BUSTECH 2015

The Fifth International Conference on Business Intelligence and Technology

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SABIT 2015

The First International Workshop on Social Aspects of Business Intelligence and Technology

March 22 - 27, 2015

Nice, France

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Forward

The Fifth International Conference on Business Intelligence and Technology (BUSTECH 2015), held between March 22-27, 2015 in Nice, France, 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 conference had the following tracks:

- Modeling and simulation
- BPM and Intelligence
- Features of business/technology development

Similar to the previous edition, this event attracted excellent contributions and active participation from all over the world. We were very pleased to receive top quality contributions.

BUSTECH 2015 also included the following workshop:

- SABIT 2015, The First International Workshop on Social Aspects of Business Intelligence and Technology

We take here the opportunity to warmly thank all the members of the BUSTECH 2015 technical program committee, as well as the numerous 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 that dedicated much of their time and effort to contribute to BUSTECH 2015. 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 also gratefully thank the members of the BUSTECH 2015 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope BUSTECH 2015 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the area of business intelligence and technology. We also hope that Nice, France provided a pleasant environment during the conference and everyone saved some time to enjoy the charm of the city.

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Comprehensive Integration of Executable Business Process Models with Semantic Concept and Task Specifications

Ralph Hoch, Hermann Kaindl, Roman Popp and Dominik Ertl
Institute of Computer Technology, Vienna University of Technology
Vienna, Austria
{hoch, kaindl, popp, ertl}@ict.tuwien.ac.at

***Abstract*—Business process models mostly exist without a corresponding reference ontology of the business and its domain, or without semantic specifications of their basic tasks to be executed through software. This work shows our 'big picture' of integrated support for modeling business processes in BPMN 2.0 (Business Process Model and Notation). It illustrates representing semantic information of such business processes and its links. So, this paper presents our comprehensive integration of executable business process models represented in BPMN 2.0 with semantic concept and service task specifications. Our integration can be used for model verification and generation, as well as model execution with assigned (software) services (or objects).**

Keywords-Business process modeling; semantics of business process models; service tasks

I. INTRODUCTION

Executable business process models should facilitate both the business itself and the development of software supporting it, which was a major motivation for the development of BPMN (Business Process Model and Notation) 2.0 [1] for representing the business process models. It has a standardized specification of business processes with the possibility to directly execute them, based on the defined BPMN 2.0 metamodel and assigned (Web) services, although we found a pitfall in this regard [2]. Instead of hand-crafting both the process models and the related software, we have a vision that integrated semantic concept and task specifications may improve on that by their possible use for automated generation and formal verification [3] as well as general support for related software development in various usage scenarios.

The remainder of this paper is organized in the following manner. First, we discuss related work on previous approaches to partial integration. Then we present our 'big picture' of integrated support for modeling business processes in BPMN 2.0. Based on that, we sketch potential use of this integration. Finally, we draw tentative conclusions and propose future work.

II. RELATED WORK

Earlier work on the interplay of business process models, service/task ontologies, and domain ontologies was carried out in the project SUPER (Semantics Utilised for Process Management within and between Enterprises) [4], where a tool named "Maestro for BPMN" was developed. Born et al. [5] describe how user-friendly semantic annotation of process artifacts with tags/markups can be achieved in business process models via Maestro. These annotations refer to semantics in domain ontologies, and based on them, this tool allows one to automatically compose activities within business processes [6]. Maestro also supports certain consistency checks of the control flow against semantic annotations of such annotated processes [6]. Born et al. [7] describe how "adequate" services can be identified for specific tasks through match-making by use of the semantic annotations. Maestro was based on a previous BPMN version, which is not suitable for direct execution of business processes. This is different to our work, which specifically focuses on *executable* business process models in BPMN 2.0. Our work also envisages a more comprehensive integration of such models with semantic concept and task specifications, and especially on even more ambitious scenarios of use of the integration also with executable models. In addition, we also focus on validation and formal verification of business processes [3].

Burkhart et al. [8] define in more recent work a *structural description of business models*. Their synthesis of eight existing ontologies is extended with state-of-the-art understanding and research progress on business models. This work proposes transformation of such structural descriptions to business process models, which is a different but possibly complementary approach to ours.

The automatic execution of business process has been studied for quite some time, primarily with *Business Process Execution Language for Web Services (BPEL4WS)*. Aslam et al. [9] describe how BPEL4WS can be enhanced with semantic information via the *Web Ontology Language for Web Services (OWL-S)*. They present a mapping strategy as well as tool support for that. BPEL4WS was primarily designed for orchestration of Web services in the sense of automatic execution of business process models using these services. Our work builds on the more recent BPMN 2.0 for this purpose, since it additionally facilitates a graphical representation of business process models, which is better understandable also by business process managers. In this way, BPMN 2.0 intends to narrow the gap between the business and the software worlds.

Marzullo et al. [10] proposed another integration effort, with

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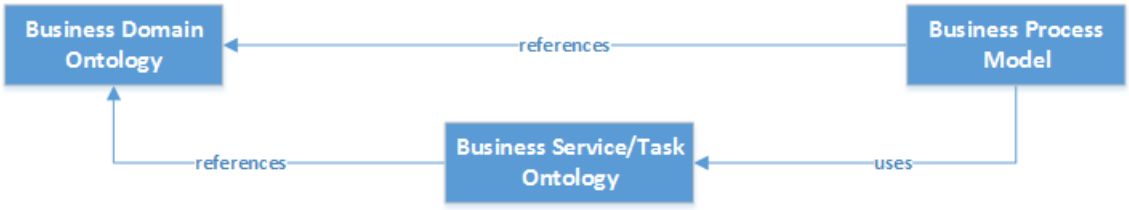

Figure 1: Conceptual View of Integration

the purpose of supporting domain-driven software development. So, it centers around a shared domain specification to be used as a reference point for software applications. The central domain repository allows exchanging information in a standardized way between different projects or companies. So, the focus is clearly on efficient software development, even though Marzullo et al. [11] describe possibilities to include business process modeling as well. In contrast to our approach, the domain specification is not based on a formal specification language or ontology. Saiyd et al. [12] describe a similar approach to Marzullo et al., but propose an ontological foundation for domain-driven design. However, their work is more focused on the specification of the ontological concepts than their actual use. So, neither of these approaches has such a comprehensive integration and the scenarios of its use in mind that we propose in our work.

While BPMN 2.0 has, in contrast to the previous version BPMN 1.0, a defined meta-model, it is not based on a logic foundation. Therefore, Natschlaeger et al. [13] propose an OWL-based (Web Ontology Language) upper ontology for BPMN 2.0 to allow a formalized specification of BPMN 2.0 processes. Using it in our integration approach would certainly be possible and interesting, since it would make it completely based on ontologies. As it stands, however, our early feasibility prototypes indicate that using the meta-model of BPMN 2.0 should be sufficient for our currently envisaged scenarios of use.

Cabral et al. [14] show in their work how business process modeling can benefit from semantic information. They describe the ontology BPMO (Business Process Modeling Ontology), which includes semantic knowledge about organizational context, workflow activities and other business process parts. Using this ontology, it is possible to refer to semantically annotated data and services for working in a coherent way. In contrast, our approach uses BPMN 2.0 as modeling and orchestration language. In addition, we focus on combining BPMN with OWL semantics rather than representing business processes in an ontology.

Semantic Business Process Management (SBPM) helps handling the life cycle of business process management through ontologies and Web services, as proposed by Filipowska et al. [15]. They illustrate with various scenarios how SBPM can be used in the business process management area. Hepp et al. [16] describe a set of ontologies for SBPM, which target the spheres of enterprise structures and operations. This work is based on *Web Service Modeling Ontology (WSMO)* [17] and its closely related representation language *Web Service Modeling Language (WSML)* [18] for combining semantic Web services with business process management [19]. In contrast, we use OWL-S for semantic specification of services, and BPMN 2.0 for execution of business processes, but we do not strive for representing business processes in an ontology.

III. Big Picture of Integration

We propose here a comprehensive integration of business processes with semantic concept and service task specifications. Figure 1 shows the conceptual view of our big picture of this integration. The *Business Domain Ontology* represents the concepts/objects of the business domain, and the *Business Service/Task Ontology* represents the services/tasks. Services operate on objects and manipulate their states. They may even be coupled with a specific object and define the operations that are possible or allowed on this object. In an artifact-centric approach, they enable the life-cycle defined for the object. The *Business Process Model* specifies how services/tasks are composed and on which objects they operate on. Taken together, this proposed integration specifies the essence of the business.

Several technologies exist for realizing each of the parts shown in Figure 1. Figure 2 shows the big picture of integration with concrete technologies chosen by us for this realization. In our approach, we chose technologies based upon their widespread availability and use, and how well they support our integration. Semantic repositories are often specified via ontologies represented in Web Ontology Language (OWL) [20], a knowledge representation language. We decided to use OWL as well, since it is widely used for representing ontologies and has a wide range of applications. The semantic specification of services is provided through an OWL-S (an ontology built upon OWL for semantic descriptions of Web services) repository, since it allows direct reference to existing OWL ontologies [21]. Furthermore, it allows additional specifications (pre- and post-conditions) for services, which expand on the typical input-/output-specification of services per se as given in WSDL (Web Service Description Language) descriptions [22].

Especially for the *Business Process Model*, several languages and technologies could be used as many companies even use their own approach to specify business processes. We chose BPMN 2.0 as it is the current version of a standardized and open specification language for business processes [1]. It also allows the automatic execution of business processes when software is available for so-called service tasks (in the form of Web services or Java objects). BPMN 2.0 is currently

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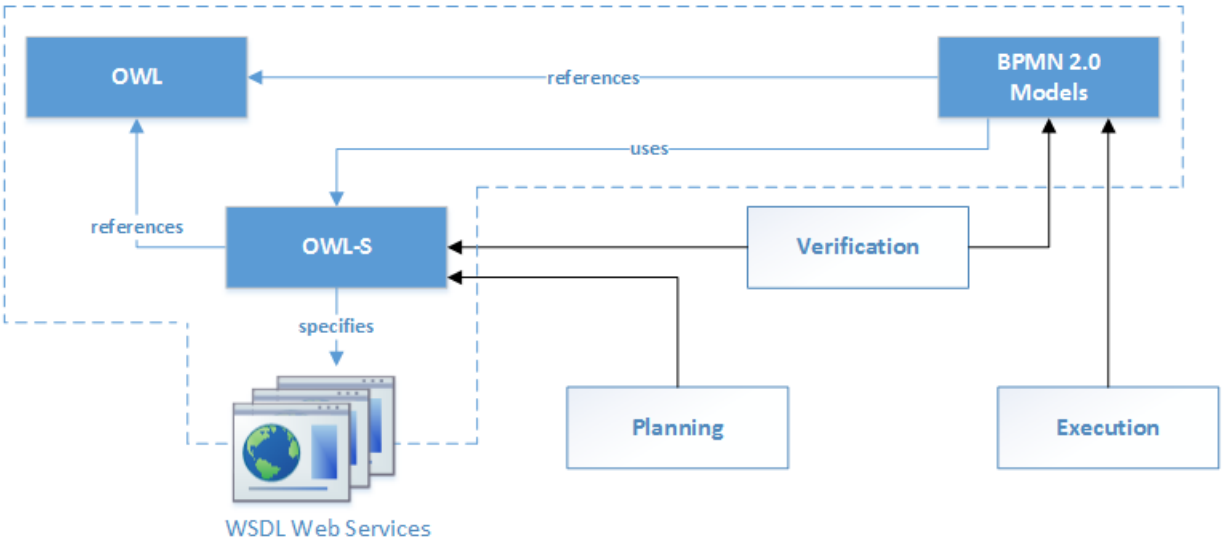

Figure 2: Big Picture of Integration and Use with Concrete Technologies

supported by a wide range of execution frameworks for that purpose.

However, BPMN 2.0 does not specify any direct relationship to OWL-S services, and only WSDL services are described in the standard. Therefore, a wrapper is needed that allows the transformation of OWL references to existing services or objects in the overall software framework. The wrapper has to be built around an existing BPMN 2.0 execution framework. Figure 3 shows how the wrapper operates and how it is integrated into the framework. Technically, the wrapper sits on top of an BPMN 2.0 execution engine and deals specifically with OWL references. To accomplish this, the OWL references have to be translated to their corresponding implementations, i.e., to Web Services specified through WSDL. The resulting address of the corresponding WSDL is then used to directly call its Web Service, and by doing so, executing the BPMN 2.0 process. In our approach, we focus on Web Services described by WSDL, but other approaches such as a mapping to implemented methods or objects are also possible.

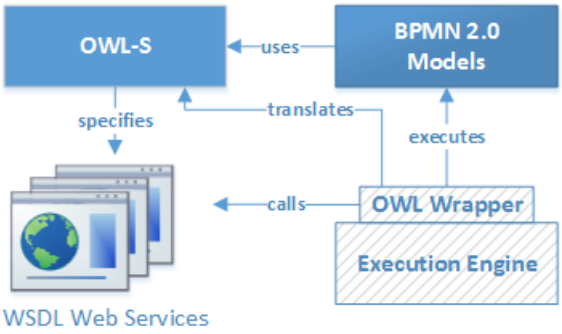

Figure 3: Wrapper for Execution Engine

IV. Potential Use of the Integration

This comprehensive integration can (potentially) be used for the following approaches, once it is implemented in an integrated tool environment:

- domain-driven development of business software with (fragments of) a business process model as its target;
- top-down development based on business process models linked to ontologies;
- automated generation of (certain kinds of) business process models through plan generation;
- formal verification of (certain kinds of) business process models through a logic-based approach [3];
- automated generation of (parts of) user interfaces for business software based on a domain ontology, and
- execution of business process models as business software [2].

While most of these approaches can be done in isolation, our proposed integration offers certain added value at least for some of them as indicated below.

Development of business software based on domain artifacts can, of course, be done based on any kind of domain model. However, ontologies may serve this approach better due to their formally defined concepts and services. In addition to bottom-up development, we envisage a certain top-down orientation by having at least fragments of a business process model as a target. We also envisage that the business software developed in this way would not just implicitly encode a business process, but also an explicit business process model should result. In an integrated environment, it would be linked with the ontologies. Possibly, the whole software could be centered around the business process model in such a way, that an engine interpreting it is integrated and drives it.

Starting development top-down from a business process model is also possible, also without our proposed integration.

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It involves adding software parts (possibly in the form of Web services) to tasks in the model. In the proposed integrated environment, this should be facilitated especially through the semantic information in the ontologies, which can, e.g., help finding relevant artifacts through semantic matching.

Based upon the OWL-S specification of services, approaches for automatic *planning* algorithms have already been proposed, which try to automatically generate composite services out of atomic services (see, e.g., Klusch et al. [23] and Ziaka et al. [24]). Figure 2 indicates this through the `Planning` box. The line with the arrow pointing towards the `OWL-S` box indicates that OWL-S is the conceptual basis for planning. Logic-based technologies, such as the Fluent Calculus [25] and its supporting tool FLUX [26], seem to be even preferable for this purpose because of their well-defined semantics. Still, a transformation from OWL-S to FLUX is necessary, such as the one given in [27]. Note, however, that only certain kinds of business process models can be generated automatically by these planning algorithms. Overall, this planning approach using FLUX can handle everything that FLUX can. Our proposed integration would make the generated business processes directly available in BPMN 2.0.

When using FLUX, a formal verification of a business process model against the specification of the services composed in it can be performed automatically [3]. Figure 2 indicates this through the `Verification` box. Analogously to generation of process models, only certain kinds of business process models can be automatically verified using this approach. Our proposed integration would directly take them from a BPMN 2.0 representation as linked to OWL-S.

Integrating these technologies can also lead to a more flexible software application with an adaptable user interface based on the ontologies. Since the domain ontology already specifies what kind of attributes are related to a concept, a simple user interface can be generated based on this specification. Changes in the domain ontology would be directly reflected in the resulting user interface. In combination with additional descriptions of the user tasks, an individual user interface for each process can be automatically generated.

Execution of process models represented in BPMN 2.0 is, in principle, possible with properly attached Web services or Java objects (while there are certain intricacies, see [2]). Our proposed integration still allows it (as indicated through the `Execution` box in Figure 2), although this integration actually makes it more difficult. In fact, BPMN 2.0 normally links to WSDL directly, so that our integration needs the additional wrapper sketched above, around the execution engine for BPMN 2.0 models.

The real added value of our proposed integration, however, comes from the combined use of (some of) these approaches. Let us sketch a few envisaged scenarios of such combined use.

Scenario 1:
Create a business process model in BPMN 2.0 using the available and specified building blocks in the ontologies and corresponding service implementation.
Verify it against the semantic specifications of its parts.
Execute it with the service implementations.

The added value of this scenario is convenient modeling and verification in an integrated tool environment, where potential errors through model translations can be avoided.

Scenario 2:
Automatically generate a business process model for a given goal.
Execute it with the service implementations.

The added value of this scenario is similar to the one of Scenario 1, but the process is even automatically generated, and verified by its very construction.

Scenario 3:
Create a business process model from scratch or take a given one.
Create semantic specifications of services not yet available.
Verify the model against the semantic specifications of its services.
Implement missing services according to their specifications.
Execute the business process model with the service implementations, both old and new.

The added value of this scenario is that our integration enables software developers and business process experts to work together in a consistent business domain without potential mismatches between their respective domains. In addition, the semantic specifications of Web services can be verified against their composition or a goal specification, even before they will be implemented.

V. Conclusion And Future Work

This is work in progress and presents a vision. Since it is primarily based yet on previous work, a conceptual view supported by a few feasibility prototypes and work on verification as well as execution in this context, only tentative conclusions can be drawn. Still, we have already sketched new scenarios of potential use of our comprehensive integration for developing business software in ways not yet envisioned in previous work (to our best knowledge). Viewed from another perspective, this approach should lead to new ways of software reuse and reusability.

Future work will, of course, have to face the challenges involved in creating (or reusing) corresponding ontologies, in building and testing several parts of this comprehensive integration, and finally to evaluate.

VI. Acknowledgment

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There is More to Intelligent Business Than Business Intelligence

Janne J. Korhonen
Department of Computer Science and Engineering
Aalto University School of Science
Espoo, Finland
janne.korhonen@aalto.fi

Isabel Page
Fraser Page
Uebersyren, Luxembourg
ipage@pt.lu

Abstract — **Business Intelligence (BI) purports to support decision-making with better insights into the organization's environment and sophisticated analysis techniques of 'Big Data' help make more effective use of the vast data for competitive advantage. Given adequate sponsorship, approval, and funding from the top level, business intelligence and analytics (BI/A) technologies are also purported to help in organizational transformations. However, BI/A come with a number of inherent limitations. The amount of organized data is relatively small and these technologies do not adequately account for the social and psychological aspects of the transformation. They provide decision-makers only with lagging indicators – view on past and present performance – and inform strategy with extrapolations of trends, at best. However, organizational transformation calls for forward-looking transformational thinking and human discretion that can be assisted with technology only to a limited extent. In this paper, we posit the potential consequences of not taking these limitations into account. We will also discuss how the business intelligence and analytics technologies on one hand, and the social technology of 'presencing,' on the other, could be synergistically combined to support integrated organizational transformation.**

Keywords — business intelligence; analytics; big data; organizational transformation; Theory U; change management.

I. INTRODUCTION

Information on the operational environment is a fundamental need for human beings and organizations alike [1]. The capability that enables monitoring changes in an organization's environment is called Business Intelligence (BI). The term usually refers to technologies and techniques for gathering, aggregating, storing, accessing, analyzing and utilizing data to support decision-making, but it can also be seen as an overall process that provides the business with better insights into the environment [2].

However, the lack of relevant information appears to be less of a critical issue for managers than an over-abundance of irrelevant information [3]. Six out of ten respondents in a global executive study [4] agreed that their organization has more data than it can use effectively. Recently, Big Data – "large pools of data that can be captured, communicated, aggregated, stored, and analyzed" [5] – has been seen as a way to cope with the growing data deluge and to harness computational power to productivity improvements and innovation. It is seen as the next source of competitive differentiation and advantage [6][7], and, indeed, top-performing organizations use analytics five times more than lower performers [4].

Business Intelligence and Analytics (BI/A) technology alone is not the silver bullet that would enable requisite strategic agility. The value of information technology (IT) stems increasingly from the capability, skills and motivation of people to leverage the technology. However, many companies pay only marginal managerial attention to this human capital, which, as a result, is misused, wasted or lost [8]. Consequently, "today's managers are trying to implement third-generation strategies through second-generation organizations with first-generation management" [8].

Sustainable organizations balance public interest with financial returns and place society and people at the core of organizational purpose [9]. As per this institutional logic, leaders need to persuade and motivate others in their organizations to make transformation a reality. High performing leaders do this by combining external data on competitive environment and industry as well as internal data in the form of gut feeling derived from experience and wisdom. Using gut feelings combined with strong systems thinking, self-awareness of their own blind spots and limitations [10], and emotional awareness of others, enlarges and enriches how leaders set and execute competitive strategy.

A social technology is "a replicable set of procedures that is designed to produce an effect upon socially important behaviours of relevant participants under a variety of real life conditions" [11]. Social technologies may be used to enable the development of skills to facilitate 'participatory competence' [12].

Turbulence is a relative condition [13]: different organizations experience threatening environmental conditions differently, depending on the amount and variety of resources and skills they have available – their adaptive capacity – for managing those conditions. Theory U [14] is a social technology that, in our view, will help recognize and navigate turbulence – misalignment between the system's adaptive capacity and complexity of its environment.

In this paper, we set out to answer the following research questions:

1. What is the role of BI/A capability in organizational change and transformation?

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2. What are the limits of BI/A technologies in supporting organizational change and transformation?
3. How can these limits be mitigated or overcome through the application of an integrative social technology, in general, and Theory U, in particular?

Our paper is conceptual and exploratory in nature. It is intended to provide a step towards deeper understanding of the nature of BI/A capability, its socio-technical underpinnings, and its role in organizational change and transformation. The contribution of our paper lies primarily in the insights into the potentially consequential role of integrative social technologies such as Theory U in complementing the use of BI/A technologies to the ends of organizational change and transformation.

The structure of the paper is as follows: In Section II, we present three progressively more advanced capabilities of using BI/A technologies. In Section III, we discuss Theory U as a social technology for transformational change: process and communication tools that help translate strategy to implementation. In Section IV, we review Babüroðlu's [25] framework of maladaptive responses to turbulence. Drawing on the prior sections and some further literature, Sections V through VII address our three research questions, respectively. Finally, in Section VIII we briefly draw conclusions, discuss the implications of our conjectures, and call for further research.

II. LEVELS OF BI/A CAPABILITY

LaValle and his colleagues [4] report the results of IBM Institute for Business Value survey of nearly 3,000 executives, managers and analysts working across more than 30 industries and 100 countries, in which they identified three distinctive levels of capability in organizations' analytics prowess:

1) Aspirational. These organizations are focusing on efficiency or automation of existing processes. The primary driver is that of cutting costs.

2) Experienced. These organizations look beyond cost management. With some analytic experience under the belt, they are developing better analytics practices and beginning to optimize their organizations.

3) Transformed. These organizations are the analytics competitors [6] that use analytics as a competitive differentiator. Having learnt to organize the necessary elements – people, processes, and tools – these organizations are focused on driving customer profitability.

Relatedly, Watson [15][16] identifies three typical 'targets' of BI initiatives, differing in "their focus; scope; level of sponsorship, commitment, and required resources; technical architecture; impact on personnel and business processes; and benefits" [16]:

1) The development of independent BI applications, each with its own users, software and data sources. These point solutions are often data marts that cater for a specific departmental need, and their sponsorship, approval, funding, and governance also occur at the departmental level.

2) The creation of enterprise-wide infrastructure that provides more consistent decision-support data and supports current and future BI needs. A critical component in this infrastructure is a data warehouse that has impact and creates benefits throughout the organization. Accordingly, senior business management provides sponsorship, approval, and funding for the initiative.

3) Organizational transformation, where the data warehouse is leveraged to the business strategy and to transform how the business competes in the marketplace. Accordingly, sponsorship, approval, and funding of the initiative originate at the highest executive levels.

We view that the type of capability developed and targets of business intelligence selected in an organization, whether by accident or intention, will strongly impact its transformational outcomes.

III. THEORY U: SOCIAL TECHNOLOGY FOR ORGANIZATIONAL TRANSFORMATION

Scharmer's [14] Theory U, as the social technology of presencing, is about profound transformation: personal, social and global, and is therefore our social technology of choice. The deep focus of Theory U is on self-awareness of personal blind spots and the building of empathy combined with the practical development of sensing. This focus sits inside a framework that takes into account levels of attention paid to the exterior (fields of attention), levels of learning and change, and the reduction and elimination of pathological anti-practice. This approach provides a far more comprehensive and integrated model for change than other popular organizational transformational models such as Appreciative Inquiry [17]. In our view, Theory U is also inexpensive, effective, decentralized, flexible, sustainable, simple and compatible with existing customs, beliefs and values. As such, it is particularly useful as a social technology [11].

Originally developed by Friedrich Glasl and Dirk Lemson as the U-procedure [18], Theory U, in its current form, has come to be understood in three ways: as a framework, as a method for leading and embedding profound organizational co-creative change and as a way of being, connecting to the more authentic aspects of our higher self [19].

Theory U is based on the premise that we cannot transform the behavior of systems unless we transform the quality of awareness and attention that people apply to their actions within these systems, both individually and collectively. Scharmer [14] maintains that through 'presencing' – being in touch with the inner place or source from which attention and intention originate – individuals, teams, organizations and global systems alike are able to raise to a higher level of operation to seize the highest future possibilities that 'want to emerge.' The deepest level of transformation not only reflects on what has happened in the past, but draws from a more generative and more authentic presence in the moment linked with the individual's or organization's highest future potential.

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A. Field structures of attention

Theory U is based on seven field structures of attention in an U-shape (Figure 1; [14]):

1) Downloading. Attention is guided by habitual patterns that go unquestioned. Existing patterns of behavior are collectively reproduced. Stopping downloading is the precondition for entering the U process.

2) Seeing. Attention moves from the center of organization (i.e., the system of habits and routines) to the periphery, i.e. to the edge of the organizational boundary, which allows the observer to become aware of what is happening outside.

3) Sensing. Attention moves from inside the organization – looking *at* the field – to outside the organizational boundaries, where perception begins to happen 'from the whole field.' The system being observed is no longer seen as something external 'out there,' but it also includes the observer as part of the system.

4) Presencing. Attention shifts to the source of the highest future possibility that is seeking to emerge. The boundaries between the presence of the past (current field) and the presence of the future (the emerging field of the future) collapse.

5) Crystallizing. Attention is sustained in the source and one starts to operate from it. Crystallizing denotes the first step in the presencing journey (connecting and operating from source): clarifying vision and intention from the highest future possibility. "We put into specific language what it is that we want to create." (p. 192).

6) Prototyping. The future is explored by doing and experimenting. The field structure of attention deepens, as the holding space advances the letting come process from envisioning to enacting.

7) Performing. Attention is focused on how presencing embodies itself into everyday practices within the larger institutional ecology. The new pattern that started to shape at the bottom of the U is now fully unfolded.

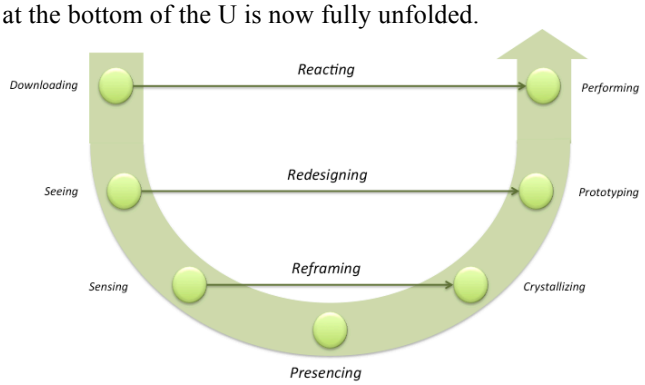

Figure 1. The U Process [14]

B. Four levels of learning and change

Figure 1 depicts the four levels of (organizational) learning and change [14].

1) *Reacting*. Response to change happens in the context of existing habits and routines [14]. This is essentially *developmental change* [20], which represents improvement of what is already known or practiced: an existing skill, method, or performance standard. The new state is an enhancement of the old state rather than a radically new one. The required decisions are likely to be 'programmed' [21] – repetitive and routine – and can hence be relatively readily supported by technology.

2) *Redesigning*. At this level, the underlying structure and processes are changed [14]. Change is *transitional* [20]: the old state of the system must be dismantled and emotionally let go of and the new state clearly created to replace the old one. However, the transition between as-is and to-be states is not as straightforward as in developmental change and should be managed [22]. These types of changes are typically required in repositioning the organization to the changing environment. Decisions tend to be non-programmed [21]: novel, unstructured, and consequential. Middle management uses its judgment and general capacity for intelligent, adaptive, problem-oriented action.

3) *Reframing*. Changing the underlying pattern of thought [14] is about the target of *transformational change* [20]. It calls for rethinking the very identity, purpose or business model of the organization, which is reflected in change of individual and collective mindsets, beliefs and values.

4) *Presencing*. "Leading from the future as it emerges" [14] can be seen as changing the context, whose content will subsequently be filled [23]. Moving from "not knowing that you don't know" to "knowing that you don't know," (cf., [23]) this transformation of the context raises more questions than it answers. Such change cannot be addressed adequately by reflecting only on the past [14].

C. Inverse U: Pathological anti-practices

If the systemic complexity of the exterior surpasses the interior capacity to access the deeper streams of emergence, the system may go off track and resort to the following anti-practices (Figure 2; [14]):

1) Downloading. The anti-space also starts with downloading: reproducing existing patterns of behavior. However, these perpetuated patterns grow increasingly disconnected from the embedding field.

2) Not seeing. This stage of 'anti-emergence' means rendering increasingly blind and unable to recognize anything new. The system is stuck in the ideology of a single truth and isolated from the parts of reality that are not congruent therewith.

3) De-sensing. This stage pertains to the inability to be in touch with the emerging social fields external to the system. The individual or collective is stuck inside its boundaries.

4) Absencing. This is the opposite of presencing: incapacity to relate to the future that wants to emerge. The space is that of self-delusional hubris, not conducive to co-evolution with the embedding social field.

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5) Self-deluding. This stage represents a total disconnect between the reality and one's image of the unfolding future.

6) Aborting. Just as prototyping is about experimenting with the future, aborting is about killing the chances of the future altogether.

7) Destroying. The last stage of anti-emergence brings the system to its inexorable end of destruction.

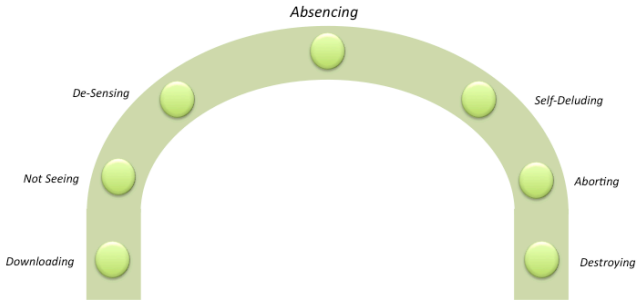

Figure 2. The anti-space of social pathology [14]

A move away from best-practice models that tend to keep organizations abreast of current trends towards an integrated approach gives rise to the possibility of innovation or industry disruption. The scope of a transformational model is therefore crucial, and should include addressing the anti-space of social pathology. Theory U provides such a framework for learning and change, allowing analysis and process in an integrated way, as well as systemic, collective, cultural and individual aspects necessary in transformational organizational change.

IV. MALADAPTIVE RESPONSES TO TURBULENCE

If the organization experiences turbulence (relatively higher external complexity than its internal adaptive capacity) for a prolonged period of time and fails to develop active adaptive strategies, its members will produce maladaptive responses [24].

Babüroðlu [24] provides a three-dimensional classification of these maladaptive responses based on Angyal's [25] dimensions of the structure of dynamic wholes:

1) The vertical dimension. The two poles of this dimension are the depth and the surface. The depth is more enduring and permanent, while the surface is more changeable. The depth is not subject to direct observation, but needs to be inferred from the surface manifestations.

2) The dimension of progression. This dimension begets a teleological means–end structure, in which each phase is the end for the preceding phase and the means for the following one.

3) The transverse dimension. This is the dimension of breadth, along which the parts exist side by side to organize into a whole.

First order maladaptive responses aim to reduce the complexity of the social field. These come in three different forms, respectively:

- *Superficiality* refers to "indifference to what needs or demands are taken as a starting point for one's behavioral responses."
- *Segmentation* pertains to separation of means and ends, wherein the social field is transformed into segments, each of which is integrated within itself but poorly with other segments.
- *Dissociation* is manifested by a lack of coordination between the parts in the whole.

Each of these three passive responses also has a respective, active correlate aimed at reducing the uncertainty and complexity of the turbulent environment ([26], cited in [24]):

- *Synoptic idealism*: an attempt to comprehensively cover all relevant information to control and to reduce the causal texture of the environment to a lower level.
- *Authoritarianism*: an attempt to impose a very rigid structure to prevent the means-ends or part-whole relationships from breaking down.
- *Evangelism*: an attempt to coordinate the field through notions such as 'all pulling together.'

While first order maladaptive responses attempt to reduce the causal texture, the second order responses crystallize it. Whereas the first order disintegrative disturbance of *segregation* would lead to fragmentation, the second order disintegrative disturbance implodes the whole into parts that can no longer be reintegrated [24]. The first order passive and active maladaptive responses will convert to the following second order maladaptive responses, respectively:

- *Monothematic dogmatism*: Dogma replaces the relevant uncertainty by 'crystal clear truth.' It becomes the normative base of the monothematic society, which is committed to the same theme (e.g., theocracy) and cannot transcend it.
- *Stalemate*: The means and ends are separated to the extent of nearly rendering the social system purposeless. The parts of the whole, in pursuit of their own agenda, do not contribute toward the common goal and may even oppose each other. As a result, the whole system is unable to pursue its ends.
- *Polarization*: The parts of the social field are polarized to cohesive and well-integrated social enclaves and sub-optimally functioning and declining social vortices [13], resulting in destructive in-group–out-group dynamic.

The development of active strategies is therefore essential to counter the development of maladaptive responses to turbulence that tend towards increased internal dogma, stalemates and polarizations.

V. THE ROLE OF BI/A CAPABILITY IN ORGANIZATIONAL CHANGE AND TRANSFORMATION

Theory U as framework for change, consists of four levels of organizational learning and change: developmental (*reacting*), changing underlying structure and processes (*redesigning*), changing the underlying pattern of thought

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(*reframing*), and leading from the future as it emerges (*presencing*) (Figure 1) [14]. In the following, we will discuss the role of BI/A technologies at each level of depth:

1) *Reacting*. Independent BI applications such as departmental data marts (cf., [15]) are helpful in diagnosing current systems and identifying opportunities for improvement. Focus on efficiency suffices.

In this stage, unless a journey through the U is implemented, a very likely outcome in terms of Scharmer's anti-practices is downloading same-old-same-old responses to challenges, reduced 'seeing' and becoming stuck with outcomes that nobody really wants.

2) *Redesigning*. At this level, tactical BI solutions can greatly support the decision-making in 'experienced' [4] organizations. These types of changes would typically fit with the BI target of creating an enterprise-wide infrastructure target [15]. Theory U would provide a framework to guide transitional change through uncovering common intent, seeing the system-in-transition with fresh eyes, and co-creating a new system.

3) *Reframing*. While 'transformed' [4] organizations leverage strategic business intelligence and big data analytics to elicit insights into external influences – technical advances, market shifts, environmental factors, or competition – developing long-term business goals, decisions at this level relies heavily on personal judgment and executive intuition. Theory U would help in 'sensing from the field,' in reflecting on the deep, taken-for-granted assumptions, and in enacting a new frame of thinking and way of being.

4) *Presencing*. Big data analytics may have a role in uncovering what is not known – the uncharted 'blue oceans' (cf., [27]) of uncontested market space amenable to new value creation – but at the end of the day, it is the intuition, judgment, and embodied experience of decision makers that underlie context-shifting strategic commitments like these. Theory U would help "connect to inner Source" to unleash the highest future potential accessible this way.

The BI/A strategy is therefore very largely dependent on the level of sophistication and integration achieved by organizations. Level 3 (reframing) may be regarded as transformative, while level 4 (presencing) is seen as essential in the formation of innovative and disruptive industry strategies.

VI. LIMITS OF BUSINESS INTELLIGENCE AND ANALYTICS

We view that there are inherent limitations for the use of BI/A in organizational transformation along the afore-mentioned 'dimensions of dynamic wholes' ([24], recasting [25]). Specifically:

- The BI/A technologies tend to focus on directly observable and measurable surface features, such as computer records. Decision-making in enterprise transformations, however, entails deeply embedded considerations of the social context and psychological undercurrents that cannot be addressed by these technologies. (The vertical dimension.)
- The BI/A provide insights into past and present performance and, at best, into how to project trends to the future. Confined to linear, closed system thinking, it cannot inform on highly complex full-system organizational transformations that are ultimately unpredictable. In other words, the means of the BI/A are not in sync with the ends (i.e., insights into the future). (The dimension of progression.)
- The BI/A technologies are of great help in supporting decision-makers with relevant and timely information. At the end of the day, however, it is human judgment and discretion as to how to integrate and make sense of the information (the transverse dimension) that is brought to bear in decision-making. (The transversal dimension.)

