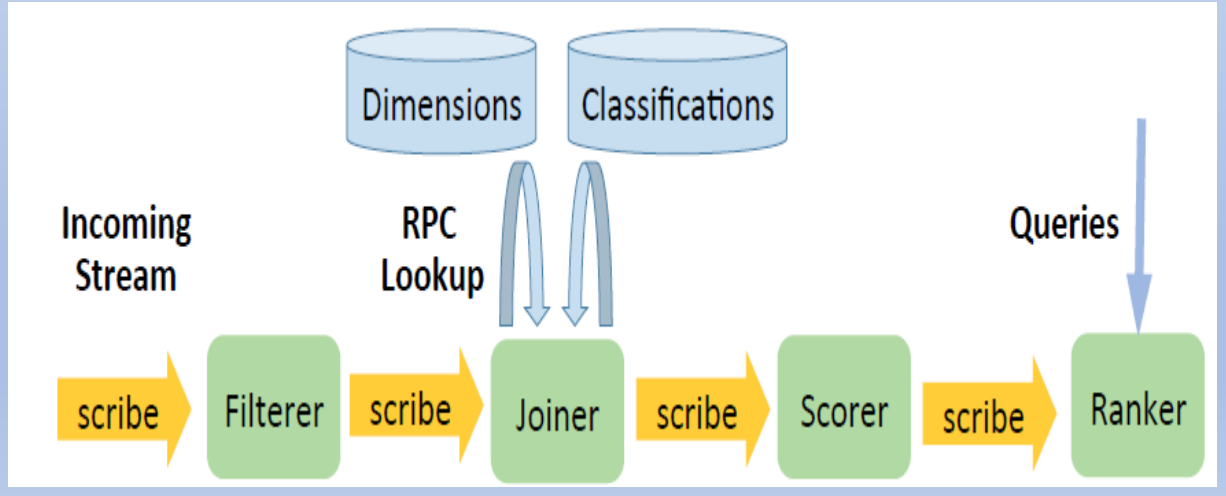
BPMN Simulation with REF4BD

Facebook Real-Time Big Data Analytics

Facebook Real-time streaming services

Many companies have developed their own systems: examples include Twitter's Storm [28] and Heron [20], Google's Millwheel [9], and LinkedIn's Samza [4].
Facebook's used its own tools known as Puma, Swift, and Stylus stream processing systems.
Facebook has identified important design decisions: **performance, fault tolerance, scalability, and correctness**.