In the following, we will discuss these limitations of the use of BI/A in the context of organizational transformation.

A. *Transformations entail social and psychological considerations*

"There's no map / to human behavior," sings Björk, referring to the fact that human beings vary from person to person and from time to time. As purposeful beings that exhibit will [28], people observe, learn, change their goals, choose their behavior and communicate with each other, making social situations inherently uncertain, indeterminate and ambiguous.

A typical, but superficial, response to the wicked complexity [29], arising from this reflexivity, intentionality and evolution of human systems and institutions [30], is to make blanket assumptions about the mix of motive patterns [31]: to what extent employee behavior is driven by fear of punishment, external rewards, or intrinsic motivation. The organizational decisions are then based on these coarse, approximate generalizations.

While Big Data can give more detailed insights into collective human behavior and even anticipate future actions [32], social media and other digital footprints provide decision-makers with markedly different kinds of data points than social data that is based on personal interactions [33]. We would argue that the leader's 'gut feeling' of the big picture integrating people and social dynamics with commercial and technical considerations continues to be an important source of insight.

B. *Transformations are inherently unpredictable*

BI/A technologies tend to provide decision-makers with lagging indicators – view on past and present performance – and to inform strategy with extrapolations of trends, at best.

However, transformational organizational change [20] cannot be predicted with logical thinking that relies on lagging (past-oriented) indicators, as transformation is a developmental movement across time that "explodes any closed system in its entirety" [34]. According to Laske [34], formal logical thinking is confined to closed systems that

cannot size up non-physical moving targets. Open, living systems always include contradictions and things 'other' than what the system in its present form openly manifests.

Davis [23] suggests that organizational transformations are shifts in context: from (1) not knowing that you don't know to (2) knowing that you don't know. The effective organization, he argues, starts from the context that it has already succeeded as opposed to the context of disparity between 'as-is' and 'to-be.' By redrawing the boundaries, what is inside the boundary of inquiry becomes what we know that we don't know. This focuses attention to create the content, a new reality that derives from this 'ground of being.' Rather than being pulled along by the strategy, organization can be used to push the strategy toward its realization [23].

C. *Ultimately, it is people who make decisions*

In The Form of Time, Jaques [35] identifies two sides of 'the human equation:' 1) the surface part of mental activity – preconscious awareness on which we consciously draw and conscious knowledge that provides context for behavior; and 2) unconscious sensing – the "continuously shifting direction of intentionality" [35].

Jaques [35] also revives the ancient Greek distinction of two dimensions of time: *chronos* and *kairos*. At each point of chronological or sequential time, a person's internal experience is framed in kairos, in which the immediacy of the present, memories of the past, and hopes for the future are intertwined [36]. This unconscious, unverbalized protomental experience:

> *comprises the psychological world of desires, of passion, of goals and intentions and will. It is the world of primally fused memory, perception, desire, and intention (the unified field which exist before we consciously differentiate the parts), combined into what might be termed the moving present, a present which is felt as moving from out of the past and into the future. It is this unconscious phenomena which give us the notion of time as having a direction which expresses goal-directedness of intentional behavior. ([35], p. 53).*

To Jaques [37], the effort experienced in decision-making pertains to giving energy and direction to this non-verbal mental processing and bringing its outcomes into verbalizable awareness to be integrated with knowledge and used in conscious problem solving. Human work can never be exclusively knowledge-based, for when all non-verbal judgment is taken out of a decision, it becomes a calculation, not a decision [37].

A recent TechAmerica study [38] tells us that 15 % of the information today is structured and 85 % is still unstructured. That means there is still a huge amount of information that has to be sifted and analyzed by human contact or discussion.

The huge amount of unsifted and unstructured information places immediate potential limitations on the value and scope of BI/A inside any transformational change initiative. Some of this data may be extremely critical. However, transformation still depends largely on the social and psychological considerations of contextual human judgment.

VII. NEGLECT SOCIAL TECHNOLOGY – AT YOUR PERIL

Business intelligence and analytics technologies have an important role in informing strategy and organizational change. However, we view that, due to the limitations outlined in Section VI, these technologies, in and of themselves, are inherently inadequate in this respect and should be complemented with appropriate change management practices and social technologies.

While BI/A technologies may help the organization deal with greater complexity and change, without the requisite capability of individuals to use these systems properly they may also prove ineffective (cf., [13]). If the organization's analytics capability falls short of the requirements of its context, maladaptive responses can be expected.

We find that an integrative social technology helps mitigate or overcome the limitations outlined in Section VI by providing a framework in which to investigate and make sense of the big picture provided by BI/A. Theory U, in particular, is a useful meta-level framework in guiding how to deliberately shift attention from the present state of the organization to its future one, and providing the practice and process tools to achieve this shift, Theory U helps midwife organizational change and transformation in a conscious way.

For instance, the efficiency focus of an 'aspirational' user of analytics and resulting deployment of independent BI solutions is too superficial, segmented and dissociated for redesigning the type of change which calls for higher awareness of the external developments in order to make valid choices among the tactical options to realign properly the business. Relying too much on partial, partitioned, and uncoordinated information at the expense of understanding the social dynamics, appreciation of the common purpose, and coordination between parties is bound to fail, as are attempts to rein in the organization through synoptic control, authoritarian leadership regime, or evangelic proclamations. 'Not seeing' the trajectories of the embedding field, technology may just deepen the rut the organization is in.

The development of analytics capability is a long process and truly adaptive strategies cannot be implemented expeditiously. Furthermore, the emergence of a higher order capability may be impeded by the current system in place (cf., [24]). Continued denial of turbulence and resort to quick fixes in terms of passive or active maladaptive strategies (de-sensing) is likely to beget second order maladaptive responses. Unless the analytics capability succeeds to outgrow its efficiency focus, the organization runs the risk of monothematic dogmatism – "This is the way things are done around here." Going unchecked, business intelligence and analytics may become self-serving and self-perpetuating, growing increasingly apart from their sensing and sense-making purpose. Individual core areas may remain pockets of performance, but the periphery erodes to a 'social vortex' [13] of limited success.

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VIII. DISCUSSION AND CONCLUSIONS

There is more to intelligent business than business intelligence. In our view, business intelligence and analytics (BI/A) technologies bear the potential to benefit organizational transformations, but in order for transformation to be successful will need to be accompanied by appropriate attention-focusing, integrative social technology such as Theory U. Whereas BI/A technologies provide a clue to possible areas in a system that may be leveraged for organizational transformation, Theory U provides a framework and process model in which to place, examine and integrate those leverage points, taking account of the context, the system and people involved in transformation initiatives.

In this conceptual paper, we have argued why it is important to integrate BI/A with a social technology, in general, and Theory U, in particular, and suggested what may happen, if the social and psychological aspects of organizational transformation are downplayed.

We have explored the following research questions:

1. What is the role of BI/A capability in organizational change and transformation?
2. What are the limits of BI/A technologies in supporting organizational change and transformation?
3. How can these limits be mitigated or overcome through the application of a social technology, in general, and Theory U, in particular?

In conclusion:

1) The deeper the organizational change, the more mature level of BI/A is required and the more pronouncedly important it is to use integrative social technologies such as Theory U.

2) BI/A technologies, per se, are not adequate to support organizational transformations due to social complexity, the non-linear nature of transformation, and the need for human judgment.

3) An integrative social technology, such as Theory U, complements BI/A technologies by directing conscious attention to the required adaptive capacity in the face of encountered environmental conditions.

Due to the explorative nature of our inquiry, our literature review was rather initial and tentative. To further develop the initial insights of this paper, we would like to construct a conceptual framework that would elaborate on the posited relationships between the theoretical elements. To this end, a more detailed and comprehensive literature review would be required. Finally, we call for empirical research to investigate the initial conjectures presented herein and in any follow-on conceptual inquiry.

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Critical Success Factors of Corporate Performance Management (CPM)

Literature Study and Empirical Findings

Friedrich Hervé Lien Mbep
University of Applied Sciences of Neu-Ulm (HNU)
Neu-Ulm, Germany
Friedrich.lien-mbep@hs-neu-ulm.de

Olaf Jacob
University of Applied Sciences of Neu-Ulm (HNU)
Neu-Ulm, Germany
Olaf.jacob@hs-neu-ulm.de

Louis Fourie
Cape Peninsula University of Technology
Cape Town, South Africa
fouriel@cput.ac.za

***Abstract*— While many studies put emphasis on the linkage between Business Intelligence (BI) and Corporate Performance Management (CPM), few analyze directly the critical success factors that characterize CPM. The aim of this study is twofold: First, the study investigates common practices regarding the factors that characterize CPM. Second, the study develops a reference process model for CPM which describes key processes for the design and implementation of BI and BI-related capabilities. Following this, we conducted a theoretical analysis using the current literature available and an empirical analysis by means of a survey. The objectives of this theoretical and empirical analysis are to assess to what extent privately listed organizations in Germany are aware of the existence of CPM factors. Using the principal factor analysis method with Promax as oblique rotation, the results delivered a consistent number of factor items for CPM, which were grouped into six main factors.**

Keywords: Corporate Performance Management; Business Intelligence; Critical Success Factors.

I. INTRODUCTION

Due to the phenomenon of globalization, organizations today are facing the problem of high dynamic and very complex business environments. Thus, executives, managers and other decision makers have been looking for systems that are appropriate to support the execution of corporate strategy by monitoring and managing the performance of management and business processes [1].

Besides several other popular decision support systems that have been developed over several decades to support this goal, e.g., Decision Support Systems (DSS), Executive Information Systems (EIS), Data Warehouses (DW), or Business Intelligence systems (BI), Corporate Performance Management (CPM) has evolved as a new concept that describes a series of business processes designed to optimize both the development and execution of business strategy [2].

Despite several definitions, CPM is coined as "*an umbrella term that describes the methodologies, metrics, processes and systems used to monitor and manage the business performance of an enterprise*" [3].

However, both the development and execution of business strategy, and the monitoring and management of the organization´s performance require accurate, timely, consistent and reliable data [4]. Thus, organizations should look at other technological systems such as Business Intelligence (BI) that can consolidate and leverage the vast masses of data to improve decision-making of management [5]. BI is coined by several academics as a broad category of applications that extract and transform data from source systems, facilitate data visualization and allow users to view subsets of data according to different dimensions [6]. Intelligence refers to the information that is valuable for an organization to manage a business. BI provides the infrastructure and technologies that help integrate business data, process data into actionable information to support meaningful decision making [7], and enable the organization to quickly adapt to their changing environment. BI is considered as a technological means to support and improve CPM at all levels of management, e.g., strategic or operative management. It provides executives, managers and other decision makers with actionable information when needed [8].

Following this, there is a link between CPM and BI. Building a strong link between CPM and BI has been highlighted by several academics, e.g., Melchert et al. [9]. This link is based upon business metrics and key performance indicators (KPIs) following a top-down approach [10], [11].

Before identifying the metrics and KPIs that define the link between CPM and BI, it is worthwhile to assess the factors that are critical to CPM. Unfortunately, there is a paucity of studies and little academic contributions that examine the success factors of CPM. To address this above-mentioned gap, the authors first completed a thorough literature review and conducted an empirical analysis of CPM factors using statistical factor analysis based on a sample of German companies.

The study is structured into eight sections including this introduction section. The second section briefly summarizes the meaning and role of CPM by reviewing and selecting appropriate literature. The third section describes in details the holistic reference process model developed for CPM. Section IV explains the research methodology conducted in this study, which is followed by the data collection in Section V. The sixth section summarizes the research results and the discussion of the results is provided in section VII. Finally, the last section includes the implications of the study for theory and practice, the research limitation and avenues for future research.

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II. THE MEANING AND ROLE OF CORPORATE PERFORMANCE MANAGEMENT

CPM is a synonym for several management and business concepts that systematically drive the strategy of organizations by leveraging their processes, methodologies and metrics. CPM is a holistic management approach that combines business strategy and technological infrastructure [9] and provides a common frame of closed-loop reference processes [12]. CPM consists of business strategy, planning, forecasting, and financial management. It also includes monitoring processes with several control or feedback loops [3]. The feedback loops in CPM facilitate communication between top and operational management. The communication directs the entire organization towards accomplishing common organizational objectives. CPM can be comprehended as a methodic approach that enables organizations to define, measure and manage their performance, guide organizations towards their strategic goals, and support management functions [12].

The current academic literature and the literature provided by BI vendors use different terms to describe the concept CPM [3], [12]. While some academics such as [2], refers to it as Enterprise Performance Management (EPM), others such as Baltaxe and Van Decker [13] and Brunner and Dinter [14] rather use the term Business Performance Management (BPM). Besides this, we observed that each BI vendor makes creative use of language and vocabulary, and uses its own unique vocabulary and associated definitions of the terms and acronyms. As such, BI vendors freely invent esoteric new acronyms, and stretch and bend commonly used terms to mean new or identical things.

SAP, for example, uses the term "Enterprise Information Management" (EIM) as an umbrella term to describe their BI products and other related applications, including SAP financial performance applications. Oracle, again, uses the term "Enterprise Performance Management" (EPM) as an umbrella term for a fairly comprehensive BI product line that features the Hyperion Performance Applications. IBM, the other major BI vendor prefers the simpler term "Performance Management" (PM) in a more contracted way. Consequently, the term CPM is actually confusing for decision makers when trying to understand and compare the options that best support the strategy for collecting, organizing, managing, analyzing and visualizing the massive amount of data that daily passes through the organization.

In an effort to provide clarity to the industry, the BPM Standard Group [15] defined BPM as a methodology focused on the optimization of the execution of business strategy. BPM consists of "*a set of integrated, closed-loop, analytical processes that are supported by technology and address both financial as well as operational needs. The core financial and operational processes of BPM include planning, consolidation, reporting, analysis and the deployment of linked key performance indicators (KPIs) throughout an organization*". Biere [3] defines CPM as "*a set of processes that assist organizations to optimize their business performance by providing a framework for organizing, automating, and analyzing business technologies, processes, and systems that drive business performance*".

As CPM, EIM, EPM and BPM nearly shape the same discipline, e.g., strategy management, planning, budgeting and forecasting, financial management, consolidation and reporting, the acronyms can be used interchangeably and be considered synonyms. However, the authors avoid the use of the acronym BPM as it causes confusion with "Business Process Management".

The role of CPM has been considerably described by a large number of academics. Aho [10] and Marx et al. [16] have underlined that CPM represents the strategic deployment of BI solutions. Miranda [17] and Olszak and Ziemba [18] have suggested the necessity to develop an integrated approach of CPM in order to build, implement and use Business Intelligence solutions effectively. The integrated approach, which consists of four basic dimensions: business, function, technology and organization, establishes a set of processes or several areas of action where BI systems can be deployed.

Biere [3] and Simmers [19] conclude that CPM is the biggest growth area in Business Intelligence Analysis. CPM is a strategic concept which tends to focus on the performance capabilities and functions of the C-suite, e.g., CEO, CFO etc. In addition, CPM refers to the basic operations of an organization and how they impact the bottom line towards the achievement of business strategy and strategic objectives. As such CPM helps organizations to find bottlenecks and efficiencies at the strategic, tactical and operational level. IT aligns Business Intelligence with strategic, business and functional processes. CPM relates to the implementation and evaluation of an organization´s vision, mission and strategic objectives by using Performance Indicators (Key Performance Indicators, metrics or variables).

III. THE HOLISTIC CPM REFERENCE PROCESS MODEL

Over the past years, only a few academics and industrial experts have attempted to develop reference process models for CPM, e.g., Ariyachandra [2], Melchert et al. [9], Oehler [12], Jetter [20], Becker et al. [21], Klaus [22], PriceWaterHouseCooper [23], van Roekel [24], and Rausch [25]. However, we assume that these reference process models were not proven to be standard for all organizations as they do not describe how an ideal and typical system for CPM should look like.

Based on the necessity suggested by [17] and [18] towards developing an integrated approach of CPM, the first efforts of this research primarily consist in developing a holistic reference process model for CPM that is generic enough and suitable to apply in any kind of organization. The holistic reference model supports to build, implement and use Business Intelligence Solutions directly in a

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particular CPM related business process, e.g., the strategy planning process or financial management process.

The CPM reference process model in Figure 1 was developed from relevant literature and from observations and experience of the authors. It can serve as a usefully broad tool and provides an overview of the major CPM processes within the organizations upon which BI can be designed and implemented successfully.

process execution at the level of the value chain, and can be described by three different architectonic connotations: First, the holistic reference process model is balanced, i.e. it puts in relationship several separate processes which can be independently supported by BI technology and related BI-resources. Second, it is arranged vertically by process areas and horizontally by business units, business departments and profit or cost centers. The reference process model is strictly hierarchical presenting five distinct closed-loops

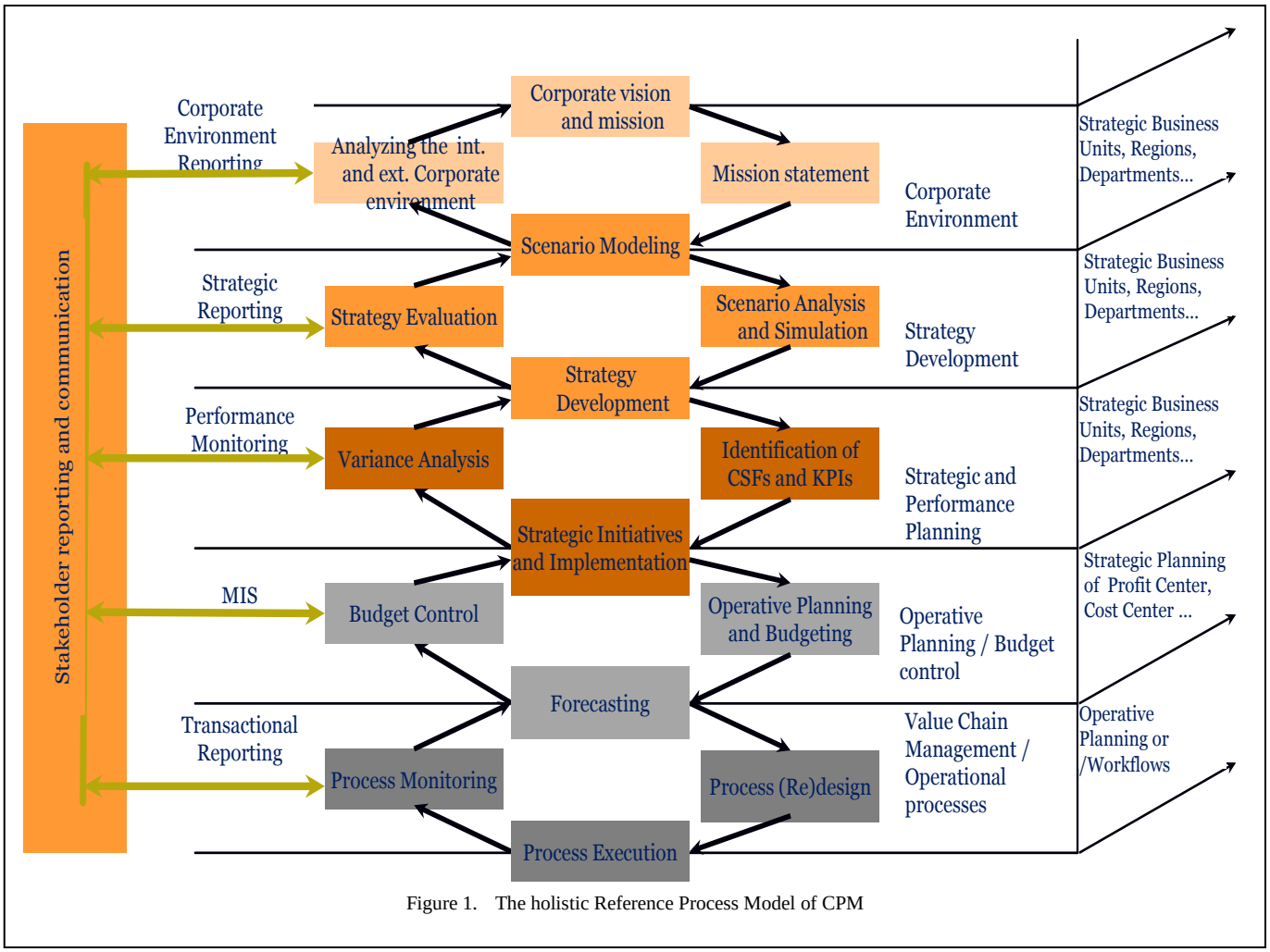

Figure 1. The holistic Reference Process Model of CPM

The reference process model is in the form of several structural hierarchical levels describing the sociotechnical system, and depicts a complete picture of the CPM-related processes of an organization. Each level is closely linked to the next and completed with a closed loop or feedback loop to ensure a continual monitoring of the process performance [12]. Few processes of the model have already been covered by existing related approaches, e.g., Ariyachandra [2], Melchert et al. [9], Oehler [12], Jetter [20].

The CPM reference process model in Figure 1 integrates strategic planning at the top level of management with the

regarding the levels of aggregation: the corporate environment level at the top, followed by the strategy development level, the performance planning level, the operative planning level and the value chain management level which constitutes the bottom line or basic operational processes, e.g., the procurement or distribution processes.

A. The corporate environment level

This level refers to the level at which executives, managers and other decision makers formulate the corporate strategy, e.g., the vision and mission of the organization while analyzing the internal and external forces that can

impact the success of the organization, e.g., the changing market conditions. To analyze the entire organization´s environment, top executives and the board of directors can use the business methodology known as STEP analysis. STEP is an acronym for Sociological changes, Technological changes, Economical changes and Political changes. The output of the analysis is a list of strategic objectives and organizational critical success factors (CSFs).

B. The strategy development level

This level is the most significant level in the CPM reference process model. It includes sub-processes such as scenario modelling, scenario analysis and simulation, and strategy evaluation. The organization´s strategy, which constitutes the output of this level, must be distinctive enough to ensure long-term profitability and a competitive advantage. The organization´s strategy must be depicted in the form of a strategy map as suggested by Kaplan and Norton in the Balanced Scorecard (BSC) methodology which structures different perspectives, (e.g., customer perspective, financial perspective, employee perspective, process perspective) in a cause-effect-relationship. All subsequent analysis and decision making are based upon the quality of the relationship values.

C. The performance planning level

This is the level where a strategy plan should be transformed in one or many action plans in order to implement the corporate and business strategy. Moreover, appropriate performance indicators, (e.g., of quantity, quality, cost effectiveness, or timeliness) must be assigned to each strategic objective or goal where applicable and to each functional area which achieves the strategic business objectives. The performance planning does not only refer to the planning of employee responsibility and accountability. Other critical performance planning elements include performance resources, e.g., processes, Information Technology Infrastructures and applications. The output of the performance planning process includes performance metrics and key performance indicators (KPIs), as well as defined initiatives. Metrics and KPIs are used to measure the effectiveness of the strategic objectives and initiatives [12].

D. The operative planning level

This level consists of planning several business or functional areas, e.g., profit centers or cost centers, identifying their respective performance indicators capable of determining their position towards the strategic objectives, and calculating their performance. The operative planning level encompasses sub-processes like forecasting, budgeting and budget controlling. This level assures the compatibility of performance indicators used in all functional areas, as well as their consistency with strategic objectives. Operative planning uses the performance measurement system to identify competitive position, locate problem areas, assist the firm in updating strategic objectives and making tactical decisions to achieve these objectives, and supply feedback after the decisions have been implemented.

E. The value chain management level

This level constitutes the lowest hierarchy level in the CPM reference process model with sub-processes like process (re)design, process execution and process monitoring. Communication and value reporting accompany each loop in the holistic reference process model.

Although the term CPM is popular amongst IT consultants, practitioners and BI Software providers, there are little academic studies examining the factors that are critical for the value of CPM. Thus, Ayo [10] stresses the necessity to provide a deeper understanding of what CPM means and highlights its potential value to the organization.

IV. RESEARCH METHODOLOGY

This section explains the research methodology used in this study. Before testing the factors empirically by adopting the survey methodology, we first considered the extensive literature as basis of the research to obtain meaningful factors for CPM.

A. Research Method

By conducting a literature review according to the well established methodology by [26], we pursued two major objectives: First, an exploration of the research landscape of CPM and second, the localization of the terra incognita for further research. In order to conceptualize the topic and to identify relevant search terms for literature selection, an explorative search with common literature databases (Google Scholar, ScienceDirect, ACM Digital Library, MS Academic search, Computer science bibliography etc.) led to a first collection of several CPM related terms, such as “Enterprise Performance Management”, “Business Performance Management”, “Advanced Performance Management”. Unfortunately, no results were found while using diverse combinations of CPM and “Critical Success Factors for CPM”, “Drivers for CPM”, or “Determinants” of CPM”. Intentionally, we omitted the keyword “Strategic Management” as it refers to the entire scope of strategic-decision making activity in an organization. The keywords have been iteratively refined and extended during the literature analysis process. We selected highly ranked and/or domain specific journals and leading conferences of the last ten years (2004–2014):

a) Journals of the AIS Senior Scholars` Basket of Journals, i.e. European Journal of Information Systems (EJIS), Information Systems Journal (ISJ), Information Systems Research (ISR), Journal of AIS (JAIS), Journal of MIS (JMIS), and MIS Quarterly (MISQ)

b) BI and social media specific journals: Decision Support Systems (DSS), International Journal of Business Intelligence Research (IJBIR), and Business Intelligence Journal for the BI domain and suitable ACM and IEEE journals

c) Leading conferences: International Conference on Information Systems (ICIS), Americas Conference on Information Systems (AMCIS), European Conference on

Information Systems (ECIS), Hawaii International Conference on System Sciences (HICSS), Conference on Information Systems and Technology (CIST), and Workshop on Information Technologies and Systems (WITS)

d) TDWI´s Business Intelligence Journal

Whereas the basket and CPM specific journals include a manageable amount of issues and articles that enables a complete scan of titles and abstracts as suggested by [26], we had to preselect conference papers by tracks related to CPM and BI. For ACM and IEEE journals, we conducted a keyword search on the whole digital library as no journals focus in particular on the CPM-related domain. We scanned for the hits (resulting from keyword searches) titles, abstracts, and keywords to assess the suitability of an article. Since we could identify only few articles by this method, we subsequently conducted a keyword search on literature databases (EBSCOhost, Scholar, ProQuest and ScienceDirect) by using the aforementioned search terms. We completed the literature pool via a backward search.

B. Analysis of the results

The literature review resulted in 17 adequate articles which analyze the Critical Success Factors for CPM. Due to the rather young research topic, this relatively small amount of articles is not surprising. Also, in most articles that appeared in conference proceedings and domain specific journals, only a very small number discussed Critical Success Factors that describe CPM. Most studies focused on the Critical Success Factors for the implementation of CPM, e.g., champion, management support or management resistance [27]. We consider the wider interest in BI and the stronger focus on the efficient implementation of CPM as reasons for the underrepresentation of such Critical Success Factors within our literature data pool.

Overall, we identified fewer articles than expected that explicitly address the Critical Success Factors of CPM.

A thorough analysis of the Critical Success Factors of CPM in the available literature, only 28 were found relevant to our study. The relevant Critical Success Factors for CPM and the corresponding references are listed in Table 1.

TABLE I. IDENTIFIED CRITICAL SUCCESS FACTORS OF CPM

Factors items	**Related studies**
Operationalization of business strategy across all business functions	[2], [10], [27]
Operationalization of business strategy across all business units	[10], [28]
Overall Process synchronization	[2], [28]
Process harmonization	[10], [29]
Aligning operational processes with strategy planning	[30], [31], [32], [33]
Strategy-conformed process alignment	[2], [29], [30], 33], [34]
Alignment of strategic planning over all business units and all business functions (horizontal alignment)	[30], [32], [34], [35]
Corporate environment feedback loop	[10]
Strategy development feedback loop	[28]
Strategic planning feedback loop	[36]
Operational planning feedback loop	[1], [34], [37]
Process monitoring	[1], [10], [28], [37]
Data integration	[2], [10], [34]
Method integration	[2], [10]
Process flexibility and dynamic availability	[35], [38]
Common process standards for data changes	[10], [39]
No arbitrary data changes	[10], [40]
Data consistency	[2], [10], [36]
Data completeness	[10], [36], [41]
Data relevance	[10], [41]
Data currency	[28], [29], [41]
Process documentation	[10], [28]
Process transparency	[10], [28], [36] [42]
Communication of processes throughout the organization	[10], [28], [32], [43], 44]
Continual process deployment	[10]
Process traceability	[45]
Standardized rules and Terminologies	[27], 34]
External process compliance	[2], 32]

In the second stage, a questionnaire was developed. Based on the assumption that CPM is the strategic deployment of the BI resources [10], and considering that CPM and BI are two existing heterogeneous management approaches (based on the factors which address CPM illustrated in Table 1), it was considered necessary to statistically test those factors. Thus, the questionnaire was to be exclusively completed by business senior executives and managers.

V. DATA COLLECTION

In order to obtain the information needed, a purposive stratified sample comprising of well-known firms throughout Germany was selected. The enterprises selected for the survey all have a BI infrastructure deployment in at least one business unit. Accordingly, Business Senior Executive Group Members comprising the Vice President,

C-suite members (CEO, CFO), and Managing Directors were asked to filled out 36 questions. The CIOs were not considered. With the aid of an external database, a total of 156 members were reached. Only fully completed questionnaires were included, resulting in a total of 86 usable cases.

An analysis of respondent demographics shows an unexpected high frequency of responses from Business Senior Executives, as well as a high frequency of responses from manufacturing companies. Fewer responses were obtained from the transport sector. From this analysis, it can be assumed that the findings may to some extent be affected by the overrepresentation of the industrial sector, although it may also indicate that CPM is more widely implemented in the manufacturing sector.

The basic structure of the questionnaire was that each identified item was measured through a number of questions to be answered by checking the appropriate value on a 7-point Likert scale. Questions like "Our company uses measurable indicators (Key Performance Indicators and metrics) based on Business Strategy" or "All process/data changes in our corporate performance management are traceable" were asked. To operationalize CPM and to ensure the correct understanding of the CPM concept, a definition of the term was given.

VI. STATISTICAL ANALYSIS

Two different statistical analysis methods were applied to analyze the data sets. These were Principal Components Analysis (PCA) and Principal Factor Analysis (PFA). The analysis was performed upon a combination of different oblique rotations techniques for the data set as recommended by Kaiser and Rice [46] and Ford et al. [47]. Both the PCA and the PFA were used on different basic types of analytical rotations including Promax, Quartimax, Equamax and Oblimin. Such a combination of different methods is useful because no single technique has been shown to be highly accurate over a wide range of conditions in pinpointing the number of factors [46], [47]. Based on numerous tests and evidence, the factor analysis method finally used in this study is the principal factor analysis with Promax as oblique rotation.

The result of this research demonstrates that CPM can be described by distinct factors that correlate with those factors identified previously in the literature review. The six factors for CPM in Table 2 explain 74,975 % of the variance. The factors are based on intrinsic value (eigenvalue), sometimes with a value which exceeds 1. The eigenvalues explains the variances of the factors [46]. Accordingly, the number of factors of the completed questionnaires for CPM was reduced on the basis of explorative factor analysis (EFA) [48]. Different measures were used to identify the appropriateness of the statistical results. First, a Kaiser-Meyer-Olkin (KMO) measure was performed as a formal test to check whether the variables selected have enough in common overall to warrant a PCA and PFA analysis.

In addition, the Bartlett Test of Homogeneity of variances and the Anti-Image-Covariance Matrices were conducted. The findings for the CPM questionnaire were positive. The overall KMO value was 0,860. According to Kaiser and Rice [46], values above 0.6 are high enough to warrant a PCA or PFA analysis.

The results of the Bartlett Test of Homogeneity of variances showed that all the variables are highly correlated. According to the statistical analysis, the value of the Anti-Image-Covariance-Matrices was under 25%. This means that the data set was appropriate for further statistical analysis [49].

TABLE II. RESULTS OF THE FACTORS ANALYSIS

Factors and related items	**Load**
Factor 1: Process Knowledge	
Communication of processes throughout the organization	**,968**
Process documentation	**,945**
Process transparency	**,891**
Methods integration	**,519**
Factor 2: Data and Method Integration	
Data integration	**,920**
Automatic seamless exchange of data	**,773**
Data consistency	**,749**
Data maintenance effort	**,638**
Process traceability	**,618**
Common process standards for data changes	**,542**
Data completeness	**,525**
Factor 3: Data Usefulness	
Data relevance	**,966**
Data currency	**,939**
Operational planning feedback loop	**,591**
Factor 4: Organizational Alignment	
Alignment of strategic planning across all business units.	**,938**
Alignment of strategic planning across all business functions	**,716**
Aligning between operational processes and strategy planning	**,658**
Factor 5: Business Strategy Operationalization	
Operationalization of business strategy across all business units	**1,008**
Operationalization of business strategy across all business functions	**,871**
Factor 6: Feedback Loop Based Process Management	
Strategy development feedback loop	**,759**
Corporate environment feedback loop	**,730**
Strategic planning feedback loop	**,574**

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Table II represents the factors describing CPM. Those factor items have been grouped in six different factors: process knowledge, data and method integration, data usefulness, organizational alignment, business strategy operationalization, and feedback loop based process management.

VII. DISCUSSION

As illustrated in Table 2, 22 factor items have been validated as describing CPM.

The CPM factor "*Process Knowledge*" emphasizes the important role documentation and transparency play in communicating CPM processes throughout the organization.

The CPM factor "*Data and Method Integration*" shows that the integration of management methods such as the Balanced Scorecard is based upon the integration and consistency of data.

The CPM factor "*Data Usefulness*" stresses that to be actionable for decision making, data must be relevant and current.

The CPM factor "*Organizational Alignment*" illustrates the importance of a strategic linkage between different organizational units or business functions.

The CPM factor "*Business Strategy Operationalization*" refers to the task of executives and other decision makers to identify meaningful KPI´s that are appropriate to evaluate whether or not a business strategy has been successfully implemented.

The CPM factor "*Feedback Loop Based Process Management*" shows that CPM is a continuous flow of processes that must be revised and any required change must be communicated throughout the organization.

Most of the CPM factors encompass 3 to 4 factor items, except the factor "Data and Method Integration" which consists of seven items. This indicates the importance of this factor for CPM. With a loading of up to ,920 data integration is an important criterium for CPM. Data integration enables not only the integration and exchange of data between disparate BI tools but also the integration of management methods such as the Balanced Scorecard and decision support processes like budgeting and forecasting.

We observed that factor items like overall process synchronization, process harmonization, strategy-conformed process alignment, process monitoring, process flexibility and dynamic availability, no arbitrary data changes, external process compliance (,499) and standardized rules and terminologies (,477) have a loading level less than 0,5. Although they were part of the literature review, they were not validated by the empirical study and statistics.

VIII. IMPLICATIONS AND CONCLUSION

The results delivered an extended reference process model for CPM and a consistent number of factor items which were grouped into 6 main factors describing CPM. The benefit of the presented study for academic and the industrial landscapes is that both the holistic reference process model and the identified and empirically tested CPM factors provide a deeper and clear understanding of the meaning of the concept of CPM.

However, the study was focused only on the empirical analysis of the critical success factors for CPM. Hence, an empirical validation whether or not these collected factors contribute to success has not yet been performed. Further studies are needed to establish the missing relationship of the collected factors with the reference process model. Especially, each collected factor needs to be linked with any process in the CPM reference model, e.g., the factor "Data and Method Integration" with the processes "Forecasting" or "Budgeting". The objective of the linkage is to see whether a factor is useful to the interrelated process, or not.

In addition, further studies are needed which operationalize the reference process model for CPM, e.g., by assessing efficient and less efficient processes. Accordingly, such studies could analyze the impact that BI and BI-related capabilities can have regarding the optimization of the CPM processes. By doing this, a maturity model of CPM processes and meaningful metrics or Key Performance Indicators (KPIs) need to be designed. Especially, metrics and KPIs can be used as tool to measure the efficiency of each process or key area in the holistic reference process model, and assess the impact of BI and BI-related capabilities within the organization.

The operationalization of both the reference process model for CPM and the identified factors using metrics or Key Performance Indicators (KPIs) will help establish their influence on success.

CPM processes so become the subject of performance management itself, as they support the management of corporate performance within organizations.

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Challenges for Workflows Technology to Support Crowd-sourcing Activities

Maria E. Orlowska
Polish-Japanese Institute of Information Technology
Warsaw, Poland
e-mail: *omaria@pjwstk.edu.pl*

Abstract **- Workflow systems deliver remarkable results in many domains of business. Deployment of workflows on a large scale set the standard of rigorous execution of complex business processes controlled by multiple constraints and often completed by physically distributed agents. The emerging trends of paid and volunteer crowd work offer potential opportunity for improving productivity and expanding creativity in performed tasks. Crowd-sourced components of a traditional organizational process can not be supported uniformly by current workflows management technology. This paper frames the major challenges that stand in the way to effectively incorporate crowd-sourcing into existing business environment to construct a new form of cooperation. We lay out research challenges in most important areas: the process design and verification, design of typical patterns to support business segments completed by asynchronous crowd involvement through unidentified partners, enhancement of workflows management system functionality to accommodate crowd-sourcing activities.**

Keywords - crowd-sourcing; workflow systems

I. INTRODUCTION

There has been an essential transformation in the way the enterprise information technology is perceived by the business in current times. The period when business process management was just concerned with a strict scheduling of predefined tasks is over. With the expansion of mobile technology, social media and crowd sourcing, the expectation from the enterprise has grown-up. The nature of social media and crowd–sourced activities challenge the industry to facilitate a business process that can interact with individuals and assist them with their requests and contributions they make. Furthermore, from the workforce perspective, in the connected world, many activities usually performed by employees of a company or social organization may benefit from some assistance from the outside. Since, the concept of cooperating parties became common and effective, the form of outsourcing as the contracting out of a business process or function to a third-party became a strategy in many domains of business [10][18][25].

The concept of outsourcing is also used to exemplify the practice of delegating fragments of the overall activity on ad hoc bases to the third party without any obligation of persistence of such relationship. Typically, outsourcing is not limited to a single country; it includes both foreign and domestic contracting, and, recently, often includes relocation of a business function to another country. In all such cases, the main service provider is aware of the subcontracting party, its competences and reputation, expected quality of work and associated costs. In outsourcing arrangements, the relationship between involved parties is covered by formal agreements. Often, the economic considerations are the driving force for such business strategy, but not always.

The concept of crowd-sourcing is one significant step further. It is the process of obtaining required services, ideas, or content by soliciting contributions from a large group of unidentified people, and especially from an online community, rather than from conventional employees or suppliers. It combines the efforts of many self-identified volunteers or part-time personnel, where each contributor of their own initiative adds a portion to the final result. Let us note that often many contributors perform the same task not knowing about each other. Consequently, selection of acceptable results is additional obligation of the owner of such out contracted process. The most natural way to differentiate crowd-sourcing from outsourcing is the fact that the completion of an individual task comes from an undefined public rather than being accomplished by a specific, named and restricted by initial agreements individual.

The most frequently used example of a crowd-sourced work is Wikipedia [4][17][26]. Other examples, but different in nature can be associated with a design and content evaluation [8][11]- [14][17][28], images labeling [1][7], extensive testing of publically accessible e-service functionality or a contest for general design of a physical entity [5][6]. The educational domain forms another group of applications with already well recognized impact [3][31].

In this paper, we look at the technology that could assist with effective and well-formed crowd-sourcing contributions to a larger business process. Established organizations have developed expertise in deployment of workflow technology for their core activities. The assignment of task to partners/workers, the methods and correctness of the process design, data flow, and time constraints for conventional workflows is extensively studied for a number of years [19]-[23]. Work on international standards constitutes the base for most products in the class of workflows allowing their cooperation and effective integrations [33]. However, there is no systemic support to incorporating publicly performed activities as a part of workflows supported processes. As initial exploitation of such mix of partners became an appealing and interesting option for some types of work, there is a well justified need for efforts towards

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technological solutions. It is clear, that the concept of business workflows partially executed by public input must be appropriately supported with a new workflow capability [33]. The call for workflow services to accommodate crowd-sourced activities with an acceptable quality is a new concept requiring further research. The purpose of this paper is to identify the scope of required extensions of the existing workflows technology to become a new generation of business process enhancement tools.

The paper is organized as follows. In Section II, we look at the impact on the process design generated by required extensions, followed by the discussion in Section III where we specify the scope of necessary modifications to the standard management systems to accommodate both groups of partners. Finally, in Section IV we summarize the discussion and outline future research work.

II. PROCESS DESIGN

Designing a business process and its partition into separate but meaningful tasks, that later are allocated to dedicated staff members, is a complex preparation phase prior to any technological solution deployment [20][21]. Clearly, not each task is suitable for crowd work. The crowd work can be seen as an element of a partnership between task provider, and, by contrast to typical business workflow, undefined workforce. Thus, when designing a process with crowd work participation, it is important to develop tools to support not only the work itself, and those performing the work, but also enhance the technology to enforce its processing according to the design decisions.

It is characteristic that in a standard business organization, completion of successfully terminated tasks is not evaluated for the final acceptance. The complete responsibility of the correctness and the quality of the execution is assigned to the experienced and trained worker discharging the activity. This observation shows the major difference in the subsequent steps of workflow structure when crowd workers are involved.

Each crowd-sourced activity can then be executed by many players, with different background, different skills and ability to complete specified assignment, and, with not necessarily converging intentions of the task provider. This is the main reason, why the subsequent verification step, following the collection of submissions, must be performed by the professional and dedicated staff. The quality confirmation and the final selection of submitted work, as a part of our business process, are necessary. Since we consider the general case of the crowd-sourcing, where activities can be performed by unidentified individuals, we must have a mechanism to evaluate the submitted outputs. This observation impacts directly on the design phase of the process. Below we identify and briefly discuss major challenges in the design process of such a workflow.

The question of a direct replacement of an existing activity within the process by a crowd sourced action is not a trivial one. The traditional business workflows have a pre-defined order of carrying out all pre-specified activities. This restriction impacts on the overall duration of the process execution and it is tightly coupled with the temporal constraints spanning segments of the process [19][22]. Allowing for a flexible engagement of the crowd-workers may force some relaxation of time constraints, due to inability to schedule such activities. Moreover, it is not easy to predict the number of the involved parties (players), but this in return, restricts corresponding definitions and the duration estimation of the evaluation procedures. Additionally, cross-checking the available data reflecting on the reputation of involved players complicates this segment of the process [29].

It is important to note, that if the crowd activity is not a stand-alone, but incorporated in the rigorous well defined process with obligation to deal with a large scale operation, the process design is a new phenomenon to be addressed.

A subsequent part of the design process is the consideration dedicated to the data flow between activities [21]. Typically, each task has its input and output data that must be maintained in complete integrity. The impact of deployment of the crowd force, to deal with the data flow cross the process, must be also carefully investigated.

An additional question relates to the fundamental workflow component – the work list. The traditional business systems supported by a workflows technology use sophisticated methods of allocating tasks to the individual and dedicated staff members. Typically, it is a small group of well trained and competent people. This condition can not be applied to the cases with unidentified partners.

Moreover, workflow patterns [9] could be examined again, at this time, for the case of a crowd-sourced execution. It seems to be rational to attempt construction of new workflow patterns to deal with these specially designed components, such as: multiple execution of a task, evaluation of task completion, concurrently performing checks of reputation [30] and reliability of a partner, the credibility of work completed, and, generation of potential rewards structure. The effectiveness of loading all those listed components into existing methodology of process design needs to be carefully examined. Another appealing option points toward keeping them rather separate, but with well-formed method of the integration into current workflows systems. Further fundamental issues are associated with workflow engine – the heart of the workflows management process [33]. Those are open questions at the current stage of the research work.

III. WORKFLOWS MANAGEMENT SYSTEM

A standard workflow management system allows the user to define multiple processes, often for different types of business activities or, recently, for scientific computation procedures [32]. At each stage of the process, one individual or a well identified group is fully responsible for

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a specific task. Once the task is completed, the workflow software ensures that the individuals responsible for the next activity are promptly notified and they receive all the data required to execute a subsequent stage of the process [26]. Often, workflows can be spanned by more complex dependencies between process components. For example, if a document is to be translated into several languages, the translation manager could select required languages, and then each selection would be activated as a scheduled work for the translation, ready to be taken by the specific contracted translators. Only, when all the translators have completed their respective tasks, the next segment of the process could be scheduled. The above example might be considered as a suitable activity for the crowd sourcing. Let us look at the differences in that case by contrast to the standard workflow execution. Here, the system will not schedule those activities to interpreters. Instead, it shall advertise the required translation job by some form of an electronic communication to attract participation. Naturally, we can't predict how many translators will undertake the work, and, how many for each language, as well as when precisely they will deliver their work. Therefore, we can't expect completion of this activity within a particular identified time. To some extent, it depends from the translators interest in the call for this activity, the conditions presented etc. Finally, the quality of the submitted work also needs attention. We shouldn't automatically include the submitted documents into production instead, verification checks are necessary. Even if it is perceived as a two steps activity, direct deployment of a standard workflow system to manage such crowd-sourcing will not be possible. An additional and important question is related to the overall economic viable of such an approach. Here, one can attempt some reasonable estimation from the hand driven experimentations.

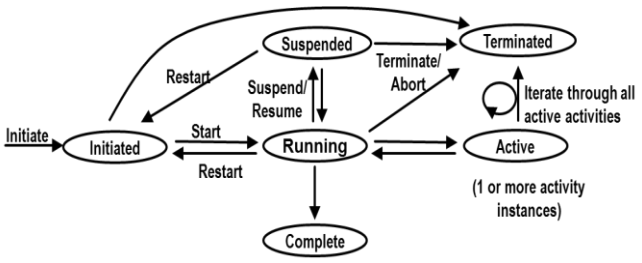

Figure 1. States transitions for a process instances

According to the Workflow Reference Model [33], the internal conditions defining the status of a process instance at a particular point in time, is maintained by the workflows system, following the transitions allowed by the defined finite state machine shown on Figure 1.

At the level of the individual process instance, the status of an activity, at a given point in time, executed by a given worker is represented by the other finite state machine as depicted in Figure 2 below.

This discussion already demonstrates that we must specify a number of novel concepts and necessary modifications to complement those already well established, to be able to address crowd sourcing incorporation into an existing process definition executed by the standard workflows technology. In summary, no direct allocation of activities indicates a necessary extension to the concept of work list handler, to release it from the organizational constraints, where competences are stored for all individuals capable to execute a given task. Further on, there should be no restrictions on the number of workers performing the job. Typical workflow systems do not allow undertaking of an activity instance for the concurrent execution by several workers. Furthermore, activations of multiple instances of the automata in Figure 1 and Figure 2 destroy the overall concept of rigid control over the process progress. This observation indicates definite loss of one of the most expected benefits of workflows deployment: a precise monitoring of the individual instances, availability of the progress development reporting, and setup alarms of any departure of the execution from the design parameters.

It is envisaged that even while not all jobs are being crowd executable, there are portions of almost any job that can be performed outside the organization.

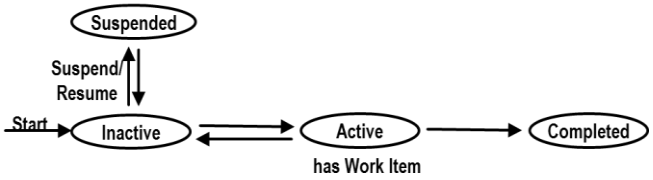

Figure 2. States transitions of activity instances

The question how we can move towards future of crowd work, that is more attractive for both requester and workers, must be addressed while building the next generation of cooperation support systems. Consideration of the worthiness of reconstruction of the current solutions versus building new from scratch to accommodate these new requirements is fundamental. This is another open question. Furthermore, it is vital to stress here that both styles of work, including the allocation of work segments relaxed from current constraints, should be offered and enforced by one pieces of technology.

IV. CONCLUSION AND FUTURE WORK

The crowd-sourcing can take place on many different levels and across a range of industries. This concept touches crosswise many social and business interactions. It can change the way we work, employ, do research and marketing. Leveraging collaborative practices and providing the tools may lead to significant business repercussion and probable restructuring.

However, crowd workflows are still quite undeveloped, and they are most successful with highly targeted single

tasks. Conversely, great potential hidden in the crowd abilities and wisdom should be better explored [28]. Unlocking this potential may improve productivity and creativity of the way the work is completed [16].

This paper lists only selected aspects of research to be undertaken to get to the next stage of a generic support for this type of crowd involvement. We pointed out that the current technology, build with overall intension of business process enforcement within a group of trusted partners, is not suitable for a simple extension.

The most promising research plan should include attempts to relax some of the constraints imposed on the standard concept of an activity. The minimum requirements for effective construction of a predefined process patterns should include crowd work progress reports, followed by a selection of the reputable partners and finally evaluation by the process owner. The new process segments should be easily customizable for the different types of activities. Further modification to the work list handler and the strict execution schema ordered by the steady finite state machines allows believing that perhaps "light" workflows solution is needed. Such a complete segment (including all the steps required to accommodate crowd work) could be perceived as a single activity of a standard workflow process.

All the considerations on the synthetic data have been promising and indicate sensibility of this approach.

To move ahead, through an iterative approach, we shall build essential components to accommodate all the crowd involvement requirements. An extensive experimentation is vital for the final usability assessment of the introduced ideas.

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Supporting Targeted Selection of Collaboration Tools for Distributed Software Development

Florian Krenn and Christian Stary

Department of Business Information Systems - Communications Engineering
Johannes Kepler University
Linz, Austria
e-mail: {firstname.lastname}@jku.at

***Abstract*—Many distributed software development teams lack targeted selection of collaboration tools, as project- and team-specific requirements are not taken into account for work support. For effective and efficient distributed team work, case-sensitive requirements engineering could help through adapting support tools to project situations. In this contribution, we detail method requirements for selecting collaboration tools for a given development context. We also analyze existing decision support techniques with respect to context adaptation. The Hybrid Knowledge-Based System (HKBS) method not only supports the context-sensitive identification of criteria, but also the selection of collaboration tools based on the development requirements. A corresponding web-based tool has been developed and evaluated in an empirical field study. The gained insights reveal the potential of HKBS and the respective tool support for targeted selection of collaboration tools in software development.**

Keywords–Global Software Development; collaboration tools; project-specific decision support; Hybrid Knowledge-Based System

I. INTRODUCTION

Globalization has affected software development and changed the manner in which software engineering projects are carried out. Software development is more and more seen as a globally distributed and multi-cultural endeavor [1][2]. This trend towards globally distributed software projects is facilitated by the widespread availability of high-speed Internet access. The distribution of projects and teams over several sites allows access to qualified workforce around the globe and enables the leverage of time zones to shorten software development cycles and time to market [3][4]. As software engineers are geographically distributed over different time zones, the time difference allows for 24-hour development (also known as "round-the-clock" or "follow-the-sun" development) facilitating a shorter project duration [4][5]. Despite the benefits of Global Software Development (GSD) new challenges arise with multi-site projects affecting communication and coordination. Due to the distance between sites, not only a drop in the frequency of communication but also reduced communication efficiency can be observed [6][7]. Communication, however, is essential for collaboration and teamwork and ultimately for the success of a project [4]. Consequences of inefficient communication can manifest in increased costs, delay, or even the discontinuation of a project [3][7][8].

In GSD, collaboration tools are used to address these challenges and support cross-site team communication. But often the collaboration tools in use do not provide adequate support for the team to ensure efficient communication [9][10]. This can be traced back to the fact that the selection of communication tools is often not aligned with the team's and the project's requirements [10]. As argued by Christian and Rotenstreich [10], an evaluation method is missing to better align the selection of collaboration tools.

In Section II, the requirements for project-specific selection of collaboration tools are inferred based on existing literature. Furthermore, existing decision support methods are analyzed based on these requirements. Criteria are required for the application of decision support methods. Relevant selection criteria for collaboration tools are presented in Section III. The results of an empirical field study are presented in Section IV. In Section V, the findings of the field study and their implications are discussed and put into context with existing literature results.

II. DEMAND FOR FLEXIBLE DECISION SUPPORT

Requirements for decision making are inferred based on the given decision context and are represented as criteria in the decision making process [11][12]. In the case of collaboration tool selection, the decision context is mainly defined by organizational and project specific factors. Picking up the proposal of Christian and Rotenstreich [10] to further investigate evaluation and selection support for collaboration tools, it becomes apparent that every project situation is unique [13]. Due to this uniqueness of the project situation and, therefore, the decision context a completely predefined set of criteria for the selection of collaboration tools is not viable. Criteria have to be selected in accordance with the decision context to reflect the needs of the organization, project, and team [13][14]. Hence, a decision method to support the selection of collaboration tools should support the context-sensitive identification and selection of criteria and should further provide enough *flexibility* to be applied in different project contexts with changing requirements and criteria.

The identification of such a decision support method to facilitate targeted selection requires a more fine-grained definition "flexibility" in this particular domain. The understanding of flexibility presented herein comprises of two aspects: 1. representation of the decision context 2. adaption of existing models to changes of the decision context in order to facilitate decision model reuse. A fundamental requirement for the representation of the decision context in the decision making process is that the decision support method is able to include all relevant criteria of the given decision context. The selection of collaboration tools and, more generally speaking, software

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products, can be categorized as a Multi Criteria Decision Analysis (MCDA) problem [13][15][16][17]. In MCDA, decision support methods need to be able to handle multiple criteria, which influence the decision making [18][19]. Furthermore, the combination of qualitative and quantitative criteria having no common unit of measurement is often relevant for the selection process.

Although a fixed, predefined set of criteria for the selection of collaboration tools is not advisable, reuse of existing decision models can be beneficial to shorten the decision making process. For instance, within an organization constant criteria which are used for every software selection will exist. By providing decision models incorporating these criteria as a starting point would only require to include the project-specific aspects and, therefore, decreasing the overall selection effort.

This leads to the following criteria for flexible decision support methods:

- Support of qualitative and quantitative criteria
- Handling of incommensurable units of measurement
- Handle dynamically changing criteria and alternatives
- Support identification and negotiation of criteria
- Adaptability of existing models (facilitate reuse)

According to a literature review conducted by Jadhav and Sonar [20], the Analytic Hierarchy Process (AHP) and the Weighted Sum Method (WSM) are the most prominent decision support methods in the context of Commercial-Of-The-Shelf (COTS) software selection. Knowledge-based decision support methods are also suited and established in the area of software selection [21][22]. In [22], a new approach to decision support, called Hybrid Knowledge-Based System (HKBS), using a hybrid knowledge-based approach is introduced. This new approach addresses relevant aspects for software selection, namely *flexibility* and *reuse*, and therefore is included in this analysis.

Analytic Hierarchy Process

AHP, introduced by Thomas L. Saaty [11][23], is a scientifically well-examined and widely-used decision support method [24]. AHP is based on the principles of *decomposition* and *relative judgments* [23]. The representation of the decision problem is based on the decomposition of the selection goals in subgoals and, ultimately, criteria resulting in a hierarchical structure. Criteria weights (i.e., the importance of each criterion) are assigned by relative comparisons on each level of the hierarchy. For this purpose a predefined scale is used. The effort needed for these pair-wise comparison depends on the number of criteria. The number of needed pair-wise comparisons can be calculated as shown in Equation 1 [22, p. 1401].

$$Comparisons = M * \frac{M-1}{2} * N \quad (1)$$

For example, in an evaluation involving four alternatives and nine criteria this would result in 54 pair-wise comparisons. Adapting the criteria hierarchy or adding an additional alternative requires to redo at least some of the comparisons. This limits the flexibility in terms of adaptability and reuse of existing models and alternatives [20]. Reusing existing decision models, respectively hierarchies, is possible to some extent, but the relative values used for comparing criteria and alternatives require to repeat at least some of the pair-wise comparisons [20].

Weighted Sum Method

WSM is considered an easy to use decision support method [15]. Each criterion used in selection process a numerical weight is assigned to express the importance of the criterion. The assigned weights are multiplied with the corresponding criterion value. The resulting values are than added up to the final score. According to WSM, the alternative with the highest score is the most suited alternative. This approach implies that only quantitative variables with the same unit of measurement can be used [15][22]. In MCDA, problems usually criteria with incommensurable units are involved and, therefore, WSM is more suited for single dimension problems [15][25]. Although the use of qualitative criteria is in principle not supported, qualitative criteria can be included in the decision process when the values are transformed to numeric values beforehand. But again, this is only valid when all other criteria are measured using the same scale [15].

The selection and assignment of criteria and weights is not supported by a defined process. This could lead to difficulties in assigning the criteria values, especially when dealing with a higher number of criteria [22].

Hybrid Knowledge-Based System

A new approach to knowledge-based decision support, which explicitly addresses flexibility, adaptability, and reuse, is introduced in [22]. HKBS combines deductive and inductive reasoning in one decision support method by including Case-Based Reasoning (CBR) and Rule-Based Reasoning (RBR) in the approach. The HKBS method, which is illustrated in Figure 1, not only covers the evaluation process itself but also covers the selection of criteria.

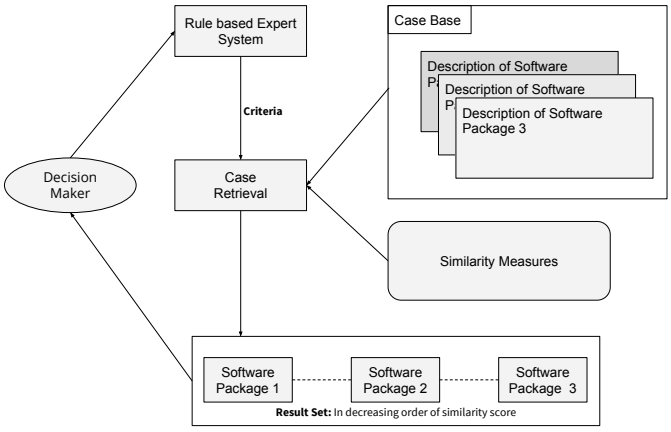

Figure 1. Components of the HKBS method according to [22, p. 1399]

HKBS allows the use of quantitative as well as qualitative criteria. Based on a rule-based system and the included expert knowledge, the requirements of the stakeholders are elicited and a suggested criteria set is derived. This suggestion can be altered and adapted by the decision makers in terms of the selected criteria as well as the assigned scales. The final set of criteria and scales is then used in the CBR process. The decision makers need to define and enter criteria values

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for each alternative. Alternatives combined with the assigned criteria values, so called *cases*, are stored in the *case base* of the CBR system. Cases stored in the case base can be edited (e.g., add new criterion) and can be reused in different query. For example, if the collaboration tool X was already entered in the case base for a selection in project *p*, it can be directly used for selection in project *r* independently of the criteria set used.

Analysis

Comparing the decision support methods based on the previously inferred criteria shows that HKBS has the potential in terms of providing flexible decision support. In connection with the case base, the CBR component allows the reuse of data entered in the system in upcoming decision processes.

Due to its applicability in several areas of application AHP is known as a flexible decision support method [26]. Nonetheless, the flexibility concerning the reuse of existing decision models is limited due to the principle of comparative judgments [22]. Due to these pair-wise judgments adapting the criteria hierarchy or adding an additional alternative requires to redo at least some of the comparisons. The adaptability of a WSM decision model depends on whether the criteria weights are in relation (e.g., sum of all weights has to be 100%) or not. If the criteria are in relation the criteria weights have to reassigned if the decision model is changed; otherwise a reassignment is not needed.

Both HKBS and AHP support qualitative and quantitative criteria, whereas, WSM does not support qualitative criteria. Qualitative values have to be transferred to numerical values to be used in the WSM decision model potentially leading to invalid decision models [15].

The comparison of the methods shows that HKBS has the potential in terms of providing flexible decision support according to the defined requirements. The HKBS method relies on the in encoded expert knowledge, which consists of criteria catalog and rules to infer the criteria suggestions, and on adequate tool support [22]. Due to the CBR and RBR components of the method, HKBS is based on complex calculations. Therefore, tool support is needed to enable a practicable application of the method [20]. In order to meet this requirement, a criteria catalog for the selection of collaboration tools has to be identified and a tool supporting the HKBS method has to be provided.

III. Identifying Relevant Criteria for Collaboration Tool Selection

The selection of collaboration tools comprises general aspects of software selection and, on a more specific level, aspects of collaboration. General criteria software selection criteria for the use with the HKBS method have already been elaborated by [22]. In a literature review, Jadhav and Sonar identified six core categories, which are applicable for software selection in general [22]. These categories are illustrated in Figure 2. Furthermore, the authors inferred the need for a seventh category dealing with functional criteria. These criteria are specific to type of the evaluated software and its area of application. Therefore, these criteria need to be specified for each application area individually [22]. In the case of collaboration tools, this would be those features and functionalities addressing specifically collaboration support (e.g., collaborative meeting scheduling).

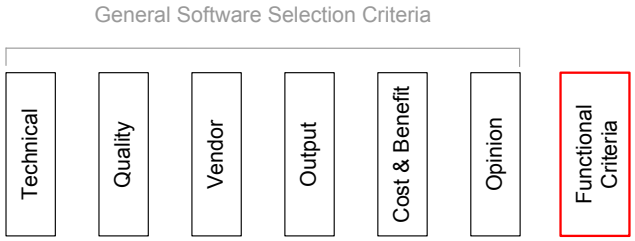

Figure 2. Software Selection Categories [22]

Distance is a limiting factor to team communication and collaboration [27][28]. In GSD projects, collaboration tools are used to overcome communication and collaboration problems caused by distance and distribution [27][29]. In order to be able to identify criteria relevant for collaboration tool selection, an understanding of how distance affects collaboration is needed. “Distance” in GSD is not only limited to the geographical separation. The term “distance” involves besides the geographical distribution of development teams also their socio-cultural diversity as well as the time difference across various sites [6][27][30].

These dimensions of distance have negative effects on three essential aspects of collaboration [27][31]: *Communication, coordination and control*. Additionally to these three aspects discussed by [31], *trust* within an team – an additional factor for successful collaboration [32] – is affected. An approach to overcome these challenges and limitations is to *provide appropriate communication channels and media* which are capable of supporting the different aspects of collaboration and communication across sites [33]. Based on existing findings, following functions could be identified for facilitating communication, control and trust building and, therefore, provide collaboration support.

- Forum/Discussion Board [27][34]
- Instant Messaging [35][36]
- Wikis [37][38]
- Blogs [27][34]
- Collaborative Calendars [10][39]
- Meeting Request/Scheduling [10]
- Task/Bug Tracking [40]
- Time/Project Planning Support [40]
- Shared Workspaces [10][41]
- Work Social Networks [42][43]
- Video Conferencing/Telephony [44]

IV. Empirical Field Study

An empirical field study was performed at *msg systems* in Passau, Germany. Results were collected using expert interviews. The expert interviews were conducted in a group setting based on the method described in [45, p. 363ff]. The designed interview guideline focused on flexibility and adaptability of the decision support method, the preselection of collaboration specific criteria and the criteria selection support. In order to check whether the preselection of criteria does not interfere with the flexibility and adaptability of the method a question targeting the flexibility of the criteria selection was included. The guideline was checked in terms of comprehensibility and structure in individual pretests involving two participants.

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A. CollabSelect - Prototypical HKBS Implementation

At the time of this study neither an open source nor a commercial implementation of a HKBS tool was available. Subsequently a brief description of design and implementation of a prototypical HKBS tool called "CollabSelect" is given. The goal of the implementation was to provide tool support for the HKBS method, including the guided selection of criteria, especially in terms of the flexibility of criteria and scales.

CollabSelect has been implemented as an web-based tool using Java Server Faces (JSF). For the realization of the CBR components, an existing Framework called "myCBR" was used [46]. Criteria are provided using an xml file which can be changed at runtime. Scales can be defined either in the xml file directly with the criteria or using the GUI editor implemented in CollabSelect. CollabSelect provides support for the entire HKBS method including:

- Support of criteria selection (on the basis of [22])
- Adaptability of criteria and scales
- Case management & reuse of existing cases
- Query execution & presentation of results
- Export to myCBR workbench

B. Field Study Setting

Using the developed tool, the HKBS method has been tested in two GSD projects. The goal was to provide indicators whether the HKBS method is able to support flexible and targeted selection of collaboration tools. The field study involved four participants assigned to two distributed projects filling different positions in the organization. All participants were involved in other distributed software developments projects prior to the current projects. Both involved projects are distributed over Europe, including sites in Passau/Germany, Cluj/Romania, and Hagenberg/Austria. 22 respectively 6 to 15 employees, depending on the workload, are assigned to the projects.

C. Method & Approach

The selection of the participants complies with the expert definition presented in [47]. Based on this definition, a project manager, an assistant project manager, and two developers were selected as participants. Results were collected using the expert interview method conducted in a group setting as described in [45]. The selected interview method requires an interview guideline to structure the interview. The designed guideline focused on flexibility and adaptability of the decision support method, the preselection of collaboration specific criteria, and the criteria selection support. In order to check whether the preselection of criteria does not interfere with the flexibility and adaptability of the method, a question targeting the flexibility of the criteria selection was included.

Prior to the field study the participants individually reflected based on their experience upon relevant aspects and criteria in terms of the selection of collaboration tools. The main part of the field study was an exemplary selection process of a collaboration tool for the participants' current projects. This selection was based on the procedure given by HKBS:

1) Criteria Selection
2) Case Creation
3) Querying the System
4) Adaption of Criteria & Scales
5) Re-Querying the system using adapted scales

This selection process was also conducted in a group involving all the participants. This setting enabled the inclusion of all decision makers in the discussion about criteria and criteria weights. Directly after the selection process the group interview was conducted based on the designed interview guideline.

D. Results

Following, the results of the audio recorded interview are aggregated and presented according to the interview guideline.

Preselected General and Functional Criteria: The preselected software selection criteria were seen as rather coarse grained covering a wide range of aspects. This leads to the usage of just small subset of the preselected criteria. However, this was not experienced as cumbersome, but rather as an advantage when selecting other types of software. Criteria which were not relevant in this context may be of relevance in a different selection context. The participants noted that the relevance of criteria does not only depend on the project situation but is also influenced by the involved decision makers and their roles.

The identified collaboration related, functional criteria have been perceived as adequate and in accordance with the participants' expectations. The participants mentioned that it would be useful to use more fine-grained functional criteria. The idea was to use the identified functional criteria as a starting point and detail the criteria based on use cases in the project. However, the participants stated that this would have to be done in every project situation separately, since the relevant use cases vary from project to project. Therefore, this would be in the responsibility of the decision makers and should be provided as an additional step in the selection process.

Flexibility of Criteria Selection: The participants perceived the selection of the criteria as "highly adaptable". Especially the possibility to adapt the suggested criteria set in terms of removing or adding criteria contributed to the flexibility to the criteria selection process. According to the participants, additionally the customizability of scales contributed to the overall flexibility.

Support of Criteria Selection: The step of criteria selection triggered intensive discussions about the requirements in the project. The participants stated that this discussion supported the identification and understanding of the relevant project-specific criteria. The criteria suggestions provided by the tool and the resulting discussions helped to identify relevant criteria which have not been seen as relevant beforehand. One of the participants noted that the tool supported suggestion of criteria may cause the decision makers to be too focused on the suggested criteria hindering them to consider additional aspects. His suggestion was that each decision maker individually reflects upon relevant criteria before the actual selection process, as done before the study, to minimize the bias caused by the criteria suggestion.

Inclusion of Relevant Criteria: The participants were asked whether all, in their opinion relevant criteria could be represented by the decision support method. Due to the support of qualitative as well as quantitative criteria and the adaptability of the criteria set, all relevant criteria could be represented in the decision model. Relevant criteria which were

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not included in the criteria set could be added ad hoc during the criteria selection.

Adaptability of Tool Selection Regarding the Project Situation: The participants considered the selection using the HKBS method as adaptable. Different selection contexts can be represented using this method. The flexibility of the criteria set and scales are seen as an important aspect supporting this adaptability. However, the participants interposed that the selection of collaboration tools in a project situation might not be suitable to evaluate this aspect, since, according to their past experiences, decisions about collaboration tools are made company-wide not on project level.

Suggestions and Improvements: The adaptability of criteria and scales lead to the demand for the possibility to annotate changes. According to the participants documenting rational for changes would be beneficial for understanding what lead to certain decisions. Furthermore, also annotating the selected criteria values when creating the alternatives was requested. Especially when dealing with qualitative criteria this would again facilitate the traceability of the given criteria values.

The participants requested, in order to facilitate the adaption of criteria and scales, that additionally to the suggestion of criteria, also a set of predefined scales should be included. The adaptability and customizability is already given but would additionally be supported by this enhancement. Moreover, a participant suggested that methodological support for defining scales, especially for qualitative scales, would facilitate the customization of scales.

V. Discussion

The study revealed advantages and shortcomings of the application of the HKBS method for collaboration tool selection. The inclusion of all relevant criteria (types) and the criteria selection support were seen as positive features of the HKBS method. Comparing HKBS and AHP in terms of the inclusion of several criteria types no real advantage of either method can be found in literature [11][22]. So it is arguable that these advantage for selecting collaboration tools applies also for other methods supporting various criteria types.

Looking at the criteria selection process the study shows that further support is needed. Considering these results the explicit inclusion of guided criteria selection in HKBS seems beneficial. Future studies should focus on how criteria selection support can be further improved. Compared to HKBS, AHP is in literature and practice the more prominent decision support method [26]. Combining the context-specific criteria selection support of HKBS with the profound decision support approach of AHP could provide a comprehensive selection support. Having developed this extension of AHP an extended survey comparing HKBS and AHP in different application areas would be of interest.

Concerning the reuseability and adaptability of decision models the results lessen the alleged advantage as discussed by [22], at least for the selection of collaboration tools. In other areas of application, reusability might be more beneficial.

VI. Conclusion

Collaboration tools provide support for distributed development teams. In order to provide adequate support, collaboration tools need to be selected based on the requirements in the project. Indicators were found that the HKBS method enables targeted selection of collaboration tools taking the specifics of the project situation into account. Also, shortcomings of the HKBS method have been identified. In addition, the results of the field study show that decision makers lack methodological guidance in customizing criteria and scales to reflect the given project situation. It was suggested to enhance the selection process with an additional upstream step. In this step, the fine-grained requirements and criteria should be identified based on project-specific use cases. This insight may also be beneficial for extensions of other decision support methods.

This initial study provides a basis for future studies, to verify the herein presented results and suggestions in multiple project settings including more participants.

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A System Framework for Complexity Measurement and Evaluation on the Example of Supply Chain

Can Sun, Hans Ehm, Stefan Heilmayer
Infineon Technologies AG
Neubiberg, Germany
can.sun@infineon.com
hans.ehm@infineon.com
stefan.heilmayer@infineon.com

Thomas Rose
Fraunhofer FIT
Sankt Augustin, Germany
thomas.rose@fit.fraunhofer.de

***Abstract*—The complexity of a system is generated by a lot of interactive and interdependent components with dynamic behaviors working together as a whole system. However, the quantitative analysis of the complexity generated by these components and their behaviors and its impact on the system still lacks practical methodology. This paper aims to design a framework to measure the complexity of complex supply chain. The first step is to understand and represent the complexity using an extended conceptual model. Due to the similarity between system and process complexity, we can thus develop the formulas to measure system complexity based on the metrics of process complexity as well as the properties of complex system. The validation is done through a classical supply chain phenomenon – the bullwhip effect, which can be demonstrated using a serious game called beer distribution game. We set two scenarios in the game and compare their complexity values. This framework can also be applied to evaluate the impact and complexity of changes in a system.**

Keywords-complex system; process complexity; complexity measurement; supply chain; bullwhip effect

I. INTRODUCTION

What is complex? Some intuitive understanding is that complex is "not easy to understand or analyze" [1] or complexity is "something difficult to replace". There are many definitions of complex system from different fields and aspects. The consensus is that a complex system has "enormous elements interact with one another and with the environment" [2].

From a scientific view, even though the complexity of various systems manifests in diverse ways, there is certain commonality among them. Bar-Yam [1] summarizes some universal properties of complex system:

- Elements (and their number)
- Interactions (and their strength)
- Environment (and its demands)
- Activities (and their objectives)
- Diversity/Variability
- Formation/Operation (and their time scales)

Supply chain is viewed as a complex system [3] consisting of a set of activities, agents, technological and physical infrastructures which interact with each other through information exchange and material flows in order to reach business goals. It is also highly influenced by the environment, e.g., the policies and external markets, and the requests for customization of products and services. The formation of supply chain refers to the emergence, e.g., a global supply network emerges with not single one firm deliberately organizing and controlling it [4].

Before measuring complexity, the first step is to understand the system, as the quantitative knowledge arises from this qualitative understanding [5].

As noticed, the difference between simple and complex system is that the latter one focuses on the "interconnected" or "interwoven" part. This requires that one must understand not only the behavior of the underlying parts but also how they act together to form the behavior of the whole complex system [1]. Experiments indicate that experts can have deeper understanding on a domain system by integrated thinking from the perspective of structural (elements of a system), behavioral (mechanisms), and functional aspects of a system; while the novices tend to focus on perceptually available, static components of the system. This can be explained by a framework called Structure–Behavior–Function (SBF) theory, which focuses on causal understandings of the relationships among different aspects of the system [6]. Therefore, it is necessary to align the common understanding that the system needs to be understood from both aspects of components and their interrelationships.