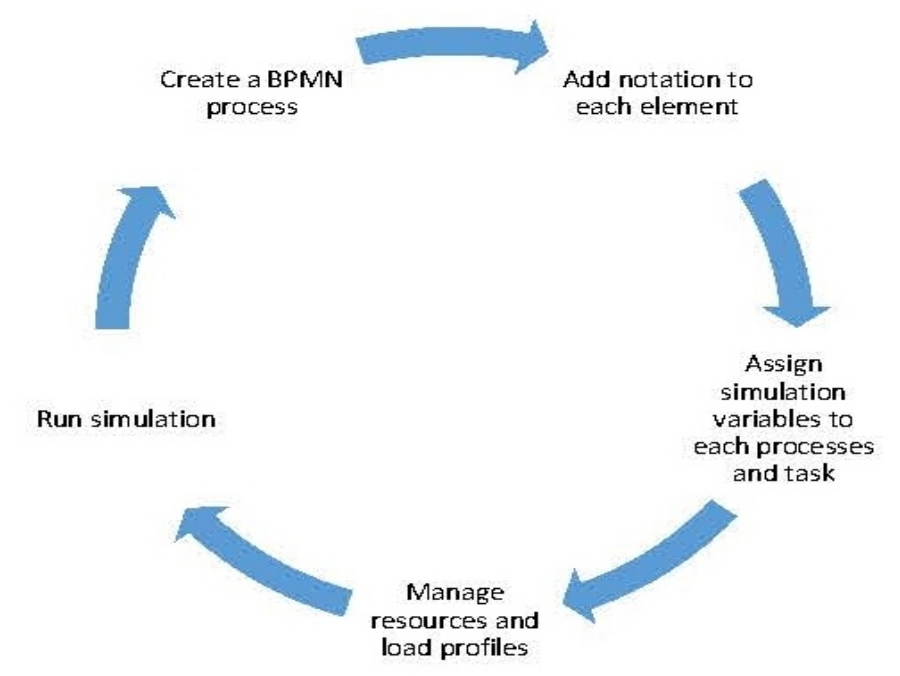


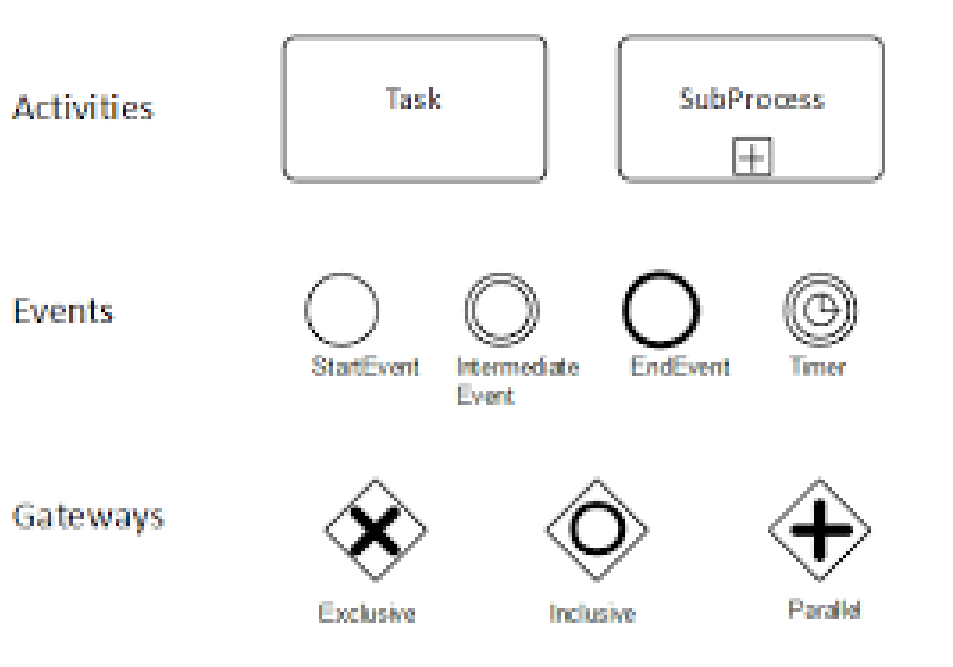


An example streaming application with 4 nodes: this application computes \trending" events.

Chen, G. J et al. (2016) Real-time Data Processing at Facebook, ACM SIGMOD 2016 San Francisco, CA USA

BPMN Framework for Validating the Reference Architecture (REF4BD)