There are two basic strategies to model a general complex system: analytic tools dealing with elements and interactions and computer simulation handling descriptions and information [1]. Some researchers argue that the analytic thinking has limitations on processing human and organization elements in system design and less support to mathematical modeling for unstructured problems [5] comparing with the simulation techniques, which can be used to model the behaviors of agents.

The application area of our research is the supply chain system and we can try to take the strong points of both analytic and simulation methods on it. The first step is to build a conceptual model via identification and description of the parts as well as their interactions in supply chain. After the key information is captured, we could go for the quantitative analysis using simulation approaches.

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The objective of this paper is 1) To extend a conceptual model based on an existing one to represent the key information of the supply chain complex system 2) To set a framework with metrics to measure system complexity 3) To validate these metrics using an industrial example.

This rest of this paper is structured as follows: in Section 2, a conceptual model based on PROS is elaborated; the relevant factors to the system complexity and their value assignment are discussed; the complexity metrics of the whole system are formulated and demonstrated. In Section 3, the findings are summarized and further research is outlined.

II. APPROACH

Previous research proposed a conceptual model called Process, Role, Object and State (PROS) to extract the key elements and their various relationships of a supply chain [7]. It is used to describe a change management process.

The quantity (size) of the elements and the relationships in a system can be easily calculated via this approach. However, this is not sufficient to reflect the "diversity" of each element, nor the various relationships among them. For example, there is only one type of serial relationship between two processes. And current description for each element is still on the abstract level, without more details to distinguish them. When evaluating their impacts on the whole system, more precise information is needed.

In this section, the conception of PROS idea is enriched and thus can be used to quantify the complex system.

A. Basic definitions

Since many terms have been defined in previous research [7], in this subsection we only focus on the new content and the parts which may cause ambiguity.

1) Goals of the system

A system usually has a definable objective or function [1]. From the supply chain view, the activities of a system are either directly related to cost reduction, turnover increase or have indirect benefits in general, e.g., quality (higher flexibility and better forecast accuracy), speed (shorter committable lead time), cost (enabler for cost reduction), customer service (better delivery reliability or delivery performance). By using these criteria as Key Performance Indicators (KPI) we have indication whether the activities in a system is valuable or not.

2) Business system and boundary

A business system has dynamic (processes) and static (objects) aspects. A business system refers to the value-added chain, which describes the value-added process. The system has boundaries and interacts with other surrounding systems via interfaces [8][9].

3) Process and activities

The supply chain process is recognized as one type of the business process. A process is made up of multiple steps, also referred to as activities, and has to be completed in a predetermined order. An atomic activity consists of a single process step or action and cannot be subdivided. There is interdependency among the activities within one process. A business process also has goals and can be viewed as a system [8][9].

4) Objects and states

Two types of objects can be distinguished: an information object and a business object. An information object is described via a data structure in an IT system and a business object presents physical objects in real-world [8][10].

5) Roles (Agents)

Roles can be replaced by the term agent in many situations. From the simulation view, agents are usually autonomous or intelligent, representing a human being, an organization or an autonomous machine [4].

6) Relationships and others

For this part please refer to our previous research [7].

The conception model can be illustrated by a serious game called beer distribution game, which was firstly invented by Jay Forrester at MIT in the 1960s to explain the bullwhip effect [11]. The purpose of this game is to understand the dynamics of a multi-roles supply chain and how demand fluctuates in the different distribution stages.

A widely-accepted beer game setup usually has five stages: customer, retailer, wholesaler, distributor and factory. Two flows run in the supply chain, one up and one down. For the order flow, the customer orders units of beer from the retailer and the retailer sends its order to its upstream - the wholesaler until the final order is received by the upstream end of the chain- the factory. Vice versa is the delivery flow: the factory produces beers and delivers to other three downstream stages until it reaches the end customer. It is noticed that, there are possible delays in the flow between each stage considering the shipping and information time.

The task for each supply chain partner is to fulfill incoming orders and keep the inventory/backorder cost at the minimum level.

We thus identify all the key components in this beer supply chain system: five roles, two main processes (*order flow*, *delivery flow*) with time delay on different stages, one main object *order* and its two states (*inventory*, *backorder*).

B. Complexity attributes and impact on system

As mentioned in Subsection A.3, a process can also be viewed as a system. Similar to the system complexity, the process complexity has the "difficulty to describe and execute a process" [12]. Therefore, we assume the methodology to measure process complexity can be learned and adapted to the system complexity measurement.

Based on the metrics and formulas to measure process complexity [12], in addition to the specific properties of complex system, we list the factors which affect the complexity of a system. The overall complexity of a system is represented as **C*s***.

- Environment: the part interacts with the internal components of a system. Environment E may have one of several variables. Let Z = number of external variables $E_1, E_2 \ldots E_z$ interacting with system.

- Components: let N = quantity (size) of all components in a system; let M be the quantity of all (static) relationships among components.
- Diversity: the more diverse a system is, the higher the complexity it contains. Let d be the value of diversity, for each component i, its diverse value d_1, $d_2 \ldots d_i \ldots d_N$; $d_i \in (0, 1]$ with 1 being very diverse, and 0 not diverse.
- Emergence: this property depends on the entire system and reflects its relationships L, $L \in (0, 1]$ with 1 the system being very cooperative, and 0 not cooperative at all.
- Interactions: complexity R_E is interactions related to the environment and complexity R_I is interactions within internal components. For each component *i*, $R_{i,z}$ is the interaction with one environment factor z, R_{iE} ($R_{iE} = \sum_{z=1}^{Z} R_{i,z}$) is the total interactions with all factors in environment; $R_{i,j}$ is the interaction with one internal component *j* and R_{iN} ($R_{iN} = \sum_{j=1}^{N} R_{i,j}$) is the total interactions within the remaining part of the system. R value depends on the different types of interactions and the rules predefined (if there are any). For the types of interaction, if component *i* and *j* belongs to the same category of components, $R_{i,j}$ has smaller value than if they belong to the different ones. For the rules, e.g., the value of interaction with outside system is assumed to be much higher than internal ones, $R_{i,z} >> R_{i,j}$.
- Activities and Goals: each activity and involved components have certain impact on the goals. The better the activity matches the goal, the less complexity the system has. This attribute can be subdivided into 3 factors: for each component, 1) its commitment to the overall goal 2) the importance (comparing with other components) to the goal 3) the collaboration with other components.
- Commitment to the intention (goal): let G be the numeric value of intention fulfillment, for each component i, G_1, $G_2 \ldots G_i \ldots G_N$; $G_i \in (0, 1]$ with 1 satisfying the intention perfectly, and 0 does not meet the goal at all.
- Order of importance to satisfy the intention: let α be the weight value of importance, for each component *i*, $\alpha_1, \alpha_2 \ldots \alpha_i \ldots \alpha_N$, $\alpha_i \in (0,1]$ with 1 being most important, and 0 not important to the goal,
- Collaboration with other components: or conflicts. Let β be the weight value for collaboration, for each component *i*, $\beta_1, \beta_2 \ldots \beta_i \ldots \beta_N$, $\beta_i \in (0, 1]$ with 1 being very collaborative, and 0 not collaborative to others at all.

Above analysis doesn't differentiate the categories of components for each C_i, in this step we need to include the individual features for each type of element in PROS. To make the analysis easier, we can simply add one coefficient γ for each type, γ_p, γ_r, γ_o, γ_s stands for the coefficient of process, role, object and state. Accordingly, for each component *i*, its complexity $C_i = \{C_p, C_r, C_o, C_s\}$.

For the role element, some additional features need to be highlighted. In this paper, we only give some qualitative analysis:

- Intelligence: If Agent is intelligent, the influence is higher than non-intelligent ones on the system.
- Influence to the system: some agents have more power than others in the organization or system.
- Level of convergence: decided by skills, experiences, knowledge, etc. A higher level of convergence correlates to a lower level of complexity in the system.

C. Formulation

Based on the attributes listed in Subsection B, we can define some formulas to measure the system complexity **C*s***.

$$\mathbf{C_i} = \prod_{\mathbf{1}}^{\mathbf{N}} \boldsymbol{\gamma_i} \cdot \mathbf{d_i} \cdot \frac{\mathbf{1}}{\boldsymbol{\alpha_i}} \cdot \frac{\mathbf{1}}{\boldsymbol{\beta_i}} \cdot \frac{\mathbf{1}}{\mathbf{G_i}} \quad \forall \mathbf{i} \in \{\mathbf{1}, \mathbf{2}, \ldots, \mathbf{N}\} \tag{1}$$

$$\mathbf{R_i} = \sum_{\boldsymbol{z=1}}^{\boldsymbol{Z}} \mathbf{R_{iz}} \cdot \sum_{\boldsymbol{j=1}}^{\boldsymbol{N}} \mathbf{R_{ij}} \quad \forall \mathbf{i} \in \{\mathbf{1}, \mathbf{2}, \ldots, \mathbf{N}\} \textbf{ and } \mathbf{i} \neq \mathbf{j} \tag{2}$$

$$\mathbf{C_S} = \frac{\mathbf{1}}{\mathbf{L}} \cdot \mathbf{N} \cdot \mathbf{M} \cdot \prod_{\mathbf{i=1}}^{\mathbf{N}} \mathbf{C_i} \prod_{\mathbf{i}}^{\mathbf{N}} \mathbf{R_i} \tag{3}$$

Equation (1) addresses the impact of one single component to the whole system; (2) focus on the interaction between one single component to the other components within and outside of system; and (3) is about the overall complexity.

We also need to know how to set the values of variables in these formulas. Based on the data sources and methods to obtain them, we can divide these variables into three types:

- N, M - the natural number, which can be acquired from the physical world directly from the statistic tools or the enumeration method.
- $R_{i,z}$, $R_{i,j}$ – the values can be perceived from the physical world on a certain degree, for example, it is easy to observe which types of relationships they are, however, for more precise weights for each relationships type, some predefined measures need to be done, which can be based on the empirical results. For example, Gruhn and Laue defined a table which summarizes all possible relationships as well as their cognitive weight values [13]. These rules are easy to understand, e.g., the weight of sequential relationship type is 1, and for the iterative type it is 4. It is obvious that the latter one is more complex than the former one.
- For these values α, β, γ, d, L and G – these values cannot be observed from the physical world directly. An easy way is to assign their values

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based on the domain experience, e.g., set three scales: low, medium and high. For calculation, the scales can be assigned value with, e.g., 0.2, 0.5, and 0.8. These values can be easily tuned within the simulation environment. A more accurate but complicated way is to collect the data via certain experiments and do statistical analysis. There are some other indirect approaches, e.g., we can subdivide one factor into several more detailed sub factors and thus get an accumulated value. Just like the γ for the agent element, it needs to consider the humans skills and influence, etc.

III. VALIDATION

We continue our validation with the beer game. It is played online via the platform provided by University of Houston and we choose the game "SCM_1409_24" for our analysis [14]. In this game, the participants were divided into two groups and each group performed one scenario.

Scenario 1 with communication (S1): supply chain partners are allowed to exchange and share information with each other in order to get better forecasting about the order quantity and thus reduce the cost of inventory/backorder.

Scenario 2 without communication (S2): supply chain players are not allowed to communicate and collaborate with each other. If the order from customer is not visible for the whole chain, the upstream stage has to forecast the demand by itself. In this game, the cost of one inventory unit is configured as 0.5, while one backorder unit costs 1. Hence the players tend to order more than necessary in order to have a safety stock. The deviations are accumulated and thus the overall supply chain cost is increased.

Table I shows the results for each supply chain partner in two scenarios, including the order quantity per week and inventory/backorder cost.

TABLE I. BEER GAME RESULTS

Roles	Scenario 1		Scenario 2	
	Order quantity/week	*Cost in 26 weeks*	*Order quantity/week*	*Cost in 26 weeks*
Customer	7	0	7	0
Retailer	7	80.5	9	483
Wholesaler	9	157	37	1039
Distributor	6	285	17	2923.5
Factory	7	324	14	226.5

We would like to compare the complexity of these two supply chain scenarios. For the simplicity, we only consider the changeable parts which have impact on the complexity. Some assumptions are given below:

- The external factors have the same impact for the two scenarios
- Diversity factor is the same for two scenarios
- The size of system components and their interrelationships (static part) are the same
- The role complexity of customer is the same; while the other 4 roles have different behaviors
- The order flow process execution time increased 33% in S1 ($\gamma_{p1} = 1.33$, $\gamma_{p2} = 1$)

From above analysis, we only need to extract the relevant factors: α, β, G, R and L.

The values of α and G (see Table II) can be calculated from the results in Table I. The α value is decided by its cost percentage in the overall supply chain. E.g., the retailor in S1 has the lowest cost, so it contributes the most importance value to the goals (to reduce the overall cost). The G value is used to evaluate the demand forecast accuracy. The closer to the end customer demand, the higher value it has.

TABLE II. COMPLEXITY FACTORS (ALPHA, G) FOR TWO SCENARIOS

Scenario	α				G			
	α_{r1}	α_{r2}	α_{r3}	α_{r4}	G_{r1}	G_{r2}	G_{r3}	G_{r4}
S1	0.90	0.81	0.66	0.62	1	0.78	0.88	1
S2	0.90	0.78	0.37	0.95	0.78	0.19	0.41	0.5

And the values of β, R (see Table III) can be acquired from the system configuration. For one single stage, β counts the total number of roles it collaborates with. R stands for the number of interactions, which is much higher in S1 than in S2.

TABLE III. COMPLEXITY FACTORS (BETA, R) FOR TWO SCENARIOS

Scenario	β				R			
	β_{r1}	β_{r2}	β_{r3}	β_{r4}	R_{r1}	R_{r2}	R_{r3}	R_{r4}
S1	1	1	1	1	3	3	3	3
S2	0.5	0.75	0.75	0.5	1	2	2	1

The L value is difficult to obtain from above data; therefore we simply set three scales for it: low, medium and high. From the observation in the game, the collaboration of S1 can be considered as the medium level. Because the highest value of L is 1, which means the total supply chain cost should be 0. In our case the total cost of S1 is 846 so we set L = 0.5; for S2 we choose L = 0.2.

By using the equations in Subsection C, we get the ratio of complexity of S2 to S1 is 5.39, which is very close to the

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cost ratio of S2 to S1, 5.52. Although it is too early to conclude that there is some causal relationship between supply chain cost and complexity, we can at least state that: 1) the supply chain complexity and cost have the same trend. 2) The communication and collaboration could reduce the overall supply chain complexity via information sharing.

IV. CONCLUSION AND NEXT STEP

This work-in-progress paper has proposed a framework to understand and measure the system complexity by capturing its key information. It analyzes the complexity influence factors and their impact on the system. Based on the process complexity and complex system attributes, the metrics to measure complexity for both individual components and the entire system are formulated. A supply chain example is used to demonstrate this framework.

So far, our work is mainly built on the hypothesis of complexity measurement. In the next step, our research will focus on the fine tuning of these metrics and further validation.

A. Value assignment for influence factors

Part of the variables, e.g., "L" is assigned based on the cognitive experience. To obtain more accurate values, we can employ survey, e.g., having interviews with experts from industry; and investigate more empirical results for similar problems.

B. The spatiotemporal features

Current measurement only considers the execution time of process, which is not sufficient to reflect a complex system. Other features, e.g., objects with lifecycles; processes in different locations should also be included.

The dynamic complexity is highly dependent on the time and space changes. Therefore, the quantitative impact of time and space need to be included in the future research.

C. The complexity of system changes

As soon as the spatiotemporal feature is considered, we could evaluate the impact of changes on system.

By using the differentiation operation on (3), we can get the ΔC_s, which stands for the complexity of changes.

D. Simulation and validation

Simulation techniques have been widely used in the complex systems. Discrete-event simulation and agent-based modeling are two popular methods.

To validate our hypothesis, we can use the simulation tool because it could support batch data processing and track many parameters in one model. By setting different values for the input parameters, we can analyze the impact of each variable to the complexity of the entire system.

The changes of system and their impact on the system can also be modeled. Fernandes, Arlindo and Henriques proposed a modeling framework to assess the impact of changes in a process, in which attributes are defined as variables and behaviors (process steps) are treated as the functions of variables [15]. This idea is worth considering for the further research on the change management of supply chain.

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Towards Process Design for Efficient Organisational Problem Solving

Dariusz W. Kaminski

Department of Computing and Communications
The Open University
Milton Keynes, United Kingdom
Email: dariusz.kaminski@ihs.com

Jon G. Hall

Department of Computing and Communications
The Open University
Milton Keynes, United Kingdom
Email: J.G.Hall@open.ac.uk

***Abstract*—This paper presents initial results on stochastic business process modelling. We interpret business processes as problem solving processes to show that certain trade-offs in stakeholder involvement can usefully be analysed. Our initial results illustrate the analytic potential of our stochastic model, which could be useful to business process analysts and designers. We show that our approach can be used to model and reason about business process resource usage. To support process improvement, and to help design process models enriched with relevant, measurable and comparable characteristics, we embed our business process modelling efforts in Problem Oriented Engineering, where we benefit from a systematic approach to problem solving.**

Keywords–Process modelling; Business process design; Problem Oriented Engineering.

I. INTRODUCTION

Organisational problem solving has become an incredibly complex topic [12]. The development of business processes as an organisation's response to problems they face is hampered by this complexity, and the tools currently available for solving organisational problems are relatively unsystematic.

Research by the second author in Problem Oriented Engineering (POE) offers an approach to the structuring of organisational problems that has been successfully applied in many organisational contexts, from the design of seating arrangements to business process reengineering in a financial engineering setting [7].

Business problems and business processes do not exist in vacuum – they are embedded in organisational contexts. Each business process is enacted by a single organisation, although it may also interact with business processes performed by other organisations [2]. When identified, a structure of a business process comprises of a set of work activities across time and place, with a beginning and an end, as well as clearly specified inputs and outputs [4]. Process identification is only one part of a lifecycle, which falls under the umbrella of Business Process Management (BPM). BPM is the art and science that is focused on work designed and executed in an organisation so that it can be done consistently and efficiently [6]. Business processes go through a lifecycle of four iterative phases: design, implementation, enactment and diagnosis [5]. During the design phase, the process creation follows a detailed requirements analysis of business operations, and in this phase process models can be enriched with functionality such as simulation, which enables *what-if* analysis. Quantifying business process characteristics is an important issue, and a research agenda introduced by Wynn *et al.* [20] focuses on the significance of cost-awareness in the area of BPM.

In this paper, we interpret part of POE as a stochastic process and consider the analytic potential this provides for the modelling of business processes with the focus on the cost/resource use metric.

The paper is organised as follows. Section II provides some background on POE. Section III presents the link between POE and business processes. In Section IV, we map the POE Process Pattern to its stochastic representation. Section V gives an overview of the study from the industrial context, which we then model with our stochastic model. An evaluation of the study and its results is given in Section VII. Related work is discussed in Section VI, while Section VII concludes the paper.

II. BACKGROUND

Rogers' definition of engineering [18] states that (abbreviations E, S, and N added by the authors):

> "Engineering refers to the practice of organising the design and construction of any artifice (S) which transforms the physical world (E) around us to meet some recognised need (N)."

Problem Oriented Engineering encodes this definition as a problem solving exercise – an engineer's task is to find S that satisfies N in environment E: represented by the proposition $E, S \vdash N$ meaning that that, when S is installed in the environment E, their combination meets the need N. For reasons of space, we do not expand on the usage of POE problem notation; the interested reader is referred to [9].

For this paper it is sufficient to consider the structure that POE suggests for problems solving steps that is illustrated in Figure 1, in which rectangles are resource consuming activities; diamonds indicate requests to stake-holders for validation either – on the left – of problem understanding, or – on the right – of a candidate solution.

POE characterises the problem solving process as illustrated in Figure 2. Briefly, in the POE Process Pattern (PPP) there are four groups of agents that interact with each other during the problem solving activity: problem explorers, problem validators, solution explorers and solution validators. During problem (resp., solution) exploration a problem's context and requirements (resp., a solution) are understood and described. Problem (resp., solution) validators are available to

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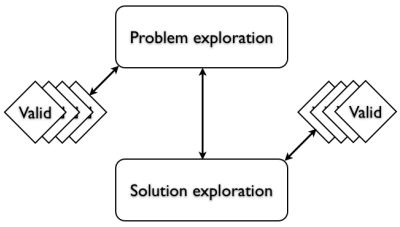

Figure 1. The POE Process Pattern: iteration between problem and solution exploration with interleaved validation (adapted from [8]).

problem (resp., solution) explorers and will perform validation (if requested) of the current problem (solution) description [7].

Each state in the PPP can be linked to the state of a problem's elements during problem solving, states represented by $\times$ (meaning element unknown or invalid), c (meaning element has a candidate description) and $\checkmark$ (meaning element has been validated). Thus, for example, $E\checkmark, S\times \vdash Nc$ represents a POE problem whose environment has been validated (by a problem validation step), the need has been proposed but not yet validated, and the solution has not yet been explored.

As shown, unsuccessful problem validation will typically result in problem exploration being extended. Successful problem validation will typically result in solution exploration being begun. Problem validation allows developmental risk to be transferred from explorer to validator. Unsuccessful solution validation is more complex as not only can it reveal that the solution does not satisfy a problem (the feedback loop between solution validation and problem exploration in Figure 2), but also that the problem was misunderstood (whether validated or not; the arc to 8 in Figure 2).

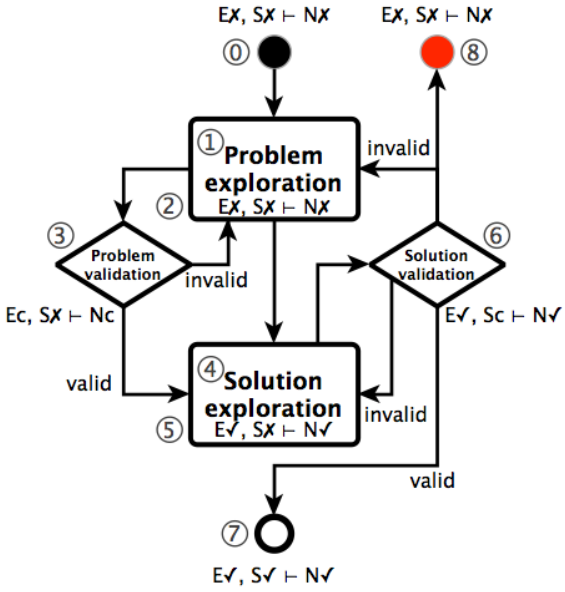

Figure 2. POE problem $E, S \vdash N$ at different points of problem solving in PPP. This is a simplified version of the pattern, where processes are sequentialised for the purposes of modelling (based on [8]). The numbers representing states will be explained in Section IV.

In PPP, it is possible for the problem exploration to be followed immediately by the solution exploration without the problem validation step, i.e., when the problem validator is not asked for validation. This possibility is shown in Figure 2 as the transition from the problem exploration to the solution exploration.

III. Business Processes as Problem Solving

Jonassen defines a problem [14] in terms of two attributes: 1) a problem is an unknown entity in some situation (the difference between a goal state and a current state); 2) finding or solving for the unknown must have some social, cultural, or intellectual value. The finding takes place during the *process of problem-solving*, so that a problem involves bridging from the current state to a goal state.

POE has been shown capable of modelling business processes (for instance, [17]). As a result of that modelling, effective business process changes have been suggested based on the properties that POE processes are expected to have. One could argue, however, that this success is to some extent fortuitous, requiring business processes that are susceptible to modelling in POE and it is not obvious that all business processes can be seen in this way. So, to be able to speak about general business processes in a POE setting, we must be able to encode them as problem solving processes.

Business processes are defined by van der Aalst and Stahl [2] as:

> "A business process consists of a set of activities that is performed in an organisational and technical environment. These activities are coordinated to jointly realise a business goal."

and so can be associated with a) an organisational and technical environment, and b) a business goal. To show that a business process is a problem-solving process in the POE sense, we will construct a problem that the business process solves from this environment and goal (the need that the solution satisfies). For the business process BP, call the environment ENV_{BP} and the goal $GOAL_{BP}$. Then form the problem:

$$Problem_{BP} : ENV_{BP}, S \vdash GOAL_{BP}$$

We see that:

1 $Problem_{BP}$ is a POE problem;

2 BP solves $Problem_{BP}$ in that when, as S, it is installed in ENV_{BP} it establishes the goal $GOAL_{BP}$.

Hence, to each business problem we can associate a POE problem that it solves. In essence, from an engineering perspective, business processes are designed and implemented in response to organisational problems. The above construction shows that business processes are problem solving processes, and we have given a representation of them in POE.

IV. Stochastic Semantics

In this section, we model a single instance of the PPP as a Markov chain, where we map PPP elements to states (numbers in Figure 2). The PPP process can be seen as a transition system. While the choices made by the validators will not be known until the execution, we can model the behaviour with Markov chains. They are a useful means of modelling processes, and can be seen as transition systems, in which state transitions are decided probabilistically [3]. This extends the PPP model by a set of probabilities, which could

be interpreted as characteristics of the agents taking part in the problem solving.

By mapping the POE Process Pattern to a Markov chain, we identified nine states (state p in Figure 2 and Figure 3 – numbered from (0) to (8)). States (0) and (7) represent the process in the initial and successfully solved state (they correspond to the black and white circles in Figure 2, respectively). Problem exploration (2) and solution exploration (5) are followed by their respective validation check points: problem validation (3) and solution validation (6). Additionally, we introduced states (1) and (4) to help model resource expenditure during explorations, i.e., transitions *Pexp* and *Sexp* increment the cost. When the process runs out of resources, or when the solution validator declares it unsolvable, then it remains unsolved – state (8). All these states, and their transition probabilities are shown in Figure 3.

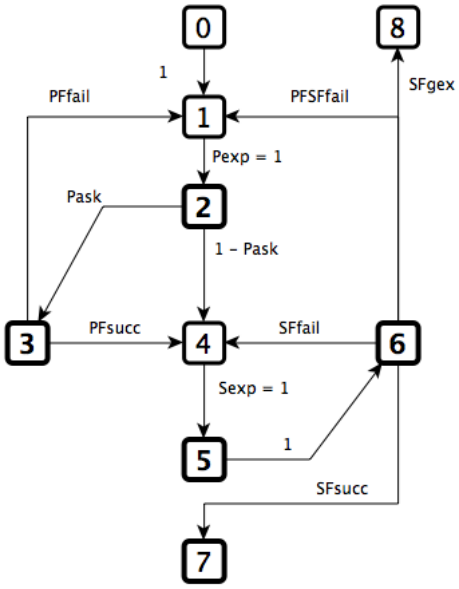

Figure 3. PPP as Markov chain.

With our model of PPP encoded as a Markov chain, we can use the PRISM model checking tool [16], which allows for process simulation and analysis. It is useful, because with this we can model the overall probability of successful problem solving under budgetary constraints, i.e., we will be able to answer questions such as, for example, this: *with a given budget of X, what is the probability that the problem solving will be successful?*

A. Team characteristics

It is reasonable to characterise the problem and solution exploration expertise of agents that perform them. A good problem exploration team is likely to reach a validatable problem understanding more quickly and within budget. Conversely, a poor team can spend all allocated resources without producing a validatable problem understanding – leaving a problem unsolved. In the Markov model, poor problem exploration team expertise translates to high *PFfail* ($= 1 - PFsucc$) and *vice versa*. Similarly, poor solution exploration team expertise translates to low *SFsucc*. Other probabilities in the model relate to: the teams' propensity to ask for validation (*Pask*),

```
1  dtmc
2          const double PFfail = 1 - PFsucc;
3          const double PFsucc;
4          const double Pask = 1.0;
5          const double PFSFfail = 0.1;
6          const double SFfail = 0.1;
7          const double SFsucc = 0.7;
8          const double SFgex = 0.1;
9          const int BUDGET;
10         const int Unsolved = 8;
11         formula Res = (cost > BUDGET);
12 module PPP
13         p: [0..8];
14         [START] p=0 & !Res -> 1: (p'=1);
15         [PEXP] p=1 & !Res -> 1: (p'=2);
16         [PASK] p=2 & !Res -> Pask: (p'=3) + (1-Pask): (p'=4);
17         [PFVAL] p=3 & !Res -> PFfail: (p'=1) + PFsucc: (p'=4);
18         [SEXP] p=4 & !Res -> 1: (p'=5);
19         [SASK] p=5 & !Res -> 1: (p'=6);
20         [SFVAL] p=6 & !Res -> PFSFfail:(p'=1)
21                 + SFfail:(p'=4)
22                 + SFsucc:(p'=7) + SFgex:(p'=8);
23         [UNSOLVED] Res -> 1: (p' = Unsolved);
24         [SOLVED] (p=7) -> 1: (p'=7);
25         [GEX] (p=8) -> 1: (p'=8);
26 endmodule
27 module Cost
28         cost : [0..BUDGET];
29         [PEXP] !(cost >= BUDGET) -> 1: (cost'=cost + 1);
30         [SEXP] !(cost >= BUDGET) -> 1: (cost'=cost + 1);
31 endmodule
```

Figure 4. PPP as a discrete-time Markov chain `dtmc` model in PRISM, which comprises two modules: `module PPP` and `module Cost`. For illustration of this experiment, we assigned arbitrary probability values for *PFSFfail*, *SFfail*, *SFsucc* and *SFgex*, but these would be expected to be variable.

probability of failed problem validation (*PFfail*), probability of failed solution validation due to an invalid problem (*PFSFfail*), probability of failed solution validation (*SFfail*), and finally, probability of a catastrophic solution validation leading to a 'global' exception (*SFgex*). We should note that, as for any Markov chain, the sum of transition probabilities from any given state has to be equal to 1, e.g., for state (6), we have $SFsucc + SFfail + PSSFfail + SFgex = 1$.

In Figure 4, the Markov chain is based on a set of probabilities guarding the transitions (lines from 2 to 8 in Figure 3), and it is composed of two modules: `PPP` and `Cost`. The former represents the states and transitions between them. For example, in line 16 we have an action `[PASK]` from state `p=2` to states `p=3` or `p=4`, guarded by their respective probabilities *Pask* and $1 - Pask$. Module `Cost` declares two actions `[PEXP]` and `[SEXP]`, each of which increments variable `cost` by an arbitrary value of 1. Formula `Res` (line 11) is a guarding condition for many transitions of the model, which monitors if the overall cost has reached the budgetary constraints (integer variable `BUDGET`).

B. Problem solving resource usage

Assigning a constant cost to each exploration action in discrete-time Markov chain (DTMC) allows us to consider the overall cost of problem solving as probabilities on the arcs change. Each team expends resources, and when a process runs out of resources, it declares the problem as unsolved.

Figure 5 shows the results from running experiments on our PPP model in PRISM, with discrete `BUDGET` (in this

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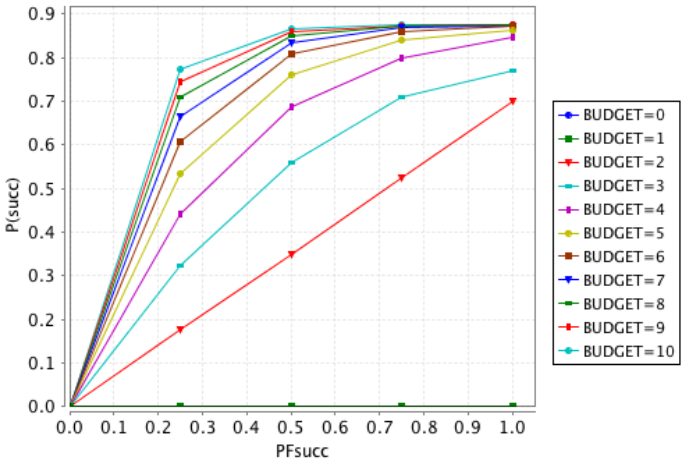

Figure 5. Probability of successful problem solving depending on *PFsucc* (curves plotted for different values of the available BUDGET).

case, values from 0 to 10 are representative enough, curves for values closer to 10 will be similar, i.e., the more budget available, the higher the probability of success), where we plot the curves representing the probability of successful solving for different values of *PFsucc*. The process never completes when *BUDGET* < 2 (the lines for *BUDGET* equal to 0 and 1 lie on the X-axis), because the PPP model needs at least 2 units of resource to complete both explorations. Depending on the available budget, we can state that with more available budget the probability of success increases. We can see that the better the team, the higher the overall probability of success.

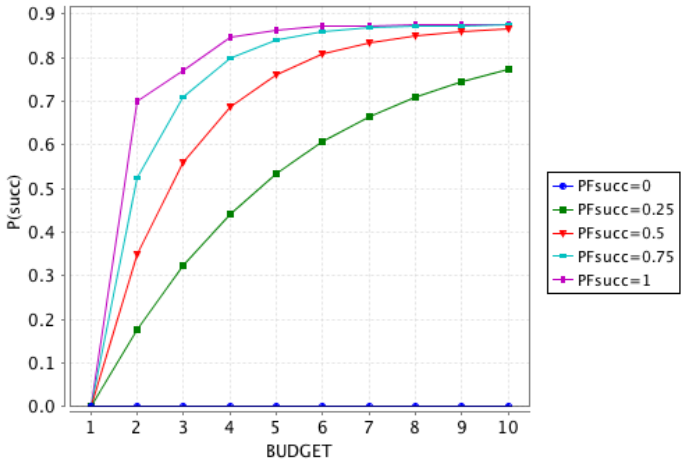

Figure 6. Probability of successful problem solving depending on the available BUDGET (curves plotted for different values of probability *PFsucc*).

In Figure 6, we plotted curves for probability of successful solving, and we observe, that this probability is increasing for increasing values of *BUDGET*. Since we only consider discrete values of *BUDGET*, from the plotted points we see, that probability of solving is 0, when *BUDGET* < 2. These results confirm that the probability of success depends on *PFsucc* – quantitative characteristic of our problem solving team, and in this case, the better the team (and the more *BUDGET* available), the higher the likelihood of solving the overall process.

V. Case Study

Nkwocha, Hall and Rapanotti model part of the defect tracking process of mortgage calculation software [17]. Essentially, software defects lead to incorrect mortgage calculations. There are two remedies: the first is tactical – incorrect data values are corrected and the calculation retried; the second is strategic – the software is debugged and the session rerun.

Tactical solutions are less expensive than strategic solutions and so are preferred by the solution provider. However, a tactical solution does not always solve the problem and, when it fails, the customer has to request the strategic solution leading to customer dissatisfaction.

In this section, we model the trade-off between the solution provider's and the customer's positions.

The process is complex (see [17]) so, for reasons of brevity, we have modelled before and after adding the problem validation step as shown in Figure 7, in which a) shows the process without and b) with problem validation. Analysis of the problem leads to the observation that problem validation was not being used to check whether the defect required a tactical or a strategic solution: the problem team would assume they understood the problem, setting the solution team to solve it (Figure 7a). Solution validation would reveal, late, that the problem understanding was deficient, and cause the problem to be re-explored. The problem that POE was used to solve was that the trade-off was not successful, too often, a tactical remedy was not effective and the defect was logged again, causing a strategic remedy. This led to an expensive process including some dissatisfaction on the part of the client. The remedy, as suggested by POE, was to insert a problem validation step into the process so that the client could confirm the problem understanding before moving onto solution exploration. This situation is presented in Figure 7b. For simplicity, and rather than build two DTMC models, we can use the probabilities associated with state transitions outgoing from state (2) in Figure 3 to omit problem validation (*Pask* $= 0$) and include it (*Pask* $= 1$).

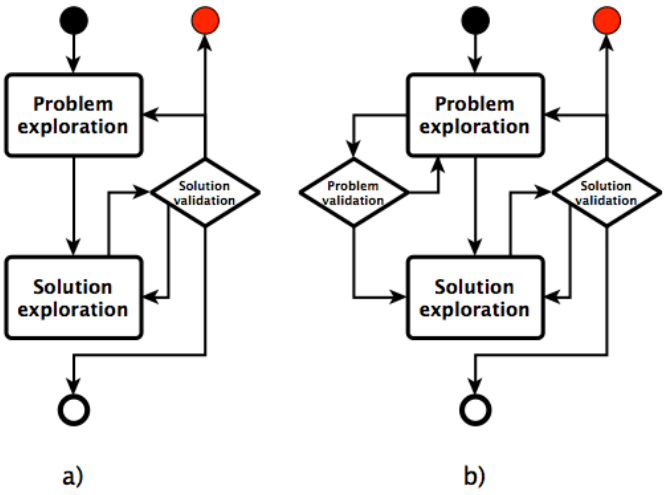

Figure 7. Process a) without asking for problem validation (*Pask* $= 0$); b) with problem validation (*Pask* $= 1$).

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We suppose that the tendency of the team is to default to the tactical solution as it is least resource intensive, only changing to the strategic solution when indicated, perhaps because there are pressures on the problem exploration team to get an answer. They can ignore the problem validation, and go for the tactical solution every time ($Pask = 0$). Indications can be made by the problem validation (PV) requiring the strategic solution, or failure to gain solution validation (SV), for example, due to a missed PV required strategic.

We set up a simple PRISM-based experiment based on the DTMC shown in Figure 4. We varied *Pask* between 0 and 1, and measured the probability of a successful solution being found ($P(succ)$) for a given budget for each datum. The results are shown in Figure 8 and described below.

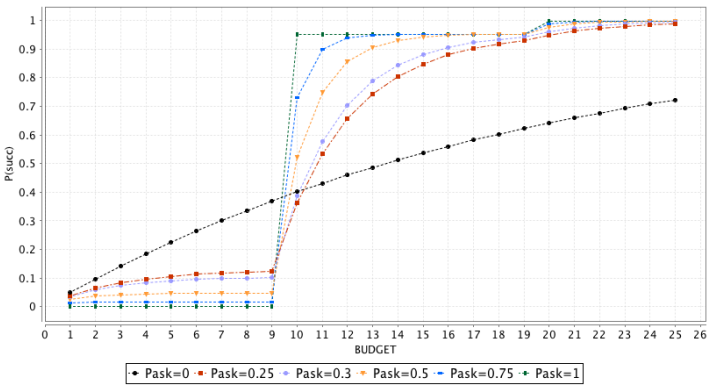

Figure 8. Results of PRISM-based experiment: the relationship between the available *BUDGET* and the probability of successful solving $P(succ)$ for various values of *Pask*.

For *the before* case of wholly tactical solutions (modelled by $Pask = 0$, the black line in Figure 8), the reader will note that $P(succ)$ increases slowly with available *BUDGET*. For example, when the process has 10 units of *BUDGET* to spend, $P(succ) = 0.4$. For *the after* case of problem analysis with customer validation, (modelled by $Pask = 1$, the green line in Figure 8) there is a sharp rise from $P(succ) = 0$, i.e., a solution is never found, to $P(succ) = 0.95$, a solution is almost always found. If the available budget is less than the cost of strategic solving (here, we supposed an arbitrary 10 units for strategic and 1 unit for tactical), it is better not to ask for PV, i.e., if $Pask > 0$, then PV could suggest expensive (over budget) solution, which would reduce the probability of successful solving.

VI. Related Work

With the abundance of business process modelling techniques, many of them are centred around capturing and visualisation of process structure, and only a limited number of techniques allow for quantitative analysis and structured process improvement [19]. While the business process modelling domain has become a ubiquitous part of the modern business enterprise, and many organisations view their operations in terms of processes [13], many approaches suffer from the common issues related to choice of languages, standardisation, and interoperability. Our approach of mapping POE processes to stochastic models goes beyond a visual process representation, because it makes it possible to annotate states and arcs with quantitative characteristics, which could then be modelled, analysed and simulated.

A good example of an approach to business process modelling that proved to be stable and relevant are Petri Nets [2]. They combine both visual and formal aspects, and can be used for both qualitative and quantitative modelling of processes. Petri Nets can also be annotated with resource use. Our approach to modelling of POE processes is based on the POE Process Patterns expressed as Markov chains, which, unlike classic Petri Nets, allow for analysis of probability of success or failure.

Wynn *et al.* present a holistic approach to managing the cost of business operations by making an explicit link between cost and processes in all phases of BPM lifecycle. Their approach is bottom-up and it is focused on real-time process-based cost information using process mining techniques, and it requires organisations to maintain accurate cost data and also to keep track of process behaviour in the form of event logs [20]. This can be useful for organisations to make cost informed and operational decisions after processed have been deployed, enacted and monitored. Our approach is top-down and focuses on a cost metric in the design phase of BPM lifecycle, where we also establish a link between team characteristics and the likelihood of successful problem solving. By annotating transitions between states in Markov chains with cost metrics, we benefit from the techniques and analytical power offered by stochastic modelling. This can be useful to process analysts and designers who wish to model optimal processes before they decide to operationalise them in their organisations.

As shown by Hillston, Markov models can be expressed as higher level constructs, and this was achieved with Performance Evaluation Process Algebra (PEPA), which is an example of a high-level description language for Markov processes, whose purpose is to model systems behaviour and evaluate response times during execution [10], [11]. PEPA models describe components, and interactions between processes built out of such components, by using a relatively small number of operators/combinators. Each action executed in the model is annotated with a parameter that specifies task duration. In our case, we do not consider task duration, but we annotate some of the actions (transitions between states) with a cost parameter, which in our view is more flexible, because it makes our models more generic, i.e., depending on types of properties, we could further enhance our models (by annotating) with other meta-data about processes, such as the risk or cycle time.

VII. Discussion

We have characterised business processes as problem solving activities, and used this result to model them as stochastic processes using the POE Process Pattern. This has allowed us to develop a model, in which we measure the comparative probabilities of success under simple process transformations: *viz.*, with and without problem validation. We have applied our techniques to a case study from [17], which provides supporting evidence that the transformation described there led to more cost effective processes. However, we have also identified that there is a point before which the trade-offs are not economic. This is a new result and one that we will further investigate.

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We recognise that Markov models require statistical observations to establish the probabilities between the transition states, and one way possible way of finding out these values could be done perhaps with process mining [1]. In this research, however, we consider such probabilities as parameters only, and we do not yet investigate their relation to processes in a real world case.

Based on the stochastic semantics presented here, future research will explore characteristics of more complex models, i.e., we will investigate arbitrarily complex processes created by composing POE processes in sequence, parallel and fractally [7]. With an increasing complexity of real-world processes, we are aware that problems often need to be decomposed into sub-tasks/problems. In this paper, we only focused on a single POE Process Pattern. While this may seem simplistic, we acknowledge that further work is in progress, based on the work by Hall and Rapanotti [7], which allows building more complex processes by composing processes together.

While we initially focus on a single POE Process Pattern, our research will further contribute to the POE Process Algebra (PPA) [15], where we introduced operators that allow for building of arbitrarily complex POE processes. PEPA is an example of a stochastic process algebra that offers a framework, which is suitable for capturing both qualitative and quantitative aspects of a system [11]. It is also a high-level language that hides the details of underlying processes, and makes it possible to operate on a more convenient level of abstraction. According to Hillston, process algebras have a number of characteristics that make them compelling: 1) they allow for building large systems (compositionality); 2) they are adequate for qualitative analysis; 3) they have a wider acceptance outside academia. For these reasons, we believe that combining a process algebraic approach with stochastic process modelling will enhance qualitative and quantitative analysis of business problem solving with POE, where the focus is inherently on activities performed by agents, and the exchange of information between them in order to transform a POE problem $E\times, S\times \vdash N\times$ into $E\checkmark, S\checkmark \vdash N\checkmark$.

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An Approach to Controlled Crowd-sourced Activities

Maria E. Orłowska, Adam Wierzbicki
Polish-Japanese Institute of Information Technology
Warsaw, Poland
email: {omaria,adamw}@pjwstk.edu.pl

***Abstract* - This paper is concerned with defining contributors' selection for crowd-sourced task execution. Based on reputation measures that we introduce, a general mathematical model of controlled crowd-sourcing is presented. The model offers easy to manage, flexible selection of predefined trustworthy contributors based on their prior performance in similar activities. A simple choice of model parameters within specified range to suit user's intended quality of the crowd involvement is introduced. The abstraction of the problem that we present can be tailored for applications in different domains and crowd-sourced activities. Further extensions of presented concepts conclude the paper.**

Keywords - crowd-sourcing; reputation; credibility

I. INTRODUCTION

Many activities normally performed by employees of a company or social organization need some form of assistance from the outside. Since the concept of cooperating parties has became commonly acceptable and effective way to achieve business goals, the term of outsourcing as the contracting out of a business process or function to a third-party became a strategy in many domains of business.

It is important to note that the concept of outsourcing is also used to exemplify the practice of delegating fragments of the overall activity on ad hoc bases to the third party without any obligation of persistence of such association. Outsourcing is not limited to a single country; it includes both foreign and domestic contracting, and recently often includes relocation of a business function to another country, but in all such cases the main player is aware of the subcontracting party, its competences and associated costs. In outsourcing situation, the relationship is covered by the formal agreements. The economical considerations are often the driving force for such business strategy but not always.

The concept of crowd-sourcing is one but significant step further [15]. It is the process of obtaining required services, ideas, or content by soliciting contributions from a large group of unidentified people, and especially from an online community, rather than from conventional employees or suppliers. It combines the efforts of many self-identified volunteers or part-time personnel, where each contributor of their own initiative adds a portion to the final result. Let us note that often many contributors perform the same task not knowing about each other. So, the final selection of acceptable results is additional function of the owner of such out contracted process. A most natural way to distinguish crowd-sourcing from outsourcing is fact that the completion of individual task comes from an undefined public rather than being made to order by a specific, named and bounded by initial agreements group. Understanding of associated issues, especially in relation to evaluation of the quality of the work completed is essential for the real applications leading to genuine business benefits [3][7][9][16].

The paper is structured as follows. In Section II only relevant related work is presented, followed by discussion on general objects evaluations in Section III in order to build a perspective on the evaluation process as discussed in Section IV. The main contribution of this work is described in Section V where the formalization of the crowd-sourcing quality involvement is introduced. Finally, in the last Section VI we indicate directions of future research work in this area.

II. RELATED WORK

The most frequently used example of a crowd-sourced work is Wikipedia. Another, but different in nature examples, can be associated with the Internet content evaluation or extensive testing of publically accessible e-service functionality or a design task.

Let us briefly discuss some related issues that occupy researchers recently. They are web content evaluation in general, its integrity, credibility and trustworthiness.

The Internet became the first source of information for many users regardless of the investigated topic. On the other hand information presented on websites either of companies or private authors, social networks and social portals frequently doesn't have any structured evaluation. Thus the credibility of content of web pages is an important issue for all the users and could serve here as a motivation example of work presented in this paper. However, the features of presented model are not limited to this application.

Perhaps, a precise definition of the credibility may vary from case to case, depending on the purpose of the examination of the content. One could look at this issue as cross check of content with any other related source providing similar information. It is easy to observe that we already strike a problem – measure and identification of information similarity. If it is not identical (a copy) then, it must be syntactically different but semantically may be similar. The issue of integrity of information, in general, is hard to define thus computing semantic similarity of two texts is not a tractable problem. There are numerous examples of cases when information on hand has different form but its content is comparable – for instance, financial data from stock exchanges, recorded temperature in the same geographical

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locations but independently provided by many sources etc. In most cases of Web information we deal with a written text, for a specific audience of readers, to achieve a specific impact, at a specific time, generally, on a large group of receivers. For instance medical information could be in form of a public forum sharing personal experience, or a professional outline presented in a simple exploratory form to provide some health related information written by an expert. The problem of measuring quality of information has been identified in particular by [5][7][16].

Numerous analyses have been dedicated to study the web credibility assessment process. This process may involve several problems that have been extensively studied in economic theory - for instance the problem of information asymmetry, which may refer to a hidden quality [19] and so called "market-of-lemons" effect, or to a hidden type [3] and the occurrence of moral hazard. The problem of assessing the credibility of Web content may involve both cases of hidden information, i.e., hidden quality for static pages or hidden type for dynamic pages. Tanaka and Yamamoto [16] have identified six measurable factors related to the five main recognized features (i.e., accuracy, authority, objectivity, currency, and coverage of topic) for judging the credibility of web information, namely referential importance, social reputation, content typicality, topic coverage, freshness, and update frequency. Fogg et al. [5] utilized prominence-interpretation theory in order to explain the process of credibility assessment. There have also been other approaches to automatic credibility assessment. These methods aggregated the values of different features. For instance Metzger [7] used information about credentials, advertisements, web page design, type of website, date of update, sentiment analysis, pre-defined search engine page ranking, information commonality, source independence, prestige, experience with the source and authority of information origin. On the other hand, Wierzbicki et al. [1][18] attempted to create a simple game-theoretic model that would capture the salient characteristics of web content credibility evaluation.

Continuing with example of the content evaluation we should bring up the term of trustworthiness. Trustworthiness of the Web content occupied many researches recently. Rapid publication of new Web content affects many aspects of everyday lives of millions of people regardless of geolocation or political beliefs [8]. Moreover, Web content becomes the basis for the operation of digital economy [6], [9] and very often an essential source of information while making decisions concerning shopping, employment, education, health (both self-diagnosis of disease and treatment selection), financial data, investments, etc. [2][20]. On the other hand, Dellarocas [4] and Thompson [17] notice that web content is increasingly often manipulated for the benefit of the authors or content providers.

In the case of crowd-sourcing where involvement of a large group of unidentified testers/evaluators offers independent opinions, the quality of such assessments may depend heavily on many factors such as the background of the participants, education level, willingness to collaborate with good intensions and many more. Thus deploying the crowd-sourcing to such process requires special preparation of the final result compilation. The analysis of collected data may suggest ignoring some submissions and to favor the others.

This brings us to the term of a controlled crowd-sourcing; meaning a well justified selection of the contributed works from a larger collection of submitted results carried out for a specific crowd-sourced activity.

The problem of selecting only credible contribution from reputable but unknown partners will be more and more important in future for large scale business processes. The concept of business workflows partially executed by public input must be properly supported with new workflow facility foreign to the current structured workflow management systems. The assignment of task to partners/workers, the methods and correctness of the process design, data flow, and time constraints for traditional workflows is extensively studied for number of years [10]-[14] by Orlowska et al. The new functionality of workflow services to accommodate crowd-sourced activities with ‘reasonable‘quality of individual tasks execution is a new direction requiring further research.

The purpose of this paper is to build a simple mathematical model of controlled crowd-sourcing when dealing with evaluation of a given set of physical objects. The objects could be selected websites, books, electronic services intended for public use, e-learning platforms, and pieces of software or any publically accessible entity. The consideration of credible contributions is dependent on several parameters that all individually can be controlled within a predefined range of values to suite user’s defined crowd involvement.

The paper is constructed as follows, firstly we point out how multiple single indicators assigned to individual objects are used to rank (order) the set of such items. Then, we construct a linear model of selection only assignments that satisfy defined ‘quality’ conditions. The presented model is general and may well form a foundation for a construction of an evaluation environment appropriate for use in different application domains, independently from the purpose of the crowd sourced involvement into processes.

The conclusion and suggestions of further extensions of these concepts close this presentation.

III. OBJECTS EVALUATION IN GENERAL

The needs to evaluate objects from a collection frequently emerge in many domains of applications. Typically, we identify collection of attributes (characteristics) that require to be evaluated independently. Normally, the set of values used to express the results of the evaluation process for each property is specified. Often, it is a finite set with rather small cardinality. Such evaluation cross multiple attributes with the overall purpose of ranking the objects (in

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contrast to many rankings on the basis of individual properties) is a simple version of a classical multi criterion optimization problem.

Most ranking systems such as for example; ranking of universities, innovation summary index for ranking countries use exactly multi-criterion approach to rank the considered objects.

For the purpose of further considerations, let us recall a few well known facts about ranking/ordering objects in a multi dimensional space defined as a Cartesian product of the domains of considered attributes.

Let us assume that objects are evaluated with respect to several attributes, each having its scale of values to be used by evaluators to express their impression.

To be able to make the ranking list, for instance to communicate the order from the best to the worst object, we must use some expression, a function from multi dimensional space to the set of real values, a 'shrinking" function.

Very often the expression used is a weighted sum of the values assigned to the individual criteria. It is worth to mention here, that regardless of the effort dedicated to the construction of the "shrinking" function, any two points being far (in the sense of Euclidian metric) from each other in multidimensional space, they may become close in the linear order resulting from the shrinking process. The simplest way to demonstrate the above statement is the application of the sum of values as the shrinking function. For example, in two dimensional space - two attributes both with domains {1,…,9} are evaluated for each object; distanced points (1,9) and (9,1) after application of the summation they all get value 10.

There is here also another aspect requiring aggregations of the raw data. Already summarized values submitted by different tester for the same object requires further "shrinking" process. This aggregation function needs to be designed to finally get a single indicator for each object based on many submissions to allow the final ranking process. Such an aggregation may take into account different weights for more experienced testers or higher weights for more credible examiners, etc. However, the masking process illustrated above will also take place here.

Concluding this brief discussion we can sum up it as follows. It is well understood that each classification or comparison procedure of objects requires two important phases. Firstly, an abstraction of the objects by selecting a number of their attributes (characteristics) and ranges of evaluation values assigned to each attribute must be provided. Secondly, functions capable to express our intuitive comparison need should be constructed to shrink the whole multidimensional task to a single, one dimensional comparison problem. Such a mapping will be called an aggregation.

IV. EVALUATION PROCESS

Let us formulate the problem a bit more precisely but still informally.

Further, we assume that the following set of data and objects are accessible;

1) Set of comparable objects - the evaluated collection,

2) Predefined scope of the evaluation in the form of defined objects' attributes. For instance in the context of websites content evaluations it could be indicated features such as reliability, correctness of the content expressed in an objective sense wherever it is possible, clarity, esthetics, usability or similar,

3) Experts' evaluation for each given examination scope or attribute called an expert value assigned to each attribute for each object.

To effectively crowd-source an evaluation process, we shall have a mechanism to identify reliable testers in a given domain for specific evaluation scope and compile the final evaluation result only on the bases of aggregations across such multiple values. It is important to note that the calculated values may substantially differ from the expert value.

The weakness of such expert's replacement approach is rather obvious. There are no two identical evaluation cases and there are no super experts. As we mentioned in the introduction remarks, it is difficult to think of a similarity function construction between the objects such as, for example websites content or a design task. In other words, based on some prior data from evaluation experience, we select testers only from formerly credible group assuming that the current evaluation task may be a bit different. Thus, in some cases, the direct comparison of recent evaluations' results with given super values may indicate substantial difference even for perfect evaluators in the past. Thus, the fundamental question is how to sensibly identify credible results to the problem based only on the prior testers' experience.

This observation indicates the difficult nature of this of problems but not a total inability to formulate it more precisely. The problem is real one, thus a level of imprecision is unavoidable, and so we must be ready to accept some estimation of perfect results in practice.

V. A FORMAL MODEL DEFINITION

For the simplicity of the presentation, but without losing generality, we assume that objects are evaluated with respect to only one attribute and evaluated by many examiners. This assumption reduces required aggregation process to a single one, only across the testers' submitted values for each object. An extension to cover the evaluation with respect to several attributes is conceptually simple and as such is deliberately omitted in this paper. Further, we assume that each object is evaluated by a different group of testers due to the voluntarial character of crowd-sourcing activities. Thus some objects may attract more opinions then others. At this stage, we assume that the experiment is done over a fixed period of time so there is no need to accommodate dynamic change of number of tests and involved testers.

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We introduce formal notation in Table 1 below where: $W = \{w_i, i \in \{1, 2,\ldots, I\}$ is a finite set of comparable objects, $E = \{e_k, k \in \{1, 2,\ldots, K\}$ is a set of examiners with different competences, s_i is an expert value for each $i \in \{1, 2,\ldots, I\}$ (a single value due to the assumption above), $f_{k,i}$ is the evaluation f by the k-th examiner for the i-th object.

TABLE I. NOTATIONS INTRODUCTION

Objects	Expert value	*Tester* e_1	*Tester* e_2	...	*Tester* e_k
w_1	s_1	$f_{1,1}$	-		$f_{k,1}$
w_2	s_2	$f_{1,2}$	$f_{2,2}$		-
…	…	…	…		…
w_j	s_j	$f_{1,j}$	$f_{2,j}$		$f_{k,j}$

In general, by the evaluation of an object by a tester we mean an assignment of a value from the predefined subset of natural numbers f: $(W, E) \rightarrow \{0, 1, \ldots, v\}$.

An extension of such notation for multiple attributes requires several evaluations f1, f2, etc for a given object by a tester. As we assumed earlier, we consider a single attribute evaluation only, hence there is only one function f in this formalization.

Further, for each tester k we assign two values $[d_k, z_k]$, where $d_k, z_k \in \{0,1,\ldots, B_k\}$ d_k is the count of so-called good evaluations submitted by the k-th evaluator, and correspondingly, z_k is the count of bad evaluations of this examiner and B_k is the total number of submitted tests by the k-th examiner $d_k + z_k = B_k$..

For the clarity of the presentation, we suggest the simplest approach to separate the good from bad evaluations below.

Formally, we define good and bad evaluations as follows;

An evaluation of an object w_i by a tester k is good if $| s_i - f_{k,i} | \leq c$, is bad otherwise, meaning

$| s_i - f_{k,i} | > c$ for each $k \in \{ 1, 2,\ldots, K\}$ where c is a constant value indicating acceptable distance to the expert evaluation.

It is obvious that one could consider immediate generalization of this approach by introducing many levels of the goodness of evaluation, however for the sake of simplicity we consider further only one cutting point c.

We illustrate graphically the concepts introduced. Let us consider the first quarter of the (D,Z) space where Z and D are sets of natural numbers. For a given period of time and given constant c, we depict collected data of k testers by assigning a single point $[d_k, z_k]$ for each k. Hence, submitting additional test by a tester k (for an object) moves its' point either to the right or to the top, depending whether the evaluation is regarded as a good or bad one. Clearly, if all evaluators would submit the same number of tests t , meaning that they all evaluated t objects but not necessarily the same set of objects as indicated by entries in the table above, then all those points would be positioned on a straight line z = - d + t.

It is easy to see that all points positioned on any straight line from the family z = *a* d, where *a* is a positive number, identify all testers with the same proportion of good to bad evaluations but with different total count of the completed tests. It is depicted on Figure 1 below.

One may interpret those points as an image of history for submitted evaluations for all testers without indication which objects these individuals examined.

Our first goal is to group testers of similar credibility into classes. We provide a simple but flexible definition of such partitioning by introducing two constant values g_1, g_2. As before, one could consider more comprehensive model by introducing additional values for a finer partition of this space. However, for the purpose of this presentation, only two values will give required flexibility and natural partition of set of all testers into tree classes.

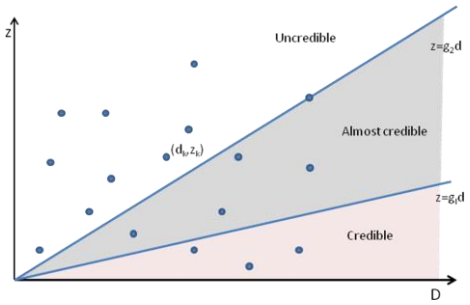

Figure 1. Illustration of introduced classes of examiners

Let us discuss in more details such a division. The two straight lines $z=g_1d$ and $z=g_2d$ divide the first quarter of space (D,Z) into three areas as depicted on Figure 1 above. We might call a tester *credible* if and only if in his history of evaluation process the count of the good evaluations was, for instance, 90%, implying the value of $g_1 = 0,1$. Consequently, the count of bad evaluations must be just 10% for this tester. The graphical interpretation of this set is the lowest triangle in Figure 1.

The other class of testers we might call almost credible. In this case, let for instance $g_2=0,25$. Naturally, this is the set of points between the two formed lines.

Finally, the third class we consider as not credible (not plausible) for all the points on lines $z=g_2d$ for all $g_2 > 0,25$.

It is important to remind us that joining the crowdsourcing evaluation process is on volunteer bases, so we cannot expect that all testers will evaluate the same set of objects and the same number of objects in general. Frequently, some individuals are more active than others so there is a need to reflect this fact in our model.

It is rather clear that if a tester has completed very few examinations then based on such limited activity its allocation to one of the classes might not be well justified. This is why, it is sensible to introduce a new constraint: a minimum

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number of evaluations m completed before assigning the tester to the appropriate class.

Formally, k-the tester's experience related condition is following $d_k + z_k > m$.

As before, only for the simplicity of the presentation, we consider only one cut-off point - the minimum m, but introduction of several levels of experience m_1, m_2, ... is natural as shown on Figure 2.

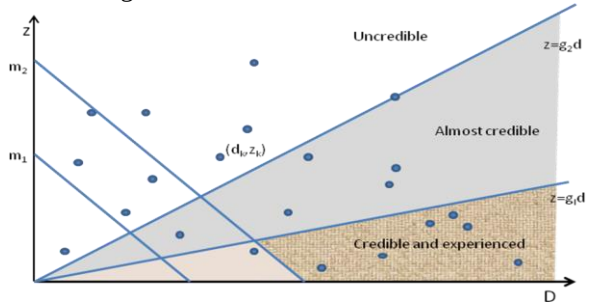

Figure 2. Illustration of introduction of minimum count condition

Introduction of this parameter to the model gives us additional flexibility of selecting only those results of evaluations that come from a group of individuals' satisfying our requirements for their general quality, as it is illustrated in Figure 2 above. Especially, in case of crowd-sourcing, a controlled selection of cooperators is vital for overall sense of sharing such activities. Let us then introduce this condition on our model.

It is easy to see that introduction of parameters in our linear model such as c, g_1, g_2, m give us opportunity to control the selection of set of points in this space in many ways. We can move those lines freely by changing the values for the parameters to make more or less strict preselection of testers.

The sum of all B_k for all k allows us to calculate the number of submitted results for our crowd-sourced task for all objects from W. However, till now, in our model we focused on testers' reputation but there is no reference to the evaluation of individual object by any means. Some objects could be evaluated by many testers, some by only few and some may not be evaluated at all. To assign the final evaluation value by combining opinion of several testers of an object one would expect to have a minimal number of tests completed for this object. Then aggregation procedure smoothes the differences of assigned values (marks) to offer a final and credible result. Theoretically, it is possible that the class of credible and experienced testers is sizeable having many elements thus satisfy model's conditions but as far as object w_i is concerned, is insufficiently rich. This is when none of the testers, or very few from this class, evaluated object w_i. In such case there is no raw data for the aggregation function to be applied.

This observation leads to requirement of introduction of subsequent control parameter v – the minimal number of tests for each object before the aggregation function can be applied. Subsequently, aggregation function combining results from at least v contributors satisfying required conditions (selected values c, g_1, g_2 and m) can be applied.

Let summarize the set of model parameters introduced earlier. They are:

1. Constant value c measuring acceptable difference between the entry and object's expert value,
2. Two constants values g_1, g_2 defining set of testers classes - credibility conditions,
3. Constant value m measuring minimal number of completed evaluations by a tester - experience condition,
4. Constant value v indicating minimal count of submitted results for the object by testers from selected class prior to the calculation of final result – object occurrence condition.

This summary concludes our discussion on selection of credible examiners, let us then return to the main problem of objects evaluation. It can be completed systematically from now on. For each object, we apply the final aggregation function only on those entries that satisfy parameters defined at the process design phase. Thus the problem has the following formulation; for a given set of objects W, for an undefined and open set of evaluators/testers E, for a given constants c, g_1, g_2, m and v of the model, for each object w_i, compute value of the aggregation function based on all $f_{k,i}$ that satisfying credibility, experience and object occurrence conditions.

In practice, it is possible that concurrent fulfillment of all the conditions may require some time. Only the conjunction of all specified conditions offers some expected level of quality of task execution.

Presented construction of a flexible environment for the visualization of entries coming from the crowd sourced activity appears to be an interesting service. An interface allowing selection of the values for the model parameters and dynamic control of separation lines is envisaged to be a useful tool independent form the application domain and purpose of the application supported. The scalability of such a system needs to be carefully considered. Over period of time, in case of considerable number of new submissions, the data content will grow in size and change of its content where some players may gain reputation but some may loose their already gained status. This observation justify introduction of an additional dimension to the model – temporal aspect. For the purpose of this preliminary presentation, it is sufficient to consider fixed length period of time for each session of the execution. Addition of continuous, dynamic observations requires more complex formalization but this is not a purpose of this article.

VI. CONCLUSION AND FUTURE WORK

Crowd-sourcing is getting a form of direct collaboration, often on a large scale, between the task provider and public contributors. There is a need to provide easy to manage

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environment to support controlled crowd-sourcing involvement.

In this paper, a linear model of selecting reputable contributors in the crowd sourced task execution has been presented. Model offers choice of parameters within predefined ranges to allow flexibility in selection of preferred submissions from the large scale crowd sourced assignments.

Automation of introduced control mechanism is a simple implementation task. The concept was tested on synthetic data sets demonstrating potential usability on a large scale. The issue of user interface to such environment should be tested exploring several options. Effective visualization of dynamically changing points' positions maybe a useful tool in practice for a big scale crowd sourcing assignments. Visual observation of the points' density and introduced functionality allowing continuous movement of the introduced lines may in return automatically compute the introduced parameters. Empirical examination of distribution of points in different segments of the dedicated screen, forming a base for future selection of parameters values appears to be an interesting scope for applied study.

The presented model may be extended in many different directions by imposing more conditions on the space defined above. Firstly, a number of levels for all types of presented constraints will bring additional precision of the observed experimentation. Secondly, for the same data segment, for each object several types of aggregation functions can be applied to tailor the best fit. Those extensions depend from the size of the problem, number of players, intended application and the domain of consideration and required expected precision.

A subsequent stage of this work will cover the change of the linear model, where separation of space segments is done by straight lines, for a class of polynomial functions. An extensive testing and analysis of large real data sets may be a useful source of pointers for well justified extensions.

The ultimate goal of technological support for collaboration of standard business processes with a crowd accomplished activities is one solution for both types of partners. It is envisaged that the deployment of the controlled crowd sourcing functionality by new generation of workflows technology will form a suite of a novel technological solution for business support and expansion.

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An Ethical Framework for the Outcomes of Web-based Collective Intelligence

Khaled Saleh Al Omoush
Al-Zytoonah University of Jordan
Amman-Jordan
e-mail:kh5_2000@yahoo.com

***Abstract*— This study aims to develop an ethical framework for the outcomes of Web-based Collective Intelligence (CI) in business organizations. The framework acts as a governance structure to organize and support the efforts of strategic planners, decision makers, systems analysts and developers in developing ethical collaborative Web-based systems and applications for harvesting an ethical CI in order to achieve the strategic business objectives. It considered five expected ethical outcomes that have to be evaluated and monitored. These outcomes include justice, satisfaction, trust, commitment, and pleasure. The framework suggests that these outcomes act as strategic leverage points to protect organization survival, serving the social acceptance of its existence, improving its public image, and achieving competitive advantage.**

Keywords-web-based collective intelligence; ethical theories; moral intelligence theories.

I. INTRODUCTION

Business organizations have to constantly innovate in new areas, make complex decisions, originate creative solutions, adapt and behave as human beings to serve its survival, prosperity, and superiority. In this context, business organizations have to be recognized as complex adaptive systems [1][2]. They must learn, self-organize, adapt, compete, and evolve, getting rid of its mechanical and procedural life to behave and think as human beings. From this perspective, organizations must grow far more intelligence to deal with the diverse and simultaneous challenges. An organization is intelligent only if it is able to nurture a high level of CI [2].

The new Information and Communication Technologies (ICTs) are organizing groups and collaboration efforts in new ways that have never been possible before in the history of humanity [3]. Lykourentzou et al. [4] described Collective Intelligence (CI) as an emerging field that seeks to merge human and machine intelligence, with an aim to achieve results unattainable by either one of these entities alone.

Studying the synergy between IT and CI is still in its early stages and many important issues are still unexplored. Kapetanios [5] clarified that the transition from personalized data, knowledge, and contents towards CI forms are at its infancy and raises many questions. CI deserves to become a full discipline, with its formal framework, tools, measuring instruments, practical applications, and ethical field [4][5] by virtue of the advances in collaborative Internet applications. While IT revolution and its role in harvesting the CI is growing continuously, a little attention has been paid to study the ethical dimension of Web-based CI. Given that, this study contributes to the ongoing stream of research through developing an ethical framework for measuring the outcomes of Web-based CI in business organizations.

The present study provides a starting point to meet the need for developing a business ethical framework that addresses the synergy between the collective humans' intelligence and collaborative ICTs. It also provides strategic planners, decision makers, systems analysts and developers with a comprehensive ethical view, guiding their efforts to develop collaborative Web applications for harvesting CI in orders to achieve the strategic business objectives.

The reminder of this paper is organized as follows: The second section will provide an overview of Web-based CI. The literature review section provides an overview of traditional ethical theories, moral intelligence, and ethical frameworks of IT-based collaborative business environments . The fourth section discusses the outcomes of ethical Web-based CI. The fifth section includes the succes story of *MarkaVIP*, a leading online store in the Arab World, and the paper is finalized with a conclusion section.

II. AN OVERVIEW OF WEB-BASED CI

There are many definitions of CI that has been built around the idea of intelligence and collaboration. For example, Lévy [7] defined CI as the capacity of human communities to co-operate intellectually in creation, innovation and invention. Lykourentzou et al. [4] asserted that CI is based on the concept that large groups of cooperating individuals can produce higher-order intelligence, solutions and innovation, and come to function as a single entity. Lévy [7] revealed that one axiom of CI is the coordination in real time through cyberspace.

Collaborative Web-based systems are the most recent paths discovered for opening up the possibilities of harvesting and improving the CI. These systems leverage combined efforts of very large groups of people to solve complex problems, and often referred to as CI systems [3] [4]. As a collaborative platform, the Web-based systems provide a single point for integrating all the company's information, applications and services that are used by employees, business partners, and customers [3]. It enables people from remote locations to meet each other and to

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share information to achieve common goals. It also facilitates knowledge delivery and creation in an open and distributed intelligent environment via networks [7].

III. LITERATURE REVIEW

A. Traditional Ethical Theories

The review of literature confirms that the basic notion of CI stands on two complementary axioms, which together constitute the concept of CI bridged by the collaboration among a group of individuals. The first axiom is related to the limited capabilities of individuals including individual's bounded rationality, cognitive limits, cognitive bias, and no one know every things [1]. The second represents the power of collective collaboration through the ability of a group to find better solutions to the same problems, evolve toward higher order complexity thought, and engage in intellectual collaboration in order to create, innovate, and invent [1] [7].

The two axioms represent convergence points that enable to accommodate many of conflicting ethical theories. Actually, from an ethical point of view, CI is closed to the Utilitarian Moral Principle that considers the benefits of society rather than the benefits of an individual [8]. In other words, one's actions are morally justified if the actions are in the greatest interest for the largest number of people, emphasizing the well-being of society at large [8]. The theme of CI also support the ethical Golden Rule that call for putting yourself into the place of others, and thinking of yourself as the object of the decision, to help thinking about fairness in decision making [9].

CI environment permits overcoming the individualism dilemma in some ethical theories, such as the Right Theory, the Categorical Imperative, and Egoism. This view is consistent with the argument of John Rawls, the author of theory of justice, that when social cooperation is lacking, the concept of justice is meaningless [10]. It is not inconsistent with the mind and rationality of individual's action of Immanuel Kant's Categorical Imperative [9][11] when the collective collaboration environment transforms the mindfulness to orgmindfulness, elevating the CI of the organization [2]. This view takes into consideration the Kant's argument that morality is a reflection of rationality and is larger than the narrow framework of "the ends justify the means" [12], where the collective collaboration can transform the individuals' bounded rationality into collective rationality. In this regard, it is important to mention that researchers of CI coined this transformation using different descriptions and terms, such as shared extended mind, collective mind, and collective cognition.

B. Moral Intelligence

Theorists and promoters of the multiple intelligences theory (e.g., [13][14][15]) posit that individuals possess a number of autonomous intelligences. Gardner [15] explains that individuals draw on these intelligences, individually and corporately, to create products and solve problems that are relevant to their societies. From this perspective, the moral intelligence is an important component of human society, where intelligence can be put to either moral or immoral uses. In the context of CI, moral intelligence emphasizes the ethical responsibilities of individual participants toward the other members of organization's society and to make sound decisions that benefit not only yourself, but others around you [13].

Moral intelligence has different dimensions and mechanisms. According to Lennick and Keil [14], it represents the mental capacity to determine how universal human principles among diverse cultures should be applied to our personal values, goals, and actions. These principles include commitment to something greater than oneself. Lennick and Kiel [14] identified four integrity competencies of moral intelligence, including acting consistently with values and beliefs, telling the truth, standing up for what is right, and keeping promises. Sama and Shoaf [15] suggested that moral intelligence is epitomized in interactive social behaviors through shared values, respect the well-being of others, cooperation, reciprocity, and transparency.

C. Ethical Frameworks of IT-based Collaborative Business Environments

Business ethics can be described as a set of rules, standards, codes, principles, and philosophy to be followed for ethical decision making in business. Ethical decision-making in today's organization is not only the right thing to do, but is vital to its survival [17]. It is becoming apparent that the ethical dimension of ICT related business decisions cannot be safely ignored, especially with the development in Internet applications and its widespread use among the members of organization's society [9].

There is a growing stream of research examining the ethical dimension of Web-based business relationships and interactions among the members of organization's society. For example, Roman [18] discussed the ethics of online retailing from the consumers' perspective. Yang et al. [19] and Limbu et al. [20] examined the effect of perceived ethical performance of shopping Websites on consumer trust, satisfaction, and loyalty. Mingers and Walsham [6] analyzed the potential of discourse ethics of Web 2.0 applications. The authors provided seven principles of ethical discourse governed by different considerations, such as involving all social groups, negotiating fair compromises between competing interests, giving equal consideration to the interests of all, and involving a great number of stakeholders in decisions and system designs. In the context of IT-based collaborative business environments, the Normative Theories of Business Ethics (NTBEs) were adopted to develop different ethical frameworks for decision making and collaboration [21][22]. These theories and their explanations are given below:

Stockholder Theory

According to the Stockholder Theory, the social responsibility of business and hence the managers, is the use of resources to increase returns on investment for the stockholders. One moral argument associated with this

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theory is that if individuals pursue profits, they will also be promoting the interests of society.