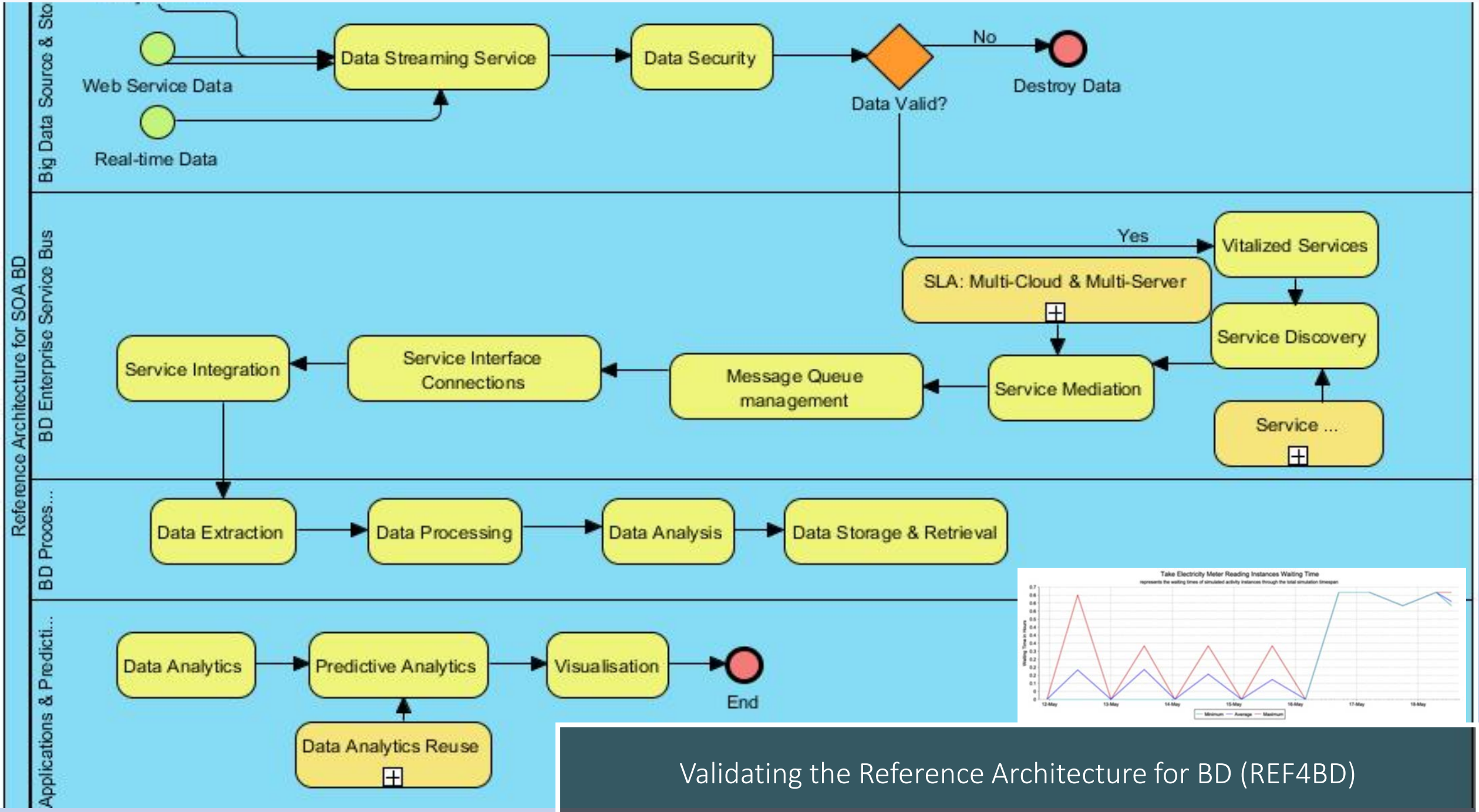




BPMN 2.0 modelling & simulation tools:
BonitaSoft 7.8, https://www.bonitasoft.com/

Visual Paradigm, https://www.visual-paradigm.com/features/bpmn-diagram-and-tools/

Bizagi Studio, https://www.bizagi.com/uk/products/bpm-suite/studio



Validating the Reference Architecture for BD (REF4BD)