Stakeholder Theory

According to this theory, managers are responsible for taking care of the interests of all the stakeholders, such as employees, suppliers, customers. It claims that managers have a fiduciary duty to give equal consideration to the legitimate interests of all such stakeholders. Under this theory, managers must recognize that all stakeholders are entitled to participate in decisions.

Social Contract Theory (SCT)

SCT proposes that all enterprises are ethically responsible and obliged to promote the welfare of society. SCT focuses on two aspects. The first is the social welfare term that stands on the obligation of the organization to improve the well-being of the society. The second is the justice term that includes the willingness of society's members to authorize corporate existence only if corporations agree to remain within the bounds of the general principles of justice. Justice also means that organization operates in a way to avoid fraud and deception, showing respect for society's members.

Based on the previous literature review on ethical theories and ethical frameworks of IT-based collaborative business environment, the framework of the present study consists of three main constructs. As shown in Table 1, these constructs include the rights and obligations of all members of organization's society, the expected outcomes of ethical Web-based CI, and the strategic business objectives that can be achieved by these ethical outcomes.

TABLE I. THE CONSTRUCTS OF FRAMEWORK.

Constructs	Dimensions	References
Dimensions of Ethical Web-based CI	Society's Needs, Rights, and Obligations	[9] [21][22]
	Stockholders' Rights and Obligations	[9] [21][22]
	External Stakeholders' Rights and Obligations	[9] [21][22]
	Internal Stakeholders' Rights and Obligations	[9] [21][22]
The Outcomes of Web-based CI	Justice	[8][10][12][23] [24]
	Satisfaction	[8][11][25][26][27] [28]
	Trust	[18][19][29][30][31]
	Commitment	[16][18][20][31]
	Pleasure	[9][11][12][32] [33]
The Strategic Business Objectives	Organization survival	[17][34]
	Social acceptance of organization existence	[9][19][22]
	Public image	[21] [31][34]
	Competitive advantage	[20][23][34] [35]

IV. THE OUTCOMES OF ETHICAL WEB-BASED CI

The framework posits that needs, rights, and obligations of all members of organization's society should be taken into consideration to develop an ethical Web-based CI.

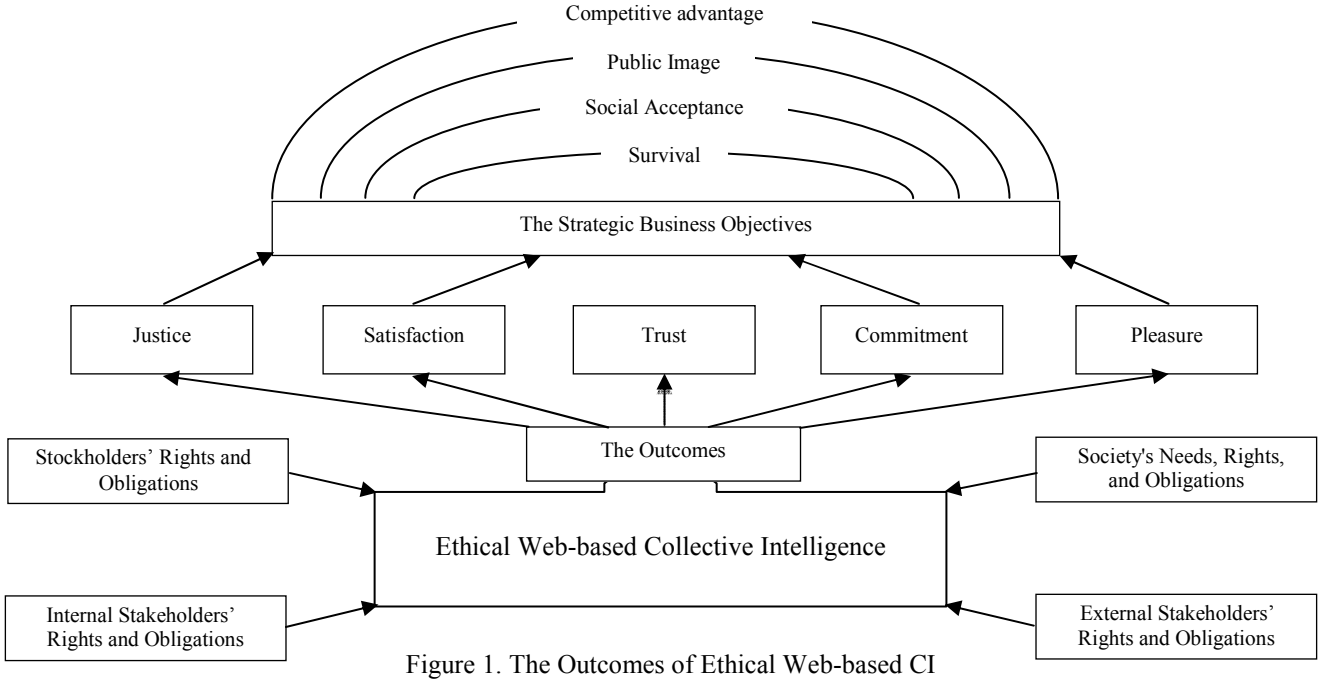

Figure 1. The Outcomes of Ethical Web-based CI

As shown in Figure 1, the framework involves all members of organization's society who can affect or be affected by the actions of the organization [9][22]. Based on NTBEs and the dimensions of interests, rights, roles, and

obligations; the present study classified members of organization's society into four categories. These include stockholders, internal stakeholders, external stakeholders, and society as a whole. Internal stakeholders are those who are members of the organization, such as employees, boards of directors, and managers. External stakeholders are those who are not internal members but have direct interests in the organization and its activities, such as suppliers, logistics companies, wholesalers, retailers, and regulators. According to NTBEs, customers are affiliated to society category.

Based on the overall review of ethical theories and ethical frameworks of IT-based decision making and collaboration; the development efforts of Web-based CI systems, management and organizational environment will work under the following ethical principles:

- Provide a democratic environment in terms of freedom of self-expression, generate and explore ideas, discussion, and consensus in which all participants are considered and treated equally.
- Provide mechanisms to support the morality of collaboration, including mutual respect, caring for collective well-being, standing up for what is right avoiding partial judgments, knowledge and ideas exchange, and consistent adherence to principles.
- Support the compliance with laws, regulations, and standards imposed, or agreed to, by the government, industry associations, stakeholders.
- Support the investigation of decisions truthfulness that complies with facts and reality.
- Provide mechanisms to support the transparency and responsibility for the consequences of decisions.
- Support the decisions that do the greatest benefit for the greatest number of members of organization's society.

These principles work as mechanisms to achieve five outcomes of the ethical Web-based CI. In general, outcome measurements have an important communications role by making organization aware of what is important to success and the areas of evaluation. Based on the literature review, the research framework proposes five expected outcomes that have to be considered, evaluated, and monitored. These outcomes include trust, commitment, justice, satisfaction, and pleasure. It is suggested that these outcomes act as important strategic leverage points to protect organization survival, serving the social acceptance of its existence, improving its public image, and achieving competitive advantage [9] [17][22][35][25][31].

A. Justice

In his distributive theory of justice, Rawls (1971) described justice as the first virtue of social institutions that protect the rights and freedoms of individuals, and support a reasonable distribution of benefits among members [8][12]. Rawls argued that social cooperation appears to be both a necessary and a sufficient condition for social justice that has meaning only within the framework of a cooperative society. In the context of business ethics, Hoffman and Moore [23] demonstrated that business ethics deal with comprehensive questions about the justice issues raised by the relationship of business to government, consumer, employees, and society at large. Murphy et al. [29] considered fairness as a principal ethical dimension of continuum relationship marketing. Hattwick [24] suggested that competitive market situations encourage the reasonably high standard of business ethics called the ethic of justice. Aryee et al. [30] investigated the relationship between organizational justice and work outcomes.

Collaborative Web-based applications advocate an equal freedom to individuals to express themselves freely, posit their views and experiences, and exchange of ideas and preferences [1][36][37]. On the other hand, the previous studies (e.g., [36][37]) confirmed that the effective management of CI is constituted by a democratic environment in terms of liberty, freedom, participation, plurality, discussion, and consensus in which all participants are considered and treated equally.

B. Satisfaction

The ethical theories have developed to provide solutions satisfying the human needs and desires. For example, Kant discussed the complete well-being and satisfaction of all one's needs and inclinations with one's condition [11]. Egoism theory considered the needs satisfaction in terms of self-interest that motivates the human actions [26]. Utilitarianism also investigated the benefits of society in terms of the action consequences that achieve the greatest satisfaction [8][12]. From this perspective, decision makers should estimate and select the solution that maximizes the satisfaction of the greatest number of society's members.

Berrone et al. [27] found that companies with strong ethical identity can obtain a greater degree of stakeholders' satisfaction, which in turn affects positively the financial performance of companies. Koonmee et al. [28] also concluded that the ethics institutionalization has a positive impact on the job satisfaction as one of employee job-related outcomes. Amine et al. [25] investigated the effect of ethics on job satisfaction as a mediating variable between ethics and corporate performance. Many of previous researches (e.g., [18][20]) examined the impact of business ethics on customer satisfaction. The issues of satisfaction also have been examined widely in the previous research (e.g., [36], [38]) to measure the success of Web-based collaborative systems adoption.

C. Trust

Trust is defined as the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party [39]. The previous studies (e.g., [28]) emphasized that the advancement of organizational trust depend, to a large extent, on organizational practices of business ethical principles. Murphy et al. [29] deemed trust as fundamental ethical virtue in relationship marketing. Aryee et al. [30] and Amine et al. [25] investigated the organizational trust as a mediating variable between ethics and performance. Koonmee et al. [28] also declared that

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ethical cultures create trust within and outside corporations encouraging appropriate risk taking, which leads to innovation, propels progress, and ultimately profitability.

Different studies (e.g., [18][19]) discussed the relationship between business ethics and customer trust. Also a major stream of research (e.g., [31][25]) investigated the impact of organizational ethics on employees trust. In the age of Internet, trust among members of organization's society has taken a special status. The previous research (e.g., [19][20]) on Web-based collaboration considered trust as an indicator to the quality of relationships.

Many researchers (e.g., [2][40]) considered sustaining trust as one of the pillars of CI. Ng and Liang [2] revealed that collaboration in the intelligent organizations can only be achieved through mutual trust. Numerous studies (e.g., [37][40]) asserted that the role of collaborative IT and digital interaction in harvesting CI is not likely to succeed if openness and mutual trust is not promoted first.

D. Commitment

Commitment refers to partners' desire to continue a valued relationship and a willingness to make short-term sacrifices to preserve the longevity of long-term relationships [20]. Murphy et al. [29] believed that commitment is a fundamental ethical virtue in business relationship. The survey of Aspen Institute [16] concluded that the company's commitment to its social responsibility has definite business benefits, including a good reputation, loyal customers, and long-term viability in the marketplace.

The review of literature showed a positive relationship between the ethics institutionalization and employees' organizational commitment [28][31]. It also revealed a positive impact of business ethics on the customers' commitment and loyalty [18][20]. Commitment is used as a central variable to determine the success and quality of Web-based collaborative relationship [20]. In the context of CI, research (e.g., [2][3][4]) indicated that the purpose of collective management is to promote the collective commitment in terms of common objectives, building long-term relationship, a sense of togetherness, and partnership.

E. Pleasure

Many ancient philosophers believed that the purpose of all human actions was attainment of pleasure. The utilitarianism considers that the rightness or wrongness of an action is determined by its contribution to hedonistic consequential benefit and the overall utility in terms of maximizing pleasure [12]. Bose [9] explained that the goal of greater happiness in utilitarian principle can be achieved by nurturing the decency of individuals, so that all can benefit from the honor of others rather than focusing on just one individual's happiness. Much works by economists have tied the ethical behavior to the pleasure principle, which can be gotten from the consumption of so much honesty, friendliness, or other ethical duty [24].

The technology acceptance models have frequently used the hedonic motivations to predict the intention and usage of IT. For example, Davis et al. [32] considered perceived hedonic value as the extent to which the action of using the technology is perceived to be enjoyable in its own right for no apparent reinforcement. Venkatesh et al. [33] added hedonic motivations to UTAUT2 describing the fun or pleasure derived from using a technology.

A considerable attention has been paid to the important role of hedonic and intrinsic motivations in harvesting CI. For example, Bothos et al. [37] described the intrinsic motivations of participants in terms of feeling of having positively impact, finding feedback potentially valuable and supportive of creativity, becoming co-creators, participating in the risk of failure or the joy of success.

V. MARKAVIP : A SUCCESS STORY

MarkaVIP [41] is an online shopping store, which was founded in 2010, selling gifts and accessories. The company chose to work in the Arab world environment, where people do not sufficiently trust paperless or faceless transactions, and buying from unknown sellers. In such a culture there are many barriers that can create customer resistance to changing from shopping at brick-and-mortar stores to virtual stores. The company started with an estimated $10,000 capital and a few suppliers who had accepted to provide MarkaVIP with commodities on credit and getting paid after receiving money from customers. Today, MarkaVIP is a leading online retailer in the Arab world and a strong competitor of the offline deep-rooted traditional stores, offering a wide variety of products ranging from goods and services for men, women, and children; electronics; and home decor. The company follows the following philosophy:

> *"We are a company that's all about people whether they are our employees, our customers or partners. We believe that having exceptional talents is fundamental to the success of our company."*

The Web-based collaboration of MarkaVIP with its online society's members has created "win to win" relationships, which represent a main feature of collective intelligence. One major strategic pillar of the company's success is based on a set of ethical rules, standards, codes, principles, and philosophy that enabled it to acquire the trust, satisfaction, commitment, and many other achievements of its society's members.

VI. CONCLUSION AND FUTURE WORK

The present study aims to develop an ethical framework for the outcomes of Web-based CI. These outcomes are expected to contribute critically in achieving the strategic business objectives of the organization, such as survival, the social accept of its existence, improving its public image, and achieving competitive advantage.

There are some limitations which can serve as directions for future research. The research framework needs to be tested empirically. Although the ethical outcomes have been measured in previous research, the present study does not provide a methodology to follow for achieving the ethical principles of Web-based CI.

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Cost Efficiency Calculation and Analysis for Business Processes Transformation to Cloud Computing Systems Architecture

Peteris Stipravietis, Edzus Zeiris, Maris Ziema
ZZ Dats SIA
Riga, Latvia
e-mails: {peteris.stipravietis, edzus.zeiris, maris.ziema}@zzdats.lv

Inita Kindzule, Rudite Cevere
Faculty of information technologies
Latvia University of Agriculture
Jelgava, Latvia
e-mails: {inita.kindzule, rudite.cevere}@llu.lv

***Abstract*—Although much has been discussed that cloud computing solutions provide a number of key benefits for enterprises which decide to apply it, however, there is a lack of a certain pattern, which could help enterprises to decide whether the architectural transformation to cloud computing solution will be economically viable. Mathematical calculations and various setting methods of identifying and calculating the costs of applying the cloud is becoming a new challenge. Owing to lack of investigative studies explaining the cost efficiency for business process transformation to cloud computing systems architecture to ensure the economic justification of the transition taken, this paper is to identify the costs of transformation to cloud computing systems architecture, outline cost efficiency method/s, and create a calculation and analytical tool that could be useful for enterprises and decision makers, and use it to assess if transformation to cloud solution was economically beneficial and cost efficient for Riga City Council.**

Keywords-cloud; cost efficiency methods; efficiency and costs calculation

I. INTRODUCTION

Cloud computing is the future of computing technology. Cloud development has a potential to completely change how Information and Communication Technologies (ICT) companies render services to their customers by using technologies. ICT enterprises know that cloud computing is able to deliver ICT services efficiently and cost-effectively and has many advantages: easy implementation, qualified staff, and scalability, making internal resources available and enabling enterprises to improve the quality of their services. Cloud computing reduces the cost of ICT services and decrease processing time while increasing reliability, availability, processing capacity and flexibility [5]. According to different reports, the revenue from cloud computing is estimated in billions of euro and the global cloud computing market will reach €193 billion in 2020 [1][7][13].

The challenge arises when making a decision about the suitability of cloud computing for enterprises that already have working and functional ICT systems. The enterprise must decide either to develop and invest in its own resources or to make changes based on consideration of the total costs or the environmental situation.

The aim of this paper is to define the cost efficiency calculation and analysis method for business processes transformation to cloud computing systems architecture to ensure that the taken transition is cost efficient and what could be used as a tool in decision making.

In the context of this article, the authors define the business process transformation as a gradual process of many stages and methods which allows executing the process in different environment. For example, if a business process runs in environment A, based on architecture X, these methods may be applied in certain order to allow the resulting process run in environment B, based on architecture Y. The transformation can be used to adapt desktop application to cloud infrastructure. By measuring how effectively alternative solutions can be used to solve a particular business issue and how an enterprise acquires most business and economic benefits for the lowest financial investment, cost efficiency ensures the economic justification of business process transformation.

This is achieved by using a multi-method approach - systematic literature review, analysis of cloud computing costs, comparison between calculation decisions, expert interviews and case study of Riga City Council has been used for the evaluation of cost efficiency method.

The paper is organized as follows. Section II describes and identifies the costs of cloud computing solution. Section III provides comparison of cost calculation methods and components for calculating the cost efficiency. Section IV provides the business case to assess if business processes transformation to cloud computing systems architecture was economically beneficial and cost efficient for Riga City Council. The acknowledgement and conclusions close the article.

II. IDENTIFICATION OF COSTS

A. Tangible Costs

Any enterprise planning to adopt cloud computing solution initially has to define the costs of transformation to cloud computing architecture that are attributable to the specific case. They should be defined so one could perform appropriate calculations and evaluations.

Many different ICT costs can be accounted: infrastructure and architecture exploration, evaluation of conformity, transformation costs, infrastructure changes and restoration costs, maintenance costs, hardware costs, software costs, human resources costs, personnel training costs, and other, although it is not possible nor needed to use all these costs in calculation. Costs should be measurable and comparable.

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To identify the costs associated with cloud application efficiency and costs calculation cloud application phases and road map of cloud objectives and benefits should be defined. Violin [2] defines that cloud application life cycle consists of four key elements: (1) application strategy, (2) choice of supplier, (3) contracting and (4) management and governance. The Walterbusch et al. [15] defines similar life cycles: (1) initiation, (2) evaluation, (3) transition, (4) activity, and also adds a fifth element -final phase-(5) continuous monitoring of costs to be able to monitor the costs and risks, and move withdraws from the cloud services. Hexware Technologies [9] also defines four-step process if an organization wants to achieve cloud goals: (1) defining cloud strategy, (2) application, (3) ICT optimization or application migration, and (4) business innovation or creation of new business models. Willcocks et al. [13] indicates that the achievement of innovation with cloud resources is a two-stage process, which initially includes: (1) an enterprise cloud computing application, and then (2) innovating using those cloud resources. Enterprises will keep looking for ways to benefit from adoption of cloud computing although the benefit of innovations enabled by cloud computing may be larger [13].

This paper shows how to create cost efficiency model on the basis of cloud application life cycle and costs and benefits during this period, as well as add business innovations phase that will provide overview of benefits and costs in long-term. It defines the road map of cloud costs, objectives and benefits (Figure 1).

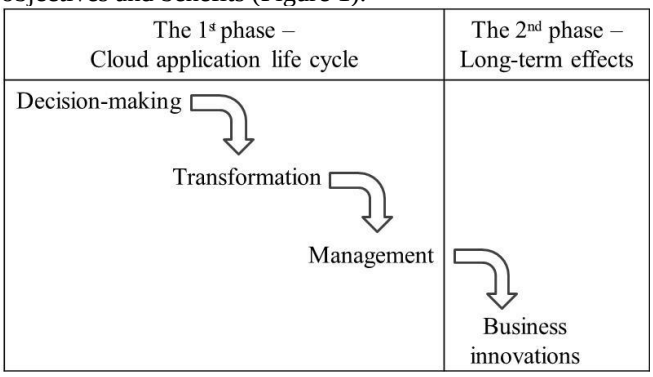

Figure 1. Road map of cloud costs, objectives and benefits.

1) Decision-making: This stage includes cost components such as time, consulting services and information for decision-making. This is a very important stage in all of the cloud application life cycle since it entails the analysis of business needs and assessment on whether the possible cloud solution is suitable for the enterprise, its local infrastructure and technologies. It includes analysis of potential costs and benefits, as well as should include calculations. These are initial costs.

2) Transformation: This is adaptation stage that includes infrastructure changes. It can be called implementation, configuration, integration and migration and covers costs of transmission and process factors. These also are initial costs. This stage also includes initial training that can be calculated by time for preparation of internal personnel and external consulting services, and other costs.

3) Management: This stage includes ongoing maintenance, operation of cloud services, ICT support and ongoing personnel training. These are running costs.

In order to reflect the full life cycle, the final *closing* stage also should be included, as it includes switch back from the cloud of suitable infrastructure. In this paper authors did not include this stage.

4) Business innovations: These have to be evaluated in long-term. It also refers to the impact on the environment and socio-economic indicators and provides a range of evaluation factors that affect use of citizen's e-services [1]. This phase includes intangible costs and benefits.

B. Intangible Costs

Besides the obvious costs of hardware, software and human resources, cloud solutions entail many other components. Costs that are not visible are always hard to measure. Nonetheless, they are one of the key factors in any analysis since they are just as important as other costs. Enterprises must understand these changes and chose reasonable cloud application strategies and contracts that can reduce risk by estimation of the Service Level Agreement (SLA). The following criteria are not imperative but they can generate extra costs that may, however, be avoided.

If any of the activities are restricted or hindered, long-term cloud benefits will be affected. Therefore, the understanding of the limitations on the cloud computing application is important, just like the factors preventing innovations when using cloud computing [13]. Risks like hidden costs must be considered since they can hurt the expected benefits [16]. It is highly recommendable to reduce the risks for enterprises intending to adopt cloud computing services with a meticulous cost analysis. It is also important to inform enterprises about the factors and various types of costs [15]. Ignoring these figures when making a decision, the enterprises may get to an outcome quite the opposite of the expected economic benefits [2].

1) Software adaptability: Interoperability and extensibility are very significant when transforming any new solution. Before any transformation it is important to find the answers to the following questions: how easy will the integration of the software be with other applications or is it going to be easy to adjust the application to enterprise's needs. Without answers to these questions, the transformation to new solution will require much more time and money [10]. Each time enterprise modifies its software, it should remember that the initial relatively low expenses may lead to high costs of backfitting or maintenance. Improvement of an existing system or installation of the onsite system at the enterprise will more likely have to be replaced in five years. Replacement costs and the amount of the initial hardware investment will be alike, so it is better that these costs are planned. Additionally, after the five-year period customers may want to upgrade the software to the latest edition. The corporate acquisition of software in all areas may reveal the system upgrade costs. It may be

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important to make sure the adjustments remain unaffected if the system of the enterprise has been customized. In some cases, when users are added before the update, it might be necessary to purchase additional licenses. On the contrary, cloud improvements tend to be iterative, limiting the improvement in the costs of operation, which is the major reason why the total costs in terms of cloud and local systems differ around the five-year range [3]. Can the cloud application be adapted to the growth of local application development, is another point to consider [10]. There are some enterprises that want to install numerous cloud applications and integrate them to offer additional opportunities for their customers, but they might find that, for example, the integration between the two applications in the cloud is in no way possible [2].

2) Data handling and storage: Data handling and storage is one of the indicators with a couple of hidden costs. Data movement often raises costs; the price can be as high as €1 000.00. Cloud providers may require a fee for each download and long-term data storage in the cloud is expensive. Besides, an internally done backup copy of the data storage cloud is more expensive [2]. It might be necessary to buy new server hardware, and these costs may rise over time.

After purchasing the cloud solution, one should plan for the same amount of server hardware investments. However, some may want to purchase a reserve server to support business data from the service provider [3]. Security and privacy policies are especially significant factors to any enterprise, that is why the following question should be answered - what kind of security and privacy policies are applicable to the cloud vendor, and how does it relate to internal policies [10][16]?

3) Performance and quality: Performance and quality are certainly the benefits expected to improve with the cloud solution, although this benefit may bring up some hidden costs. SLA could be used to measure quality factors like reliability and availability. The type of guarantees and the risks of changing the technology matter if enterprises go for a cloud solution. Moreover, it is necessary to examine the data center and operations' quality in each technology solution, as well as personnel involvement [10].

The necessity to test the software before transformation to the cloud technology may also bring up hidden costs. Although using cloud configuration can be really cost-efficient and save few hundred thousand euros, it may be necessary to stabilize the system [2]. With a cloud solution, the seller assumes the duty to provide software deployment and maintenance, also ensuring data security. The seller also determines how the enterprise limits its internal ICT costs, although it is not entirely avoidable because there will still be the need to manage the system configuration and local testing to ensure that application is running in the appropriate local ICT environment. ICT has an unpredictable nature and its issues makes it difficult to accurately identify and predict the amount of investment to ensure smooth work of the system, and the ways to manage ICT locally, which can significantly increase the total cost of ownership of the enterprise [3].

Naturally, there are many costs related with the maintenance of the system of internal resources, but not all of them are covered from the ICT budget. With the arrival of the cloud, the basic infrastructure costs are included in the overall costs. In result, the enterprise has to pay for something (for example, electricity and rent) it was not charged before. Overall, cloud computing application provides lower costs, but requires overall budget changes [2].

Every mathematical approach should apply restrictions that should be considered in the framework of the practical application thereby distancing from the cost types that are not applicable to the given situation [10]. Cost components of each individual situation will vary. Therefore, every case should be evaluated specifically.

III. METHODS FOR CALCULATING THE COST EFFICIENCY

Many studies illustrate and provide information on how the enterprises can benefit from cloud services, but only few enterprises have taken note of this beneficial effect before a final decision [15][17]. Despite the fact that most attention is paid to risks and safety issues, there are authors who have already begun to create new cost calculating models and methods. Most studies illustrate the economic benefits of cloud computing solutions for enterprises; however, a question arises - which method would be most appropriate for calculating cost efficiency and how cost efficiency should be measured?

Frequently used cost calculation methods should be assessed:

A. Return on Investment

Return on Investment (ROI) is one of commonly used calculation method what estimates financial outcome of business investment and provides an assessment of how valuable will be a contribution [11][20]. It includes both the cost of investment (initial, running and closing costs) and the expected benefit from investment (tangible and intangible gains).

Simple calculation formula for ROI is the following:

$$ROI = \frac{(expected\ \ benefit\ \ from\ \ investment\ \ - cost\ \ of\ \ investment\ \ )}{cost\ \ of\ \ investment}. \quad (1)$$

The result is expressed as a percentage or proportion. If ratio is greater than 0, it is expected that benefits are greater than costs, so that the investment can be regarded as beneficial [11]. Investment with the highest ROI is regarded as better business decision [14]. Obtaining a meaningful result depends on all the variables for calculating and defining a clear and consistent period of time [19]. For clear estimates, it is important to define clear and measurable benefits and easily known costs. It can be found that ROI calculation can be difficult and misleading for more specific investments, such as cloud computing systems and services [14][20]. Also, the usage of ROI calculation as the only

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financial measurement of decision making would not help to predict the feasibility of profit or the risks involved with a particular investment [11]. It is, therefore, necessary to look at other economic benefit calculations.

B. Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) is widely used calculation method what obtains the difference between costs and benefits to decide whether to make changes [14].

To compare the benefits and costs of cloud computing, a number of variations of CBA can be used – Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR). For example, NPV compares the expected benefits and costs of a predetermined time period through rate, which assists in calculating the present value of the future cash flows of transactions [8][11].

The formula to calculate simple NPV of the project is:

$$NPV = \sum_{t=1}^{T} (benefit_t - cost_t) / (1+r)^t . \quad (2)$$

Costs can be initial and regular, while benefits are mostly received over the time. The time effect is included in the analysis, in the calculation of payback period. This is the time it takes to change benefits for reimbursement of expenditure [14]. Benefits and costs are the future value at specified time *t* (number of periods from the beginning of the project); *r* is the discount rate, and *t* is the year. Also CBA evaluates each project and are defined as successful, if the calculated value is greater than 0 [11].

Simplified cloud CBA would evaluate the economic benefits of cloud computing usage [14], but despite it allows comparisons to be made between investments, it may not be able to include all criteria which are deemed important in evaluation [8]. It is, therefore, necessary to look at another calculation.

C. Total Costs of Ownership

Total Costs of Ownership (TCO) is one of the most recognized calculation methods in assessing potential opportunities for business applications. It helps consumers and enterprise managers determine all the costs (direct and indirect; initial, running and closure) related to a product, service or system throughout its lifetime [14][20]. Basically, TCO is sum of all costs accounted during the life cycle of the solution [15].

The overall TCO can be calculated as:

$$TCO_T = \sum cost_{c,i}^t = a_{f,i}^t * b_f^t. \quad (3)$$

TCO calculation includes several cost categories *t* and components *c* in time period *i*. All costs are calculated using variables for consumed or necessary quantity α^t_f in period *i* with unit costs and prices b^t_f. It comprehensively considers the entire lifetime spending, capital costs, cost of operations and hence is suitable for base cost estimation [12][20].

It can be concluded that all calculation methods use the information of costs and are valuable tools for decision making. But, it is not possible to identify one for all needs of businesses.

Advantages and disadvantages of each calculation method should be identified (Table 1).

TABLE I. COMPARISION OF COST CALCULATION METHODS

	Advantages	**Disadvantages**
ROI	- Information about expected savings [6]. - Great for clear and measurable expected benefits and easily known cost of investment [14][20]. - Evaluates the benefits and costs of proposed alternatives [11]. - Calculates costs: return and investment costs (initial costs, running costs, closing costs), time, expected benefits [11][14][20].	- Difficult to use and misleading for more specific investments such as cloud [19]. - Looks at business benefits, which often cannot be measured as objectively as costs [18]. - Only one ROI calculation would not help to predict the feasibility of profit or the risks involved with a particular investment [11]. - Not very detailed, and thus may not be very accurate [14].
CBA	- Information about earnings, expected benefits and costs of cloud computing usage of a predetermined time period through rate, which assists in calculating the present value of the future cash flows of transactions [11][14]. - Evaluates the difference between benefits and costs [6][12]. - Calculates costs: initial and regular costs, benefits over the time, payback period (number of periods from the beginning of the project) [11][14].	- Not very detailed, and thus may not be very accurate [8][14]. - Does not include process changes and personnel costs or, for example, the benefits of mobility systems [14]. - Future benefits and costs are not measured [8]. - The chosen rate can radically change the results of analysis [8].
TCO	- Very detailed and allows the assessment of all the costs throughout the lifetime of the system, service, process or product [12][14][15][20]. - Good to compare two or more alternatives [14]. - Provides a realistic and holistic measure of the long-term costs required to acquire and operate technology solutions [18]. - Identifies hidden costs [4].	- Only one alternative TCO solution would not prove whether transformation to cloud is efficient, or not [10]. - Is not complete cost benefit analysis [4].

Disadvantage to point out of all previously compared calculation methods is that intangible costs are difficult to value. More sophisticated assessment approaches try to add financial value of the intangible costs. The same is about intangible benefits. For calculating costs of cloud computing solutions it is especially a challenge.

ROI and CBA evaluate investments, but both look at business benefits what cannot be measured as accurately and objectively as costs. It can be seen that CBA and ROI make use of information about earnings and benefits and show how the solution is effective or ineffective. However,

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at the same time, the two estimates are not very detailed, and thus may not be very accurate.

TCO can be used as most appropriate calculation method to compare two or more alternatives. It is very detailed, and allows the assessment of all the costs, including identification of hidden costs. But only one alternative TCO solution would not prove whether transformation to cloud is efficient and economically beneficial or not.

Ideally, the enterprise will use several methods of financial indicators in decision, whether to transform the existing business process to cloud computing systems architecture, or improve the local architecture. For cost efficiency calculation most appropriate would be TCO, but it should be improved.

The cloud cost efficiency model can be formed on the basis of cloud activity indicators – Key performance indicators [20], which are assessed as costs in each category:

- Time: It includes the time required for the implementation of the solution, as well as the availability period of the service.
- Costs: Costs are based on one or more of the method's results described previously. This paper suggests that TCO is most appropriate as a base for comparing two or more alternatives and it allows calculating costs throughout the life cycle of solution.
- Margin: Profitability is the difference between cloud computing solutions and local infrastructure solutions.
- Quality: It includes performance and intangible costs.

Cost efficiency method should be at hand to compare two alternatives (two alternative solutions - transformation to cloud solution and improvements of local architecture) for solution of one problem or business needs to calculate which alternative is economically beneficial and cost efficient.

Rigorous cost efficiency calculation and analysis sequence of actions have been defined in Table 2.

TABLE II. COST EFFICIENCY ANALYSIS

A. Business needs	Define the business needs and define potential cloud service model.
B. Evaluation **1) Time** **2) Costs** **a) Decision-making** **b) Transformation** **c) Management** **d) Business innovations** **3) Margin** **4) Quality**	Evaluate alternatives: (1) define the possible required time for solution implementation, (2) identify the possible costs of cloud computing solution and local infrastructure development, and evaluate them, (3) calculate the cost-efficiency and conduct an assessment, (4) define the potential quality indicators, including the identification of intangible costs.
C. Final decision	Make the final decision.

The alternative is cost efficient if its realization during its life cycle requires the lowest investment. Cost efficiency analysis should include definition of business needs, evaluation and comparison of alternative solutions and final decision. Evaluation should include calculation and analysis of tangible and intangible costs.

IV. COST EFFICIENCY BUSINESS CASE

A. Business needs

Common ICT solutions development and support for employees to provide fast and effective high quality services to clients is the main goal of Riga City Council concerning the ICT. Centralization in local authorities including Education, Culture and Sports Department subordinate institutions – schools was one of the biggest challenges for Riga City Council in the year 2011/2012.

Municipality had to find a new ICT solution that could be appropriate for financial statements delivery to employees, ensuring the confidentiality of documents and electronic accessibility. There are more than 10 thousand school employees and pupils in schools of Riga City.

It was necessary to decide whether to invest in its local infrastructure or transform to cloud solution. Potential benefits of cloud solution allowed make the decision, but whether it was cost efficient?

In this case, it is not possible to perform the measurement of economic performance with existing solutions, because there was no solution at all. E-mail implementation was a new challenge for decision makers. Without a new e-mail solution, it would not be possible to provide the current technological opportunities.

B. Evaluation

1) Time: Transformation to the cloud as a whole took three months. Ad hoc solution would need at least six months. Usually enterprises for adopting cloud solution would need less time. When outsourcing data to the cloud, users and enterprises essentially lose control over their data, but Municipality has strong regulations and requirements on data handling and storage. Also acceptance of other decisions needed more time.

Service accessibility time would be identical for both decisions.

2) Costs

a) Decision-making: Decision making costs include all involved specialist's time, what is necessary for strategic decision, expenses of information upon which to base the decision and expenses of consultations.

In example of Riga City Council, strategic decision took 16 work hours. Hourly rate of the decision-maker and the ICT personnel was 50€/h. Information materials were not used. The evaluation was conducted by an external consultant pricing at 70€/h and it took 40 hours. Decision making would require an identical time for both – improvements of local system and transformation to cloud computing system's architecture.

b) Transformation: Transformation costs of cloud computing approach demanded €50 000.00. Implementation, including the training, was carried out in 5 days. Standardized transformation to cloud solution took less time than it would take if Municipality would improve its local architecture. The calculations do not include purchase of new hardware because it was not necessary.

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c) Management: In evaluation of the management phase of business processes that is dependent on the service provider's offer, the service availability is very important, and needs to be available 99.99% of time. These values can be provided only by a cloud service provider.

In addition, cloud technology application reduces the capital and operation costs associated with servers, system licenses, system maintenance, data center and necessary support personnel. Maintenance is very important for service availability. Cloud computing approach requires only one day a year, which is 8 hours x €70 hourly rate of the service provider. For traditional enterprise software it would be €50 000.00, which includes servers and disk space, licensing and maintenance as well as additional required human resources.

Access to e-mail is provided to 17 000 employees and 30 000 pupils. Access price is set as part of annual maintenance.

Closing costs were not included in the calculation. In both cases, it would be €56 000.00.

TABLE III. COMPARISION OF COSTS

	Transformation to Cloud Solution	Improvements of Local Architecture
Decision making	3 600.00	3 600.00
Transformation	52 000.00	56 000.00
Management	47 560.00	97 000.00
Total:	**103 160.00**	**156 600.00**

Table III reflects that costs of transformation to cloud computing architecture are lower - €103 160.00 compared to €156 000.00 if Municipality would decide to invest in developing its local architecture. It can be concluded that the transformation to the cloud solution has been cost beneficial.

Figure 2 confirms that costs of transformation to chosen cloud solution was less than if improvements of local architecture would be implemented.

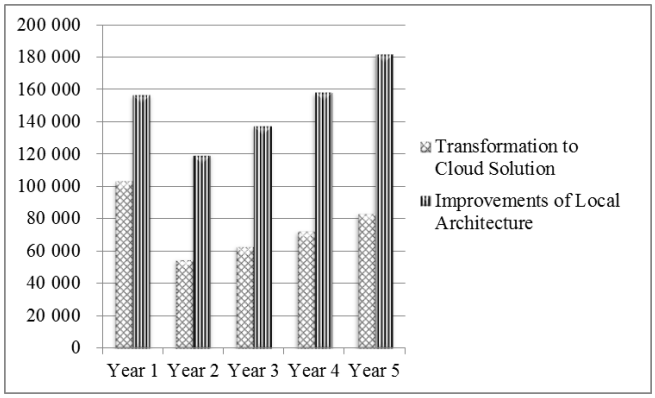

Figure 2. Comparison of costs (five year perspective).

Costs have to be assessed in at least five years perspective, to make sure that cost of two alternative solutions differences also in further years, since the first year involves investments in a new technological solution. The first year also involves the costs of decision making and transformation. Starting from the second year, these costs are not included. Growth of costs is assessed with a 15% inflation increase. Inflation rate shows the difference margin more effectively.

d) Business innovations

Business development: Faster response ability can improve service delivery, satisfaction and corporate relations of citizens, businesses, employees and suppliers. Redistribution of ICT operational activities offers enterprises the opportunity to focus on business development, including new and innovative applications that enable business and product development to provide better services. Cloud solution often causes creation of new solutions that were not technically and/or economically feasible without it [15]. Cloud computing can help to maintain or analyze large amounts of data disclosure and fraud. Thus, it can control corruption and improve e-governance processes - application migration to any resident, lost data recovery, data copy establishment, pollution reduction, and other expenses [21]. Cloud computing can also help human recourses professionals to cope with various issues to ensure effective talent management, since it can help to solve the main problems of affordability, accessibility, timeliness, ease of use as well as integration. It also offers a technological solution with a potential of organic change that would happen in accordance with the enterprise's own changing needs. Personnel have important role as from it depend decision whether transformation to cloud computing solution will be chosed and integration has been done correctly.

Impact on the environment: As one of the quality indicators can be counted green and sustainability costs. Impact on the environment means savings from paper, energy and electricity.

The e-mail cloud solution also used service that delivers documents electronically. As a result, there was no need for the printing of large amount of papers and transportation anymore. That is, since there are 17 000 employees receiving payment documentation every month, and, if the cost of one printout is €0.10, causing the costs of electricity, depreciation of equipment and tear, as well as petrol consumed in the process of delivering the payment documentation, it can be concluded that for Riga City Council it costs €1 700.00 monthly. That makes €20 400.00 per year. In five-year's perspective, savings are €102 000.00 already. This is the whole amount if costs do not increase each subsequent year.

This solution is an important factor in impact reduction of technologies to the environment (air conditioning, electricity, and other), that allows to achieve significant long-term goals.

Impact on society: This cloud solution provides a number of key benefits, which affect not only the e-governance areas but has an impact on society too.

Every pupil and teacher is provided with a single e-mail address that can be used for professional purposes and provides a corporate image. Pupils may use this tool for sending documents, mutual communication projects, as well as for sharing documents. It saves their time and resources. On the other hand, by using this e-mail, teachers can send

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transcripts to pupils – that is comfortable and safe. The Microsoft e-mail can be used as a tool for a variety of projects; it is possible to create groups and chat. It provides a quick and convenient use. It also ensures the reliability of the Municipality and sent documents.

3) Margin: As shown in Table IV, in five-year perspective, estimating an inflation of 15%, cost difference between cloud solution and improvements of local architecture will be formed as €377 236.90 savings.

TABLE IV. COST MARGIN

Year	Transformation to Cloud Solution	Improvements of Local Architecture	Margin
1st	103 160.00	156 600.00	534 40.00
2nd	54 694.00	119 539.30	648 45.30
3rd	62 898.10	137 470.20	745 72.10
4th	72 332.82	158 090.72	857 57.91
5th	83 182.74	181 804.33	986 21.60
Total:	**376 267.65**	**753 504.55**	**377 236.90**

It should be noted that in five-year perspective, the ad hoc solution would need to include system upgrade costs.

4) Quality

a) Software adaptability: This solution has brought several intangible costs. The first was adaptability as it was necessary to integrate the application with Riga City Council's local cloud solution and local systems. The first challenge was to create a mechanism that would find out how teachers and pupils are going to receive e-mail addresses and access them, and an identity maintenance was created for employees and pupils. This would also be necessary if the local infrastructure was developed.

b) Data handling and storage: Microsoft changed the technological infrastructure standard from Live@EDU to Office365 one year later, so it was necessary to remake authentication solution as well as develop local systems. To ensure that the existing Office365 authentication temporary solution replacement and school infrastructure business continuity, authentication solution development demanded €54 000.00, but system development – €18 000.00. Unfortunately, a vendor may keep the rights to change its solution.

c) Performance and quality: Quality also includes calls to errors or losses. Larger losses would be caused in the case of ad hoc improvements. It would go up to €200 000.00 while the cloud solution is €50 000.00 which is €150 000.00 less.

C. Final decision

Technology develops fast, and society develops along with it. At present, it is inconceivable that employees and pupils of Riga City Council would not have a uniform e-mail system. Although they do not have to worry about the costs of the solution, indirectly this solution also reduces their costs – in terms of time and finance. Nowadays cloud computing is the ICT sector's innovation around the world that provides immediate benefits but more importantly - the substantial long-term benefits. This solution is flexible because it is available on mobile devices, directly contributing to the development of the information society. Riga Municipality ICT architecture strategic direction is to move to a new ICT governance model for the implementation of a significant innovation, thus providing substantial economic and social benefits for its customers (citizens and employees).

We conclude that business process transformation to cloud computing systems architecture was cost efficient, and provided analysis method for business processes transformation to cloud computing systems architecture can be useful as a tool in decision making.

V. CONCLUSIONS

While cloud computing can provide clear benefits of total costs to any enterprise, which can be calculated by taking into account the TCO calculation method, it is crucial to take into account also the individual business requirements and hence the applicable components for each case individually. This can all be fixed in the decision-making phase.

It is necessary to understand that some enterprises may require specific features or functionality that is not available as a cloud solution. It is necessary to assess whether the enterprise wishes to customize the solution to the basic level, something that is only possible in the local, on-site software model. There is a need to assess business requirements and then evaluate each vendor's ability to meet this requirement. In the given example, the business cloud solution was available, and by calculation, as well as through business assessment, it can be concluded that the decision has been economically beneficial and efficient.

Enterprises planning to use the cloud computing services are advised to thoroughly analyze costs to minimize risks and learn about all the cost types and factors.

In order to select the most appropriate solution and decide whether to improve the existing architecture or to implement the cloud computing solutions, it is recommended to invest more in the decision-making stage (evaluation) - a process that enterprises often neglect and as a result it can lead to inadequate achievements. This is particularly important because every cloud solution varies depending on the components; it is suggested that the costs and benefits must be carefully considered over at least a five-year perspective, including intangible costs and benefits. Generally, enterprises can see that costs pay off in the second year already, as it is well presented in the given example. As technology develops approximately every five years, it is necessary to take into account that use of the ad hoc solution will require to invest in infrastructure and technological improvements. Those costs can be as much as the initial costs of the solution. That is why it would be useful to be aware of costs in more than a five-year perspective. However, if the enterprise has chosen the cloud solution, and especially outsourcing, it does not have to think about it.

During the cost efficiency evaluation to determine whether the cloud computing is an economically beneficial and effective solution, other important factors also has to be assessed that are related to cloud innovation stage, which is associated with long-term and socio-economic factors.

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After all, the purchase and implementation of the software is a business, not a technology decision. The type of technology that is chosen according to the business requirements of enterprises and organizations is different compared to the corporate business objectives, needs and risks the company is willing to admit. It is crucial to understand that each delivery model has advantages and disadvantages, both the financial and technological restrictions must be taken into account, as well as the specifics of the business.

ACKNOWLEDGMENT

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Using Text Mining for Automated Customer Inquiry Classification

Raoul Praful Jetley and Jinendra K. Gugaliya
ABB Corporate Research
Software Research Group
Bangalore, India
Email: {raoul.jetley, jinendra.gugaliya}@in.abb.com

Sana Javed
International Institute of Information Technology
Department of Computer Science
Bangalore, India
Email: sanaiiitb@gmail.com

***Abstract*—Understanding the customer's needs and issues is central to business survival and growth. Typically, customer inquiries are captured by a dedicated customer service center using unstructured narrative text. The number of such customer inquiries can vary from several thousands to millions depending on the business size and customer penetration. Analyzing such a huge number of customer inquiries manually is cumbersome, prone to errors and costly. More importantly, it is not possible to identify broad signals and trends among this data. In this paper, we describe an automated approach to analyze customer inquiries, and show how this approach can help classify customer inquiries. We illustrate the application of this approach through an example related to a leading multinational automation company.**

***Keywords*—text mining; information retrival; intention analysis; query classififcation; service center.**

I. INTRODUCTION

Customers are the biggest asset for any business organization. It becomes imperative, therefore, for an organization to ensure that its customer opinions are heard and their feedback and concerns addressed appropriately. In most organizations, this function is performed through a dedicated customer service center. For a typical organization, the customer support center is responsible for:

- receiving and addressing inquiries related to different products and services offered by the organization,
- providing a sounding board for customer questions and complaints, and directing these to the appropriate business unit, and
- interfacing with the customers to gather feedback for specific products.

A typical large organization could receive hundreds of thousands or even millions of customer inquiries every year, originating from different parts of the world. It is the responsibility of the customer service representative (CSR) to identify and channel these to the concerned person within the organization who can respond to the inquiry.

Traditionally, this has been done manually, with the CSR reviewing individual inquiries and addressing them accordingly. This approach, however, becomes infeasible as the number of inquiries increase and data becomes too large to analyze manually. What is needed is a method to automate the process of classifying customer inquiries. The automated classification can aid the CSR by reducing the effort required to manually scan each inquiry. Moreover, it ensures that a uniform classification scheme is used for classifying all inquiries and the CSR doesn't need to rely on personal expertise and judgment to make these decisions.

In this paper, we describe one such automated approach to identify and classify customer inquiries. The approach is based on text retrieval and data analytics techniques, which are used for identifying the intent of the inquiry and classifying these based on the narrative text contained within the customer inquiries.

We use this approach to classify customer inquiries for a large multinational automation engineering company. This classification helps the customer service center direct the inquiries to appropriate (teams and) business units. In addition, the classification also helps in identifying trends in the inquiries received.

As an example, consider a scenario where many complaints are received regarding licensing of a certain product. Inquiry classification helps isolate inquiries related to the product. Intention analysis isolates sales/procurement/licensing related queries within these. Finally, sentiment based filtering can be used to identify complaints among these inquiries - indicating that users are unhappy with the licensing scheme. This can then be raised as a signal by the analysis tool which is used by the analyst to take appropriate action (in this case notify the related product's sales team to review licensing policy).

The rest of the paper is organized as follows. Section II lists existing research related to this study. Section III describes the approach used for analysis. Section IV lists the results of the analysis. Finally, Section V summarizes the paper and discusses future directions.

II. RELATED WORK

Traditional analysis of customer service data has been limited to pure data and statistical analysis. Shen and Huang describe an approach for analyzing this data using singular value decomposition (SVD) [8]. Brown et. al. present several statistical techniques for analyzing data collected at a telephone call center [1]. These include forecasting based on a Poisson distribution and estimation of the mean function in a nonparametric regression.

In the context of using text analytics for custom service centers, IBM has implemented a text analysis and knowledge mining (TAKMI) tool at its own customer service centers to ease the task of the CSR. They have used this to demonstrate inquiry classification on the Statistical Package for the Social Sciences (SPSS) platform [4]. The focus of the tool is on analyzing survey forms to identify the frequency at which types or patterns exist. Moreover, the tool relies on experts

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to feed in a comprehensive listing of product types, and does not glean this information from existing data, as proposed in our approach.

A study by Carlos et. al. [2] uses a nave Bayesian classifier to identify common patterns across customer service reports and categorize them into different buckets. The work analyzes the intentions in customer inquiries without considering which service or product is being referred. Weiss et. al. [9] on the other hand, provide a generic approach for text mining and handling unstructured information.

In our study, we demonstrate how text analytics based on information retrieval techniques can be used for performing a combination of intention analysis and data classification analysis using customer service reports.

III. Approach

Figure 1 shows an overview of the workflow used for text analysis of inquiries received by the custmomer service center. As shown in the figure, the text mining workflow employed comprises of four main processes. The first of these is indexing, which is used to extract text data from source documents and store them in a well-defined index. The Indexing process constitutes of tokenization, text pre-processing and attribute definition. Tokenization involves parsing of the text data and identifying individual terms that need to be stored in the index. The parsed tokens are then subject to pre-processing to clean the data and remove superfluous elements. Attributes or fields are identified for classifying the individual tokens before storing them as a record, or document in the index.

The next step, Information Retrieval, defines means and methods for extracting relevant information stored in the index. This is done by defining a search mechanism to query the index and retrieve relevant records that match the query. The results from the information retrieval process are then used to perform detailed analysis to identify signals and trends within the data. The analyses employed in this study include inquiry classification and intention analysis. The analysis algorithms can be applied individually or in tandem. Finally, results of the different analyses are displayed to the user in an interactive manner through generalized visualization schemes.

A. Indexing the Customer Inquiries

The process of indexing customer service inquiries entails parsing individual customer inquiries to identify the terms used therein. These terms are then stored in an index (essentially an inverse lookup table) [6]. The terms identified within the individual inquiries are added to the index generated from the data. Each token identified is added as a term in the index, and is annotated based on the corresponding field for the document.

Tokenization and Text Pre-processing: Once the tokens within each document are identified, they are added to the index, with the corresponding link to the document and associated term frequencies. However, simply adding all identified tokens to the index can introduce a number of inefficiencies, owing primarily to the commonly used terms (like articles, prepositions, conjunctions, etc.), which not only clutters up the index, but can also adversely affect the search/retrieval results. To avoid this, a common strategy is to clean the tokens to eliminate unwanted words before populating the index. Another pre-processing strategy that is commonly employed is to group together similar words (based on their meanings) to provide a semantic search capability and improve the hit rate when searching for related terms.

Commonly employed text pre-processing methods include stop word removal, stemming and lemmatization. Stop word removal entails filtering the tokens identified in the data to identify and remove commonly used words. Such words could be articles (‘a’, ‘an’, ‘the’), prepositions, conjunctions or numeric literals, pronouns among others. Additional stop words may be defined by the analyst based on the specific corpus of documents being indexed.

Stemming is another commonly employed method of text pre-processing. Stemming attempts to reduce a word to its stem or root form. Thus, the key terms of a query or document are represented by stems rather than by the original words. This not only means that different variants of a term can be conflated to a single representative form - it also reduces the dictionary size, that is, the number of distinct terms needed for representing a set of documents. A smaller dictionary size results in a saving of storage space and processing time.

An associated pre-processing method, called lemmatization is usually used to remove inflectional endings and to return the base or dictionary form of a word, known as the lemma. If confronted with the token *saw*, stemming might return just *s*, whereas lemmatization would attempt to return either *see* or *saw* depending on whether the use of the token was as a verb or a noun.

In our study, we evaluated all three text pre-processing techniques, and found stop word removal as the most effective. For the rest of the paper, we present results of our analysis when using only stop word removal during indexing.

Handling Multi-lingual Data: A special consideration needed to be made for the customer inquiry data, as it is collected from feedback received from across the globe. Consequently, the (text) data is in multiple languages, reflecting the region that the record originated from. In order to adequately process text in these multiple languages, special care is needed to translate this text to a common language before storing it in the index.

During Index Generation, the textual (narrative text) data is extracted from the multi-lingual repository a single record at a time. Each record corresponds to a user inquiry in a specific language. The record may thus consist of various fields, including a narrative text field containing the natural language user input. In a customer inquiry scenario, this could correspond to customer feedback, questions regarding specific products, request for quotations, general advertising related data, etc.

A statistical language detection algorithm is used to detect the language used within the record. The statistical detection method maintains a database for commonly used words in various languages (for each of the handled languages). When the narrative text from a particular record is parsed, the individual words in the record are matched against the commonly used words database. The matches are ranked in order of relevance. Some of these may match common words for more than one language. In such cases, the primary language and secondary languages are identified and scored accordingly. Customized heuristics are used to determine number of tokens to match to identify the language.

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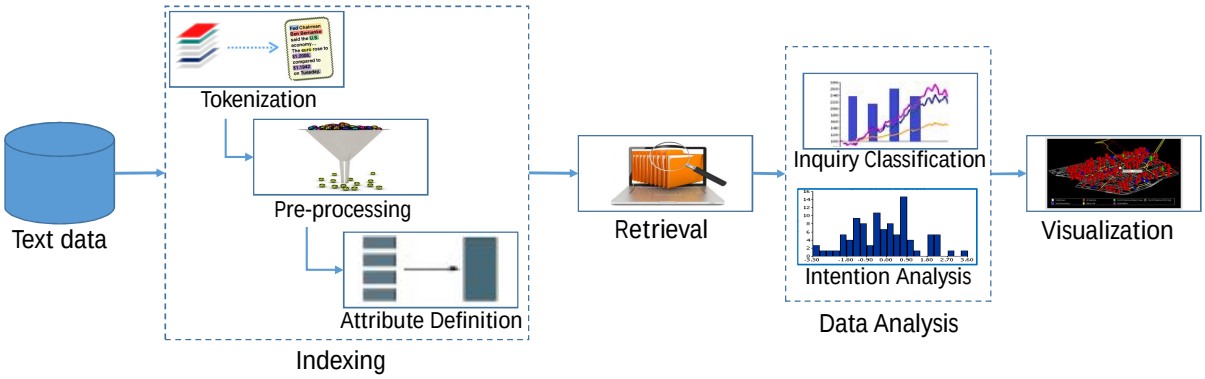

Fig. 1. Overview of the Text Mining Process for analyzing Customer Inquiries

If the narrative text data is in a language other than base language (English in our case), it is translated to generate a version of the textual data in the common language. We use an open source API, based on the Google translation service [5] to perform the translation. The translation here does not need to be perfect; simply identifying and translating key words in the text should suffice. The indexer is not so much concerned with grammar here, but simply aggregates words from transliterated text. The translated tokens are stored in a separate field. Text in English, is parsed normally (without any translation) and stored as it would be in the general case.

When searching against the index, the search string is provided in the common language. It is then searched against the translated text field for any matches. The results of the search/information retrieval thus include matches for documents in English as well as those in other languages.

B. Information Retrieval

Information Retrieval (IR) is the process of obtaining information resources relevant to an information need from a corpus of available data (the index of customer inquiries). The IR process begins with the user entering a query into the system. The query is then evaluated against the index based on the specific syntax and semantics of the query description language. Results of the query are returned as a set or list of matches, ordered according to their relevance score. The relevance score is computed using a product of term frequencies and inverse document frequencies (TF-IDF) for the given index [3]. The results obtained are then used to perform additional analysis on the data set, either manually or automatically.

It is important not only to take into account the actual words in the query, but also the meaning of the words searched for, the order of words in the query, related terms and synonyms and perform automated spell checking and diacritics restoration. The key goal of IR is to retrieve all the items that are relevant to a user query, while retrieving as few non-relevant items as possible. In order to maximize the relevance of the search results, sophisticated ranking algorithms and querying methods are used.

A number of different query methods are used to extract information from the customer inquiry index. The most trivial search method is a nave keyword based search, where individual keywords are matched against the terms contained within the index. The terms can be matched against specific fields in the index, by specifying which field they should be searched against. An extension of simple keyword search is querying using *wildcards*. Wildcards (such as '?' and '*') can be used to match for variations of a term or multiple words at once. For example, the query 'te?t*' will match the terms text, test, tester and tested.

A *Boolean query* is a simple method to combine results of two queries or add a modifier to existing queries. Most IR engines support the AND, OR and NOT operators for Boolean queries and searches. An example of a Boolean query would be "text: python OR text: boa AND class: reptile", indicating that the searcher should look for the terms python or boa in the field labeled text, while the (structured) field class is given as reptile.

Fuzzy queries are used to search for terms similar to the given word. The fuzziness factor is based on the Levenshtein Distance, or Edit Distance algorithm [7], and is used to match words that sound similar (or are spelled similarly) to the given query term. For example, when searching for a term similar in spelling to "roam" the fuzzy search algorithm will find terms like "foam" and "roams". Fuzzy searches are useful when searching for terms that may often be misspelled or have slight variations in spelling in different regions (for example, "analyze" vs. "analyse").

Proximity searches are used to search for words in a given document that are used within a specified distance of each other. For example, one may search for the words "voltage" and "meter" occurring within 10 words of each other in a document. Proximity searches are a useful tool when looking for correlations between terms.

Finally, *Range queries* allow one to match documents whose field(s) values are between the lower and upper bound specified by the Range Query. Range Queries can be inclusive or exclusive of the upper and lower bounds. Sorting is done lexicographically. A range query can be specified for numeric fields, text fields or date fields (for example, "mod_date:[20020101 to 20030101]", indicates the range of all dates from January 1^{st} 2002 to January 1^{st} 2003).

C. Intention Analysis for Customer Inquiry Data

Once the data is retrieved from the index, various analyses can be performed to discover knowledge that can aid in making

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business decisions. The analysis techniques we have employed include *Intention Analysis* and *Inquiry Classification*.

Intention analysis was carried out to identify the intention of the customer from the text of the inquiry. The intention could be to purchase, to sell, to complain, to accuse, to inquire, etc. Manual analysis of sample data from the customer inquiry data indicated that there are four major classes in which the inquiry can be classified. These classes are summarized in TABLE I. Intention analysis was used to detect the basic four intentions and their various combinations, i.e., a total of 16 intentions. The documents for which intentions could not be found out were put under the "Unclassified" class.

TABLE I. INTENTION CLASSES FOR CUSTOMER INQUIRY DATA

Intention	Explanation	Need
Sales	To purchase or inquire (price and availability) of some product or service	To detect customer needs for products
Service	To ask for some help or assistance on some product or service	To detect customer common problems
Career Training	To seek training on some courses, job intention (job/internship)	To find suitable candidates for some job position
Complaint	To complain about some product or service	To detect customer pain points
Unclassified	Motives that cannot be classified	-

A manual analysis of data was carried out to find customers' common writing pattern. A list of intentions was created from this list. For every word of a document in the corpus, the word was matched with the intentions. If a match was found, the corresponding intention was assigned a point. The intention with the maximum weight was assigned as the class for the document. Fuzzy search was used to take care of misspelled words. The algorithm used for fuzzy searching is outlined in Figure 2. TABLE II gives sample results of intention analysis performed on the customer inquiry data.

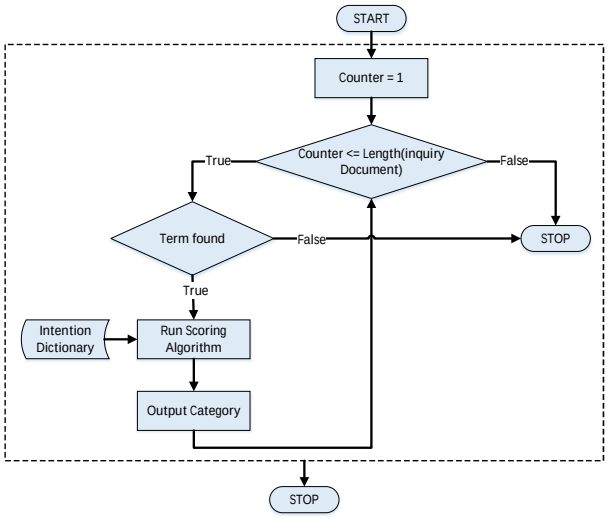

Fig. 2. Workflow for Intention Analysis

In order to check the accuracy of the algorithm, 150 randomly selected queries were taken which were also manually classified by the Contact Center (CC) executive. The result of the manual classification vs algorithm classification are summarized in TABLE III. This comparison indicates that free-flow text messages can be properly classified based on the intention of the message. Sometimes, the classification can be even improved over manual classification.

TABLE II. SAMPLE RESULTS OF INTENTION ANALYSIS

Inquiry Details	Intention Class
Please quote us your best price lead time as below controller vfd for fdf motor 440v 55kw 101a 60hz rpm 891rev min	Sales
I have a technical question in regards to a frequency drive model XV550. We have a problem with the drive where parameter maximum speed tends to change on its own. The drive is programmed to a max speed of 3510 rpm and on one occasion, the parameter changed to 1740 rpm. No other parameter changed. This could be a one-time occurrence. However, I'm just wondering if there is something that could be causing that to happen; perhaps another parameter as a result of an alarm. Your help would be appreciated	Service
Dear sir, I'd like to know about any job opportunity for business development profile. I have 6 years' experience in ac drives field and ERP arena. Due to loss in my business venture I'm looking for a suitable job in gulf countries for my drives profile	Career Training
We purchased a 150 hp 960 rpm foot mounting motor from your dealer. Now we are finding huge ampere variation. We lodged verbal complaint with the dealer who in turn forwarded the complaint to your service center. Subsequently, we were promised that a service engineer will be sent to check the motor. In spite of all our efforts and promises made, no one has visited us as yet. The amp variation is causing huge increase in electricity cost and we are unable to run our plant causing huge financial losses. We need your instant resolution of the problem	Complaint
No communication	Unclassified

TABLE III. COMPARISON OF MANUAL CLASSIFICATION VS. ALGORITHM CLASSIFICATION

	Analysis Conducted by	
	CC Executive	Algorithm
Correct Classification	109	124
Incorrect Classification	39	18
Multiple Classification	-	6
Undetermined	2	2
% Accuracy (Approx.)	73%	83%

D. Inquiry Classification

The objective of inquiry classification is proper organization of datasets, so that data can be handled with much efficiency and ease. In this study, customer inquiry data was categorized by mapping it to specific product categories. Proximity search was performed for individual products to find patterns (like commonly used specifications, name of the product, etc.), and a list of product offerings created based on the product's name and specifications. The list was sorted based on term frequency.

For example, proximity search was performed for the product "breakers" on the customer inquiry data. As result of the search, a list was generated that included the terms "circuit breaker", "generator breaker", "sf6", "air circuit breaker", "vacuum circuit breaker", "sace", "voltage breaker".

A search for the product and its associated terms was then carried out for all documents in the corpus and the matching documents were associated with the product. A similar approach was used on other products to build dictionary of words corresponding to those products.

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An example of product classification on various product inquiries is summarized in TABLE IV. TABLE V shows how the inquiry has been categorized. The last column in the table indicates which product category the inquiry pertains to.

Though this study develops library of key words for a few popular products, a comprehensive library could be built for each and every product within the organization. A comprehensive listing of the products and services offered by the organization would need to be generated for this purpose. The list could be generated using the proximity search based approach as described above.

TABLE IV. PROXIMITY SEARCH FOR THE WORD "BREAKERS"

Term	Frequency
circuit	1575
generator	149
part	135
sf6	124
model	121
vacuum	114
air	108
sace	100
pole	90
manufacture	82
breaker	67
voltage	55
kv	49
case	49

TABLE V. PRODUCT CLASSIFICATION EXAMPLES

Inquiry Details	Product
Dear sir, we are looking for distribution transformer type 250kva. We need offer price	250kva distribution transformer
Please send your quote for 3 units current transformer 5 kva. Thank you.	5kva current transformer
We immediately need to order the following transformer pl advice with techno commercial details type distribution transformer 315kva	315kva distribution transformer
We want information on distributed control systems. Need contact name, phone number	DCS
We are in Hawaii. Can we purchase a box cooling fan for a vfd drive?	Variable frequency drive (vfd)
Looking for some help on the XS350 setup	XS350
Sir, I need a sf6 breaker up to 15 kv. Immediately so can you send me specification of this breaker?	sf6 breaker
Kindly quote us the item below 1 circuit breaker 100amps 400volts	circuit breaker

IV. RESULTS

As described above, intention analysis is used to classify the customer's intention and inquiry classification is performed to identify which product is being mentioned in the customer inquiry. Combining the results from these two analyses can provide further insight into the types and trends within the available data. For instance, combining results from the two analyses can provide information for the number of sales or service queries related to a certain product. Some of these results are presented in this section.

Figure 3 shows the distribution of customer inquiries across different types of drives. Based on the data, it can be inferred that the maximum number of sales requests are for AC system (ACS) drives. However, these drives also have the largest number of service and training related inquiries, hinting that these drives have a large number of unresolved issues, and that

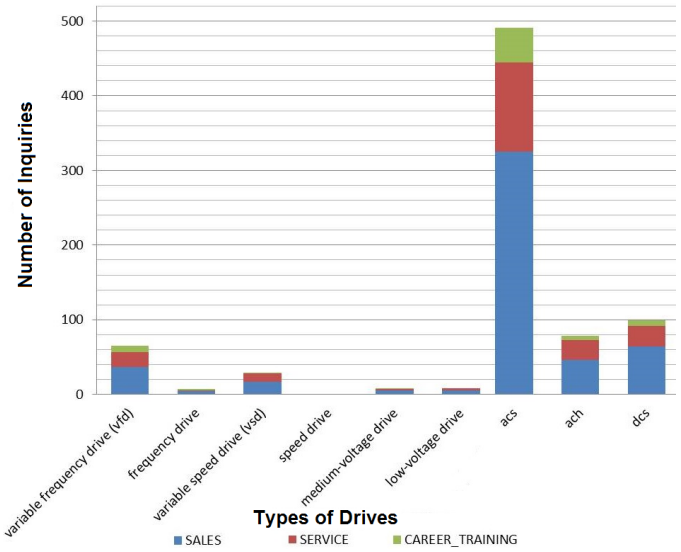

Fig. 3. Inquiries Related to Drives

customers feel the need for additional training in order to use them effectively.

Figure 4 drills down to specific products within ACS drives. The data indicates that ACS 800 and ACS 550 are the two most popular series of ACS drives, based on the number of sales inquiries. The data also shows a disproportionately large percentage of service inquiries for the drives ACS 355 and ACS 600. This could indicate that the drives have some inherent design defect that needs to be addressed. Further analysis of the specific service inquiries for these products will help identify the nature of the problem.

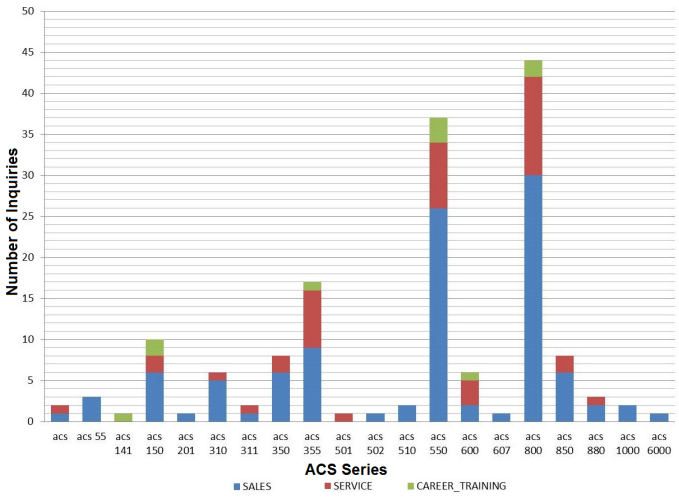

Fig. 4. Inquiries for the ACS Drives Product Series

Similarly, Figure 5 shows some data from analysis performed on transformers. The results indicate that the only service related inquiries for the transformers device class relates to power transformers. There are no service inquiries related to other transformers. This implies that customers are generally happy with the service provided for transformers.

Figure 6 indicates that the number of inquiries related to

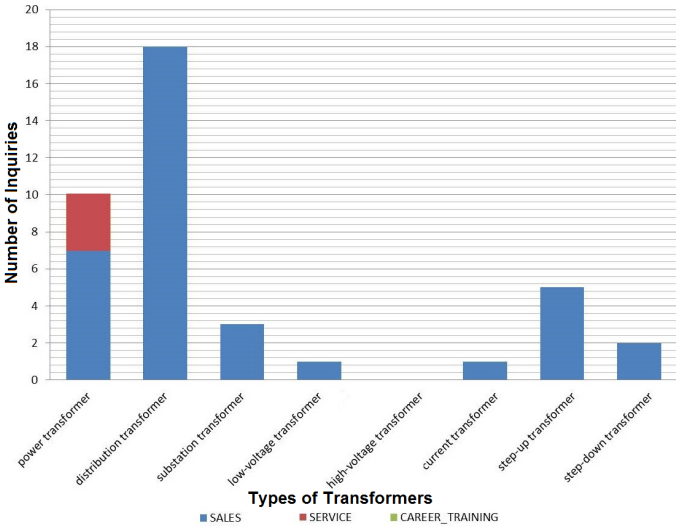

Fig. 5. Inquiries for different types of Transformers

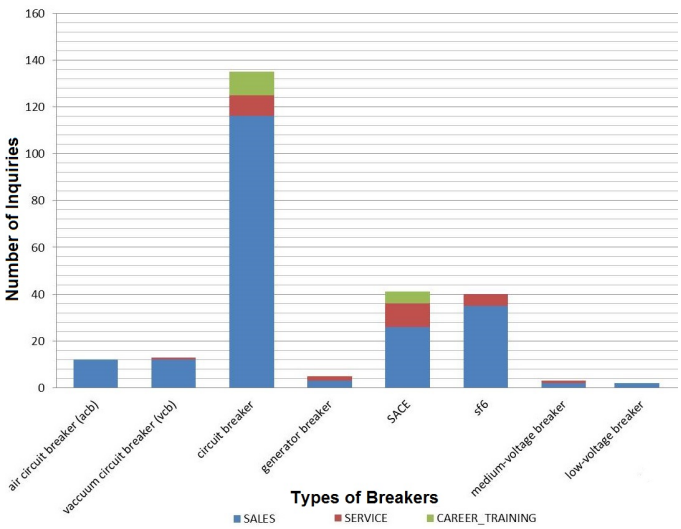

Fig. 7. Queries for different types of Breakers

training are significantly higher for Supervisory Control and Data Acquisition (SCADA) products as opposed to Distributed Control System (DCS) products. This implies that the SCADA products are comparatively more complex to configure and maintain. Thus engineers may need to focus on the usability aspects for these products.

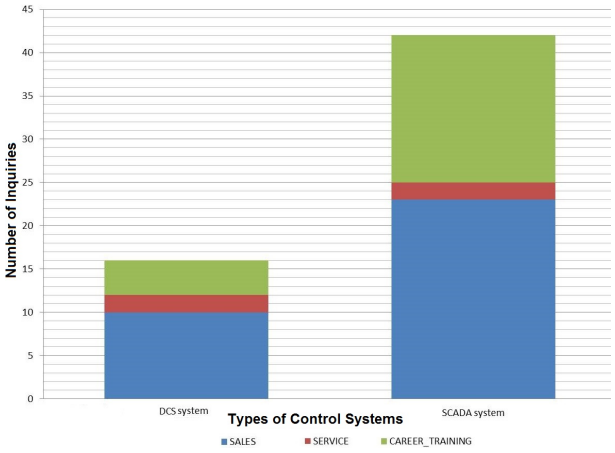

Fig. 6. Inquiries for types of Control Systems

Finally, a comparison between the circuit breakers sace and sf6 in Figure 7 shows that despite having a higher volume of sales inquiries, the sace breakers received fewer service requests and no training inquiries. This indicates that sace breakers perform better and are generally preferred by the customers when compared to sf6 breakers.

The examples above cite just a few examples of how text based analysis of customer inquiries could help organizations infer signals and trends within the data collected by its customer service center. Other such analysis can be performed at various levels of granularity to uncover additional signals and provide critical business intelligence. Further, once a signal is detected, it can be directed to the appropriate personnel for follow-up leading to reduction in manual efforts and errors and improved response time.

V. SUMMARY

This paper has illustrated the use of customer inquiry classification and intention analysis on customer inquiries, primarily in the form of unstructured multi-lingual text data. The paper has demonstrated an automated way of such analysis resulting in significant savings of manual efforts, without compromising on accuracy of analysis. In fact, in some cases the automated analysis has proved better than manual analysis.

The automated analysis provides insights into the customer inquiries not readily available to the customer service representative by simply browsing through the textual reports. The signals and trends identified through these analyses can be used to support more informed business decisions.