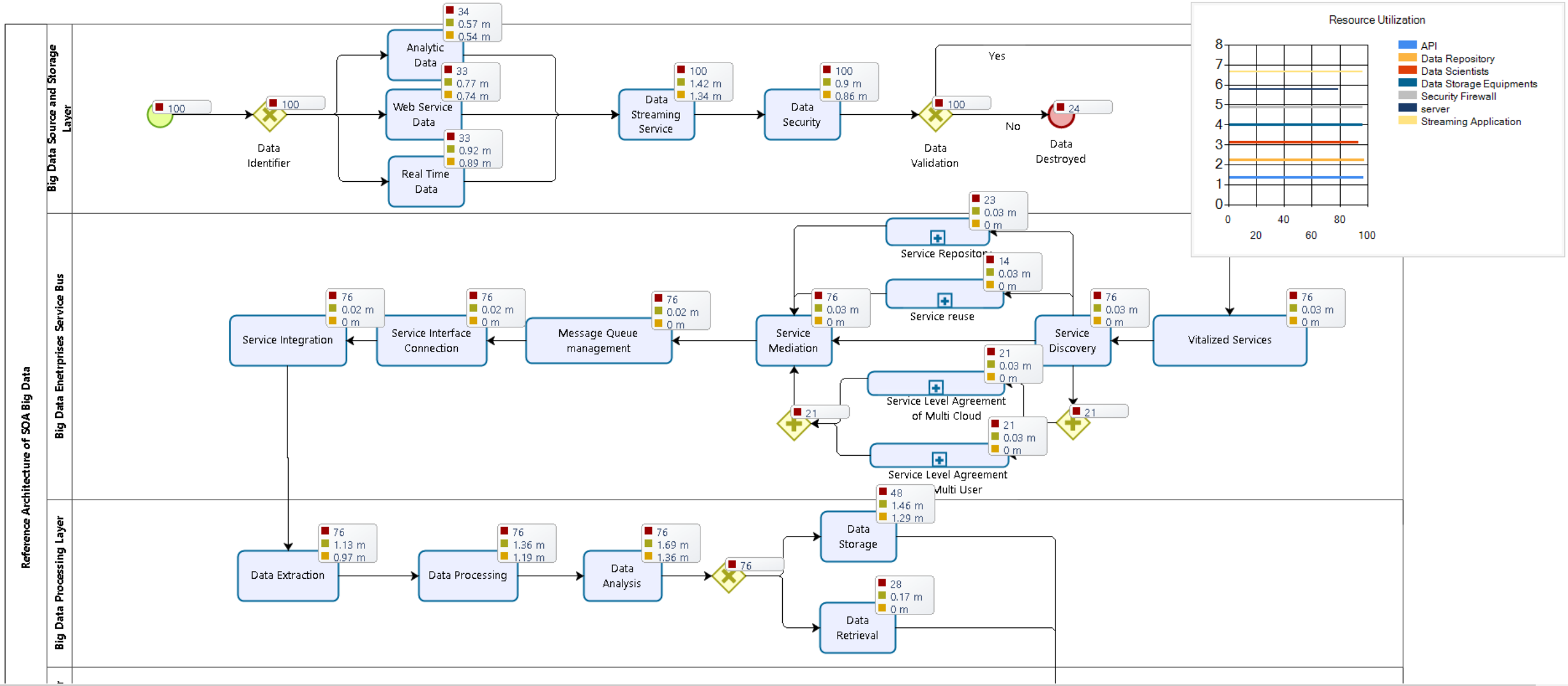
Process Simulation

Start | Scenario | Stop | Results — Simulation

Display | Off | Position | Analysis — Real Time Display

Completed | Average time | Average time waiting | Total time | Total time waiting

Close window — Close



Elapsed Time : 00.00:16:35.000

Type here to search

15:41
01/02/2018

Results, Analysis, and Conclusion

- The results shows number of times a particular business service used to process that data, and time taken.
- In addition, BPMN 2.0 also shows a number of time each resource have been used such as API, Data Scientist (Human Tasks in BPMN), Data Repository, Servers, Firewall, Data Storage, etc.
- The results shows by implementing Facebook types of big data processing into REF4BD is more secure and uses resources efficiently than suing non-standard architectures. The efficiency result shows about 95% use of automated processing by API and Data Application (Service Components) services.
- Compared to Facebook streaming application which uses more filters which has extra-overheads and resources required whereas REF4BD is more predictable, and can achieve correctness, fault-tolerance, and scalability since it is standardised across all data process applications and services.

Summary and Questions

- SOA has emerged based on established software design principles of find-request-service paradigm suitable for service-oriented applications such as big data processing and analytics. Therefore, it is time to consider systematic and engineering approach to developing and deploying big data services as the data-driven applications and devices increasing rapidly.
- In this context, this paper proposed a software engineering framework and a reference architecture which is SOA based for big data applications' development. This paper also concluded with a simulation of a complex big data Facebook application with real-time streaming using BPMN simulation to study the characteristics before big data service design, development, and deployment. The simulation results demonstrated the efficiency and effectiveness of developing big data applications using the reference architecture framework for big data.
- To be sustainable, we need an approach which is systematic, business-driven (supporting business-process and value driven), and based on established Software Engineering practices

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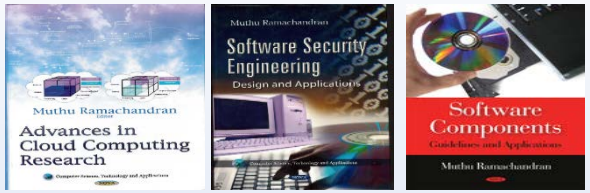

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