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Choice of Design Techniques for Scaling Mission Critical High Volume Applications

Muralidaran Natarajan
BIT Mesra
Mumbai, India
Email: muralidaransk@gmail.com

Nandlal L. Sarda
IIT Bombay
Bombay, India
Email: nls@cse.iitb.ac.in

Sharad C. Srivastava
BIT Mesra
Ranchi, India
Email: sharad.scs@bitmesra.ac.in

Abstract-- In today's Services business, self-servicing models with thousands of users operating "Anytime Anywhere" concurrently and generating millions of transactions have increased the performance requirements multi-fold. However, these systems are monolithic and are not flexible for business transformations and changes. To scale beyond this, many organizations have started to transform these systems to new generation of multi-core platforms. This being architecturally different, the existing applications will have to be decomposed and re-architected to run as parallel components, have near zero contention and take advantage of these new generation platforms. This paper studies the choice of design techniques with the elements of concurrency and parallelism to arrive at an optimal setup to scale the performance of high volume mission critical real time applications on modern platforms. The choices are further validated with the simulation runs conducted to narrow down the combination setup giving the best performance. The results, analysis and the recommendations aim to provide an approach to the design architects in transforming mission critical applications.

Keywords- layering; concurrency; parallelism; mutual exclusion; visibility of change.

I. INTRODUCTION

Any business today has a critical dependence upon information that is acquired, processed, transported and delivered with well-defined Quality of Service (QoS) [1]. The ultimate intention of these organizations is to attain a competitive advantages in decision-making, customer service, and to respond in a timely manner to changes in the current market place and stakeholder expectations.

Traditionally, large enterprise On Line Transaction Processing (OLTP) solutions relied on using clusters of mainframes running proprietary information systems software. Many of these applications were developed in low level/procedural languages and evolved over a period of time [2]. Originally, the applications were designed to implement specific business models and related functions to support enterprise automation in the monolithic form. The monolithic form in the single processor offered good performance benefits with very minimal inter process communication overheads in the earlier era. As the requirements expanded, the applications were modified using wrapper-like methodology to satisfy the business demands without any design change, thus ending up with sub-optimal solutions [3].

With business growth and emerging markets, the changes in the business scenario resulted in new business models. Often, the transaction patterns and the concentration/volume of each pattern turned out to be very different from the original business objectives and specifications based on which systems were designed and developed. The emerging self-servicing models and ease in customer service using pervasive new generation devices/interfaces multiplied the access points and interfaces. This resulted in an increase in security issues [4].

Over time, the flexibility of the monolithic systems considerably reduced and reached a breakpoint beyond which the system can only continue to run "AS IS" without much modification; hence, unable to handle the changing trends and demands of the emerging business. This resulted in the need for transforming these legacy OLTP systems to agile real-time data stream processing applications to assure high throughput and low latency [4].

Typically, Pre-Processing, Core Business Processing and Response Processing (R-Service, referred to as "Response Delivery Layer" in this paper) are the key components of any mission critical real time application. The "Response Delivery Layer" can be parallelized for performance using multiple senders as this stage is normally stateless. This flow involves Central Processing Unit (CPU) bound activities, memory bound activities and Input/output (I/O) bound activities.

This paper analyses and provides insight to the application developers on different architecture constructs to scale the performance of only the "Response Delivery Layer" in mission critical real time high performance application systems towards meeting the QoS expectations of the end customer. Section II describes some of the key architecture approaches and implementation challenges in the transformation. Section III describes the design techniques that can be used in the process and the implementation challenges. Section IV presents the performance study for the implementation alternatives discussed in previous sections, details and results analysis of the simulation runs. Section V provides conclusion and future work.

II. ARCHITECTURE APPROACHES AND IMPLEMENATION CHALLENGES

In this era of multi CPU and multi-core, large computing power is available at the disposal of the developer. It is imperative that the developer looks at various architecture approaches and design alternatives to exploit the computing power available in delivering high throughput and low latency in service oriented mission critical real time systems that are in use.

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This paper examines the following architecture approaches and provides design and implementation recommendations to the developer in transformation of mission critical real time business systems to take benefit of the computing power available in the new generation hardware: (i) Layered architecture, (ii) Concurrency and Parallelism and (iii) Use of higher computing power of multi-core technology [5][6]. In addition, these architecture approaches are proposed to be studied with the possible design models, design techniques, interaction models across tasks and key aspects of implementation in the new multi-core environment available.

A. Layered architecture approach for high throughput

The immediate previous generation mission critical real time high volume application systems were architected for clustered main frames, and were designed with procedural languages and tools as building blocks. These systems which support the core business functions of the organization became large monolithic pieces, with more and more interfaces getting added to support business growth and changes without architectural redesign, rendering these systems sub-optimal. Typical systems like railways and airline reservations, retail banking, etc. have the following tasks: (i) receiving the inputs, validations and pre-processing, (ii) business processing and (iii) response and delivery of output as part of a large monolithic module. Although, this makes the coding and development simpler, it poses limitations; it makes the modules tightly coupled and rigid. Any addition/change, be it functional or technical, results in changing the core of the system; thereby, making the development, testing and release process complex and lengthy [7]. Further, it also increases the risk to the organization. Localizing the errors for a faster response to guarantee the Service Level Agreement (SLA) becomes a challenging task. To introduce self-servicing and straight through processing, as the interface handling is not standardized, the handshaking and processing are not clearly demarcated from the core system functionality. This introduces limitations in handling throughput and latency thereby constraining the business expansion and customer values. This necessitates the implementation of a multi-tiered and layered architecture to introduce flexibility and scalability [8][9].

In a layered architecture, the monolithic application is split into manageable and logical functional layers [5]. In each of the layers, the processing is decomposed into various tasks, and each task is connected using a suitable Inter Process Communication (IPC) mechanism. This IPC mechanism, which enables the upstream/downstream communication between the tasks, is referred to as "connector" in this paper. Given that a complex process can be divided into a series of sequential tasks, this approach can provide increased performance under the following three types of computational scenarios: (i) In a multi-step business process, the modularity helps in initiating the next task before the final completion of the previous task. As soon as the core transaction is complete, the information can be passed on to the next task in a modular design and internal operations like logging and safe store commit can continue off the critical path, thereby isolating the performance of "critical transaction path" from other internal operations [10]. (ii) if the processing can be done in parallel for multiple data sets until a certain stage in the processing path, the sequencing of the process steps assist in creating multiple instances of these tasks. Having multiple instances of a task minimizes the idle time of CPU and offers faster response. Running multiple instances also offers fault-tolerance and load balancing [11][12]. If an instance fails due to exceptions, another instance can take care of further processing. If there are multiple processors, the instances can be distributed across those processors [10]. (iii) In a multi-step business process using the modular design, any change can be localized at a task level, making the development and deployment process simple with moderate risk.

In order to introduce concurrency and parallelism, the modular design uses various models, such as: data parallel model, task graph model, master-slave model, pipeline model and hybrid model [13]. In the data stream application, pipeline and master-slave models are commonly used [14]. These models do not decrease the time for processing a data element, but are aimed at increasing the performance of the system while processing a stream of datasets. A modular system requires more resources as one task cannot use the resources of the previous task as compared to the monolithic case. Also, the task to task communication introduces some latency. It is therefore necessary to balance the number of tasks carefully for optimal throughput and latency.

B. Concurrency and parallelism for high performance

Once a monolithic process is decomposed into multi-step business sub-processes or tasks, the next goal is to achieve concurrency and parallelism in execution of these sub-processes or tasks to improve the overall end to end throughput and latency of the process chain. In data stream based service oriented systems, where thousands of retail users accessing the self-service facilities are simultaneously connected and transacting, implementation of concurrency and parallelism plays a crucial role in the architecture construct and choice of design techniques to achieve the desired throughput and latency demands of the changing business models and scenarios.

1) Concurrency for high performance

In software, concurrency is two or more tasks happening in overlapping time period. They may be interacting with each other and also they could contend on access to resources. The contended resource may be a database, file, socket or even a location in memory [15]. When a business function can be segregated into logical tasks and they can possibly interact and make progress in overlapping time periods, they can be deployed in concurrency mode to maximize the performance.

The interaction models for concurrent tasks are message passing connectors and shared memory, and the mode of interaction is either synchronous or asynchronous communication [16][17]. The elements of concurrency are threads, events, notification routines etc [5][15]. The

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challenges in concurrent execution are handling mutual exclusion not resulting in deadlocks, serialization where needed and visibility of change across concurrent tasks.

2) Parallelism for multi-fold performance scaling

While concurrency enables maximum throughput on a single processor, parallelism increases the throughput multi-fold by executing tasks simultaneously on a multi-core/multiprocessor hardware that supports multiple process execution at a time [15]. Over four decades, the performance of the hardware processors has been continuously increasing, and the software applications have been constantly adopting upgrades to take benefit and satisfy the business demands. With the single core becoming more complex, power consumption was becoming a bottleneck, which has resulted in a new era of multiple simple cores on a chip. Due to the complete change in hardware architecture, applications designed for single core processors will have to be re-designed to take advantage of the multi-core processors capabilities in delivering high throughput and low latency.

The two key factors that decide the benefits of parallelism are the (i) length of the critical path of the business transaction and (ii) need based optimal access to the shared resources [18]. If the length of the critical path is nearly the same as total work, the parallelism is of no significance, however powerful the parallel hardware is. Similarly, the critical section that manages the shared resources could be a bottleneck in parallelism as it serializes the access [19][20]. The methods to control this are by minimizing the length of the critical section and/or by limiting the number of threads/tasks entering the critical section at a time.

While more threads introduced for concurrency minimize the idle time and maximize the CPU usage, the optimal number of threads needs to be carefully architected depending on the number of cores available and the contention bottlenecks. The Operating System (OS) schedules the threads to the CPU in a round-robin time-priority scheduling. Every schedule change involves a context switch and takes a few hundreds of CPU cycles [21]. The transaction/data access patterns may not be consistent and could vary widely under various scenarios. A good implementation is the one that has bounded contention, not completely driven by end user transaction/data access patterns and limited context switching. In high volume systems, it is recommended to use thread pools to have bounded number of threads for latency predictability rather than dynamically creating threads [18][22]. CPU affinity may have to be introduced to avoid threads being constantly shuffled across cores or processors.

III. DESIGN TECHNIQUES AND IMPLEMENTATION CHALLENGES

This section of the paper discusses the implementation challenges and techniques to address those challenges in interaction models such as message passing queues and shared memory; concurrency elements such as threads, events, notification routines; key aspects like mutual exclusion and visibility of changes; the use of layering, concurrency and parallelism [23]. Major mission critical systems like banking, trading, telecom, aviation and e-commerce applications that are reliable and flexible are based on message driven and self-servicing business models. These systems support low response time and high throughput due to their ability to process multiple messages concurrently using component based layers.

A. Techniques for high performance in message passing

Queues and shared memory are used as connectors to exchange information across concurrent tasks. However, in high performance systems queues are preferred over shared memory [16][17]. The message communication can be point-to-point messaging queues or publish subscriber model. The following sub sections describe the techniques for boosting the performance of the message passing systems [24]. Queues are introduced for point-to-point communication. Senders publish or write the messages to the queue and the receivers receive or read the messages from the queue. Producers and consumers can be dynamically added and deleted allowing the message queue to enlarge and collapse as and when needed. The producer can send a message irrespective of the consumer being up or down, and the consumer can read when it comes up. The order in which the messages are consumed depends on the priority, expiration time and the processing capacity of consumers.

A simple point-to-point messaging consists of a producer and consumer sending and receiving messages through a queue. It is possible to increase the throughput by having multiple queues. The producer needs to maintain the list of queues in an array, and select the next queue to be used for sending from the array. The algorithm to choose the right queue for sending is crucial.

Throughput of a messaging system can also be increased by introducing multiple consumers to a queue under specific conditions. Although multiple consumers can receive from a queue, a message from the queue can be consumed by only one consumer. Adding multiple consumers to a queue increases the overall throughput of the messaging system, provided the order of processing is not significant. When multiple consumers access a queue, the load balancing among them takes into account the consumer's capacity and the message processing rate. A more complex messaging system would consist of multiple queues each having multiple producers and consumers connected.

There are situations in which the multiple consumers implementation cannot be used to increase the throughput, due to high resource consumption and the need to preserve the order of the messages. It then forces the configuration of one consumer per queue. In such cases, the publish/subscribe model is recommended. The publish/subscribe model normally uses topics and is generally used to broadcast information. This model is significantly faster than point-to-point, as it is a push technology. The queues are to be replaced with topics and needs to ensure that more than one subscriber is not

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listening to the same topic; you get the implementation similar to point-to-point but much faster because of less overheads in such implementation.

While queues and topics are persisted and made durable within the messaging system, there is an impact on performance. Persistence can be selectively used in a messaging system, depending on the need and criticality [24]. For e.g., if you are running batch processing application and reading the input from a file/database and sending through a messaging component, in case of system failure, you can restart the processing from the last transaction and overwrite the prior processing and hence persistence is not essential. The non-persistence is to be implemented carefully to boost the performance.

B. Contention management for high performance

Real-time transaction processing with large volumes demands scalable access to rapidly changing data, ensuring consistency across millions of transactions and thousands of users. The multi-threaded processes in these applications for concurrency need to be re-designed to exploit the high degree of hardware parallelism introduced in the recent multi-core architecture towards boosting the performance. The increasing number of parallel processes increases the contention, and poses new challenges. The cost of mutual exclusion locks and degrades the performance of parallel applications significantly. The shared resource could be any object ranging from a simple block of memory to a set of objects, and instructions protected through a critical section.

In high performance applications, the design of contention management plays a significant role. It is therefore important to make the right choice of mutual exclusion methodology. Blocking based approaches introduce overheads on the critical path due to context switching and is further complicated by scheduling decisions resulting in priority inversion. Non-blocking (spinning) approaches consume significant processor resources. Non-blocking is attractive because there is no idle time as soon as the shared resource becomes available to the waiting process. However, non-blocking produces a type of priority inversion by hindering the lock holder from running and releasing the lock, thus limiting scalability [18][25][26].

But the blocking holds the waiting thread from running and allows other threads to use the complete CPU resources. Once the shared resource is available, the waiting thread has to be scheduled again. This introduces bottlenecks in the critical path, at least by 2x. Blocking is robust but makes very bad outliers [26]. These outliers (around 0.1%) are normally 5-10 times the normal latency. In high throughput systems, any delay not only affects that event but thousands of subsequent transactions. Any resource creation and freeing has a cost and therefore, to avoid jitters, the design needs to accommodate creation of synchronization objects, reuse/recycle and free them as a housekeeping job.

The length of the critical section again is a factor with the increase in number of threads and contention. The length of the critical section, and the duration of the held locks need to be optimal to achieve the desired result under heavy loads [27].The cost of entering and leaving the critical section has to be taken into account if there are too many very short critical sections. In case of long critical sections, the scheduling and priority inversions will impact the performance. As critical sections have a direct impact on performance, the coding should be done in language and libraries with native support and not a wrapped up piece which is meant for open systems integration. There has to be careful balance in implementing the blocking approach, non-blocking approach and the length of critical section. As discussed above, with the increase in contention due to concurrent and parallel processing there is a need to move towards fine-grained synchronization instead of coarse-grained synchronization [28][29].

C. Memory management for high performance

The technology advances have transformed the hardware and software platforms for applications from single processor to multiple cores and from single process to multi-process/multi-threaded to increase the throughput. However, the memory managers have not changed on par. The memory management is a key factor in designing the architecture of a system for high performance.

As the processors/cores are added, the application gradually degrades due to heap contention. Memory managers must therefore offer less space overheads, limited defragmentation and speed. Memory allocation and freeing has a performance cost in terms of CPU cycles as they involve a switch between the user mode and kernel mode and will impact the predictability of latency and response time. In critical systems, unbounded memory consumption poses the risk of crash with too many small, frequent memory allocations and freeing. Every memory allocation has the overhead of metadata and in too many small allocations, the overhead will be high. The effective solution is one having bounded memory by allocating a large chunk and managing the application requirements within the chunk [30].

IV. PERFORMANCE STUDY FOR THE DESIGN ALTERNATIVES

A. Performance study - Overview of the "Response Service" module taken up for study

In trying to address the transformation challenges described in the previous sections, design options emerged through a rigorous mix of the various approaches, combining the design models, design techniques and addressing the implementation challenges that we saw as being deterrents in restricting the scalability and performance of such real-time service oriented systems. The approach also focuses on ensuring the minimization of contention. In pipelined systems with multiple numbers of readers and writers on queues, in our performance study, it is ensured that any data should be owned by only one thread for write access; thereby, eliminating write contention completely.

This section describes the details of performance studies conducted to arrive at a suitable design approach and implementation nuances of design techniques to overcome

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the limitations, to meet the QOS objectives to support high throughput and low latency. The typical flow of a mission critical real time processing application is as follows; **Pre-Process** takes care of routine housekeeping, filtering, enrichment, master updates and just in time dynamic validation if any. Besides, it handles the stateless validations that may be carried out before reaching the business tier in parallel. **Core Business Process** does the actual business transaction processing taking into account the external events and update/processing of the incoming transactions and essential I/O that may be needed for recovery in a real-time mission critical application. **Response Service** (R-Service) is the process responsible for sending the output to multiple receivers and interfaces over network (referred to as "Response delivery Layer" in this paper). The same can be parallelised for performance using multiple senders as this stage is normally stateless. In this particular exercise, the design alternatives are tested only in the response or outbound path. However, the other two components are retained to simulate end to end behaviour of such real-time event processing systems.

In high performance systems, wherein the output of the business process is to be sent real-time to the end-users, the receiving of the input is independent of sending the response. The two activities proceed independently. To handle heavy loads and huge number of connections, clusters of "Processing Machines" and "Connection Machines" are deployed. However, if there is huge backlog at the dispatching of response, it creates heavy back pressure on all the previous stages. The "R-Service" process that is after the "Core Business Process" stage in the end to end processing path is considered for validating the design alternatives towards improving the throughput and response time.

In this, the "R-Service" process which is in the outbound path is used to deliver the processed information to the end consumer and there are no specific SLAs in the maintaining sequence of the messages across the end users. Hence, this service can be looked at as a potential candidate for exploiting the abundant computing power using (i) modular design approach, (ii) concurrency and parallelism in introducing multiple publishers and (iii) dedicating processing power by way of assigning individual cores to the publishers in picking up the packets from their respective queues and forwarding to the end consumers.

In the proposed design approach, "R-Service" process is broken into the following 3 tasks (a) "R-Processor", i.e., response processor, (b) "R-Sender", i.e., response sender and (c) "R-Gateway", i.e., final end user delivery unit. In addition, the design techniques and the limitations are examined and factored to maximize the throughput and reduce the latency. The following design techniques and implementation variations are used in the performance study (i) Queues vs. shared memory grid (ii) Bounded queues in the form of ring-buffers vs. unbounded shared memory grid (iii) Pre allocated memory buffers by pre-filling upfront for the bounded queues for faster access and to overcome issues of fragmentation (iv) With and without CPU core binding at task level to make dedicated processing power available and thereby improving the predictability of the task by minimizing the jitter.

B. Performance study – Implementation alternatives

1) Design alternative 1: Pipelining with blocking shared memory IPC connectors

In this setup, the approach of pipelining is used as design model (Figure 1). The "R-Service" process is split into 3 different tasks, the "R-Processor" and the "R-Sender" on the business processing machine itself and the "R-Gateway" on a different hardware. In addition, the following are the design techniques considered for the implementation. (i) The communication between the sub process/task "R-Processor" (Writer) and "R-Sender" (Reader) is through a shared memory grid. (ii) For synchronization of access to shared grid, writer and reader use locks, i.e., blocking mode of mutual exclusion is used for the read write operation. (iii) Every "R-Sender" is single threaded, which services a set of business users connected to one "R-Gateway" (One to one). (iv) Communication between the sub-process/task "R-Sender" to "R-Gateway" is using topics of any messaging application.

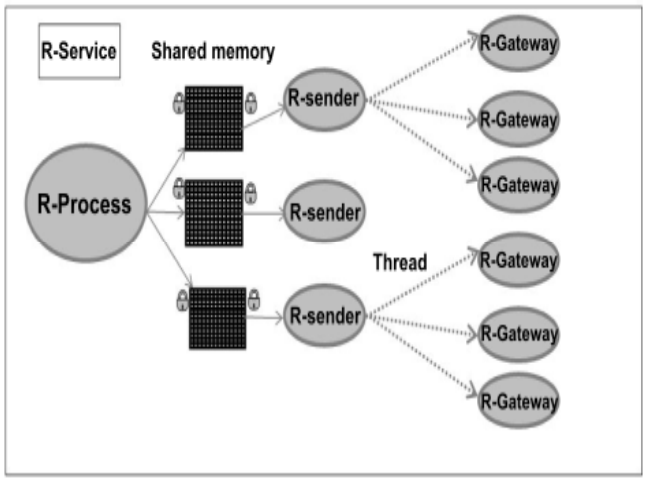

Figure 1. Pipelining with Blocking Shared Memory IPC connectors

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2) Design alternative 2: Using bounded circular FIFO queues for IPC

In this setup shared memory grid is replaced by queues and concurrency is introduced in "R-Sender" (Figure 2). In addition, the following are the design techniques considered for the implementation along with variation in number of "R-Senders" and CPU core binding. (i) The communication between the "R-Processor" (Writer) and "R-Sender" (Reader) is through bounded circular First in First Out (FIFO) queues. (ii) Bulk read is used for boosting the performance in case of any lag in the "R-Sender". (iii) The queue elements are pre-filled and initialized to avoid fragmentation and faster access to increase the throughput (iv) Each "R-Sender" is connected through its own queue to the "R-Processor" and hence there is a single reader and writer for each queue. The Lock-free non-blocking design technique is used in the implementation. (v) Concurrency is introduced in "R-Sender" using multi-threaded in sending

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data to multiple "R-Gateways". (One to Many) (vi) "R-Sender" publishes data using different topics. Each "R-Gateway" listens only to a specific topic. (vii) Parallelism is used by varying the number of "R-Senders" and the CPU core binding to arrive at the optimal implementation mix for improved performance.

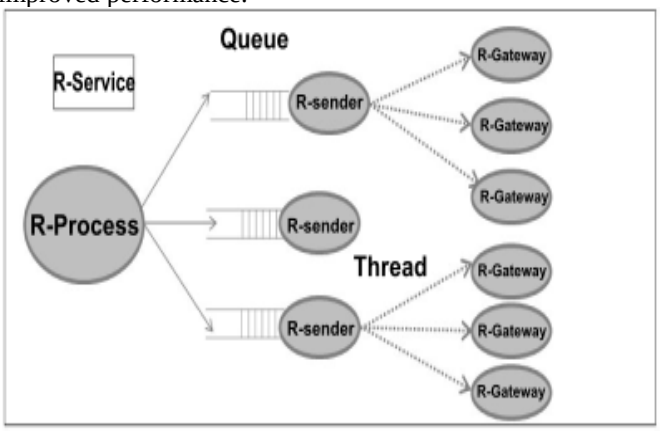

Figure 2. Bounded Circular FIFO Queues for IPC.

C. *Implementation alternatives - Simulation studies*

With the above setups, multiple runs were carried out to ascertain the behaviour of the design alternatives and impact of the design techniques by varying the number of "R-Sender" with and without processor affinity enabled.

The study runs were executed with a 2 CPU Xeon Intel processor with 8 Core each running linux6.x operating system. The CPU 0 was used for the critical path services and the CPU 1 was used for all other ancillary services. Within CPU 0, Core 0 was assigned to OS; Cores 1-3 were used for "Receiver" and "Business Processor" and 4-7 were used for "R-Service" components.

"Blocking with Shared Memory (run 1)": This run was carried out using the setup in alternative-1 with 20 "R-Senders" and 20 "R-Gateways". This is to record the latency response behaviour of the service using shared memory for message exchange and in blocking mode. This is used as baseline to compare the performance of non-blocking implementation variations.

Non-blocking with Queues (run 2): This run was carried out using setup in alternative-2 with 20 "R-Senders" and 20 "R-Gateways". This is to record the latency response behaviour of the service in the non-blocking mode using FIFO circular-buffer. Queues were used instead of shared memory for message passing.

Non-blocking with Queues and Resources binding (run 3): This run was carried out using setup in alternative-2 with 6 "R-Senders" and 3-4 "R-Gateways". In addition dedicated CPU core was allocated for each "R-Sender" and the corresponding threads to study the concurrency and parallelism. This is to record the latency response behaviour of the system in the non-blocking mode and with dedicated computing resources.

Non-blocking with Queues and Resource binding and "R-senders" variation (runs 4-7): These runs were carried out using setup in alternative-2 with 3, 4, 2 and 1 "R-Senders" and each having multiple "R-Gateways". In addition, dedicated core was allocated for each "R-Sender" and the corresponding threads to study the impact of concurrency and parallelism. This experiment is to record the latency response behaviour of the system in the non-blocking mode and with dedicated computing resources and variation in the number of "R-Senders" to arrive at a sweet spot combination for optimal performance and throughput.

1) *Performance study - Results and analysis*

The percentage of packets processed for each of the latency buckets is shown in Table 1.

TABLE 1. PERCENTAGE OF PACKETS PROCESSED FOR EACH OF THE LATENCY BUCKETS.

	Response Senders						
	Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**
Latency	**Baseline**	**20**	**6**	**4**	**3**	**2**	**1**
21-30	**0.131**	**24.117**	**47.103**	**86.954**	**83.946**	**81.684**	**77.379**
31-40	**6.193**	**63.822**	**86.802**	**96.045**	**94.470**	**93.937**	**88.011**
41-50	**16.171**	**83.320**	**94.035**	**98.500**	**97.902**	**97.629**	**92.370**
51-60	**34.237**	**89.286**	**97.432**	**99.419**	**99.189**	**98.987**	**94.884**
61-70	**62.610**	**93.289**	**98.915**	**99.741**	**99.685**	**99.581**	**96.559**
71-80	**82.029**	**95.674**	**99.523**	**99.862**	**99.858**	**99.807**	**97.746**
81-90	**91.530**	**97.400**	**99.754**	**99.920**	**99.926**	**99.893**	**98.594**
91-100	**95.296**	**98.554**	**99.843**	**99.945**	**99.956**	**99.932**	**99.211**
101-110	**97.091**	**99.275**	**99.889**	**99.955**	**99.969**	**99.951**	**99.638**
111-120	**98.109**	**99.664**	**99.913**	**99.962**	**99.975**	**99.960**	**99.881**
121-130	**98.732**						
131-140	**99.110**						

• It is observed that in non-blocking mode (run2) performance has improved over blocking mode (run1).

a) 90 percentile order latency reduced by 30µs. Latency moved from 90µs to 60µs.
b) 99 percentile order latency reduced by 65µs. Latency moved from 140µs to 110µs.

• Variation in number of "R-Senders" with dedicated computing resources shows that optimal number of "R-Senders" minimizes the contention and improves the performance further.

• In case of 6 "R-Senders" (run 3) over the baseline, i.e., blocking (run 1), the following are the observations:

a) 90 percentile order latency reduced by 45µs. Latency moved from 90µs to 45µs, 50% improvement.
b) 99 percentile order latency reduced by 65µs. Latency moved from 140µs to 75µs, 46% improvement.

• In case of 3 "R-Senders" (run 5) over the baseline, i.e., blocking (run 1), the following are the observations:

a) 90 percentile order latency reduced by 55µs. Latency moved from 90µs to 35µs, 61% improvement.
b) 99 percentile order latency reduced by 80µs. Latency moved from 140µs to 60µs, 57% improvement.

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However, further reduction in "R-Senders" to 2 and 1 in runs 6&7, the performance degrades compared to the above two runs, indicating the number of parallel processes is not sufficient to handle the load. Hence it is important to arrive at the number that gives the optimal performance. The results are under random rate of input arrival to simulate real life conditions. Under uniform input arrival rates, the performance is expected to be better. The architecture along with design components are to be fine-tuned to specific problem situation for optimal implementation. Specific care is to be taken to keep the critical path short and concurrent tasks with minimal or zero contention in the critical path.

V. CONCLUSION AND FUTURE WORK

This paper discusses the use of layering with concurrency and parallelism for high throughput and performance in a multi-core hardware platform. Also, the research work covers the choice of design techniques for interaction models and contention management in the architecture approaches. In addition, memory management strategy is suggested, taking into consideration the volume of data handled by these systems. Based on the above approach, simulation results are compared for the implementation alternatives, viz., blocking with shared memory, non-blocking with queues, non-blocking with queues and resources binding, and all these parameters with variation in number of R-sender processes. In summary, the study is aimed at providing a ready reckoner to the developer community the technical concept, implementation alternatives and choice of implementation based on simulation results in the transformation exercise.

In the end to end processing path, besides the "Response Delivery Layer", the other layers such as Pre-Process, Core Business Process, I/O in the critical path and in-memory database are being taken as future work items.

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Governance, Risk and Compliance in BPM - A Survey of Software Tools

Falko Koetter, Monika Kochanowski, Jens Drawehn
Fraunhofer Institute for Industrial Engineering IAO
and University of Stuttgart IAT
Stuttgart, Germany
Email: firstname.lastname@iao.fraunhofer.de

***Abstract*—Governance, risk and compliance (GRC) are current research topics in business process management (BPM). However, the state of the art in research and practice does not match. In this work, we investigate the practice of GRC in BPM tools based on a survey of 14 software providers. Identifying commonly shared features and components we determine the state of the art of GRC support in BPM tools. We found software providers agree in their definitions of GRC. Today's tools provide mature solutions for GRC, displaying a common base of features. This provides a basis for further research in the area of GRC.**

Keywords–business process management; governance; risk; compliance; state of practice

I. INTRODUCTION

Compliance to laws and regulations is a growing challenge in Business Process Management (BPM) [1] and has become a mature research topic [2]. However, compared to research, which may tackle the topic of compliance independently, often rethinking solutions and processes from scratch, commercial software needs to integrate in existing business process management systems and organizational structures [3]. Thus, the solution provided by industry and research differ [2]. In our applied research projects, we cooperate with insurance companies, banks, etc. active in the German market [4]. To understand the challenges these companies face in achieving business process compliance, the current state of practice and available commercial software needs to be surveyed. In this work, we summarize the results of a survey of software tools for business process compliance [5]. Using the results, we determine the state of the art in Governance, risk and compliance (GRC) in business process management tools in the German market.

The remainder of this work is structured as follows. Related work investigating the state of the art in science and practice is described in Section II. In Section III, we describe the focus of the survey and how it was chosen. Section IV describes the methodology of the survey. In Section V, the role of GRC in the BPM lifecycle is described. The results of the survey are given in Section VI, both regarding the software providers as well as the tool support for GRC. Finally, a conclusion and outlook are given in Section VII.

II. RELATED WORK

In [2], we conducted preliminary interviews with different stakeholders in business process compliance: experts from a BPM department, from a compliance and law department, participants at a compliance conference and BPM tool providers. We used these interviews to construct the questionnaire [6] for the survey summarized in this work. Especially we found a divide between the feature set offered by tool providers and the features and tools used by the other stakeholders. While practitioners showed an organizational divide between IT, BPM and compliance departments, tool providers divided their functionality in GRC.

Two studies regarding the state of the art of compliance in German insurance companies have been conducted in 2010 [7] and 2013 [8]. Both studies find a lack of integration between compliance and other processes. Only 11 percent and 7 percent respectively state a full integration with other processes. In another survey [9], 93 percent of insurance companies state that their compliance activities are not or only partially supported by IT.

[1] provides an analysis of emerging IT challenges for compliance management by conducting interviews with Australian compliance experts. Challenges identified include the high cost and the difficulty of providing evidence for compliance. A need for affordable software tools is identified, which not only tackle compliance in BPM but also the communication to and among staff as well as the documentation of compliance knowledge and the incentivization of a compliance culture.

[3] presents the results of an exploratory study of 8 GRC software providers. The survey found differing understanding of GRC between the vendors and found solutions to differ in their degree of integration. As marketable software must be compatible to existing enterprise structures, it differs from GRC research, which may propose more sweeping changes and rethink GRC outside of the constraints of the status quo.

Forrester publishes a periodic report [10] on GRC platforms. For this, 66 GRC customers were surveyed, almost half of which use more than one GRC platform. Use cases among customers vary extremely, leading to tools with broad capabilities. Though users found benefit in the GRC tools, overall satisfaction with end user interfaces, dashboards and analytics was low. 18 software providers were studied and classified by current offerings, strategy and market presence, though the classification was not broken down to a feature level. Compared to the companies in this work, the chosen companies were larger global players and not limited to BPM tool providers.

Similarly, Gartner published multiple studies in the area of GRC. However, Gartner decided in 2014 to reset their approach to GRC, focusing on use cases and real life use [11] instead of features. Similarly to this work, they found feature sets and presentation to be similar and use this reset to better differentiate between tools.

III. FOCUS OF THE SURVEY

During preliminary interviews we discovered that *Compliance* as a general term does not fully match the features software tools provide [2]. Therefore, we extended the scope to GRC. In [12], a frame of reference for GRC is constructed,

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in which GRC is defined as *an integrated, holistic approach to organization-wide governance, risk and compliance ensuring that an organization acts ethically correct and in accordance with its risk appetite, internal policies and external regulations through the alignment of strategy, processes, technology and people, thereby improving efficiency and effectiveness'* [12].

This frame of reference is used to define the focus of the survey, as shown in Figure 1. While GRC encompasses all aspects of an organization, the survey focuses on the aspects relevant to processes, though this distinction is not clear-cut. Governance in the context of BPM includes the governance of processes and the governance of IT which is used to realize these processes. Risk management is realized by internal controls or enterprise risk management (ERM). Compliance of business processes is often part of BPM products or realized by extensions or integrated components.

IV. Methodology

We invited all known BPM software providers active in the German market to participate in our survey. 28 providers partook in a general survey of BPM tools [13]. Of these providers, 14 opted to partake in an additional in-depth GRC survey. A full survey describing each provider in detail is available [5] in German. The providers were sent an online questionnaire containing 46 structured and unstructured questions regarding the software tool and the software provider. All 14 providers fully completed the questionnaire.

The full questionnaire can be found at [6] (in German).

The results of the questionnaire are listed in detail and analyzed in the GRC survey [5]. This work summarizes the findings of the survey to determine the state of the art among all 14 providers.

V. GRC in the BPM lifecycle

The BPM lifecycle shows the phases a business process goes through organized in a cycle to indicate that activities are performed continuously to optimize the process [14]. Figure 2 shows the lifecycle and GRC activities associated to each phase, which will be explained in the following section.

Governance spans the whole process lifecycle, prescribing frameworks, templates and best practices for all steps and artifacts. During process redesign and implementation different versions of a process need to be tracked as well as protected from unauthorized access and changes. Before a new version is implemented, a sign-off process can take place to make sure the new version is authorized.

In the area of risk management, during process discovery and process analysis risks need to be identified and assessed. These risks can be modeled and visualized during process (re)-design to make informed design decisions. This includes the definition of internal controls for risk management. During process execution risks need to be tracked and if necessary internal controls need to counteract occurring risks. Finally, the results of these activities need to be stored in a verifiable and traceable way, to provide data for analysis and reporting.

Compliance requirements are defined during process (re)-design and enforced at the appropriate parts of the process lifecycle. Requirements can be enforced during process (re)-design, implementation and execution. Requirement fulfillment needs to be monitored and stored to provide documentation and reports as well as provide a basis for analysis.

During our research we identified four types of BPM software supporting GRC functionality.

- **Process modeling tools** allow creating process models, but provide little functionality beyond that. In comparison to other tools, they have a low barrier to entry and are used if the main task is documenting processes. They may be used to model relevant risks and internal controls and to document compliance requirements already covered within the process models. Regarding governance, these tools provide process model management support, for example templates, sign-off and version control.
- **Process analytics tools** allow analyzing processes and may contain functionality for process simulation and optimization. These tools often contain process modeling functionality or are bundled with a process modeling tool to provide models as a basis for analysis.
- **Business process management tools** or BPM systems [14] support the whole process lifecycle including process execution. Typically process models are used to create and run process instances. This offers extensive possibilities to support internal controls, risk tracking, enforcement and monitoring of compliance requirements. Additionally, BPM tools can fully support governance processes. Some BPM tools may not offer a full execution environment but rather provide parts of the described functionality - for example by offering internal controls for a process executed by other means.
- **Workflow management systems** are focused on process execution. Similar to BPM tools they use process models to instantiate and run processes. Other parts of the process lifecycle are supported scarcely or not at all.

Note that the survey was limited to BPM providers, which is why dedicated GRC tools without a BPM component are not covered by the survey.

VI. Results

In this section, we give the results of the survey to illuminate the state of the art in business process management software regarding GRC.

A. Participants

All 14 participants are business process management software providers active in the German market, which offer GRC functionality as part of their tools. Of these 14 participants, 6 are companies with less than 100 employees, while 8 are companies with 100 or more employees.

For 6 providers, BPM is the only business segment. For 5 providers, it is the most important business segment. For the remaining 3 providers, it is one of several important business segments. All 14 companies offer BPM software and all but one additionally offer BPM consulting services. 6 companies offer other software. 6 companies offer other consulting services.

During the survey, companies were questioned since when compliance is a focus of their activities. All companies except one started focusing on compliance after the year 2000. 9 companies named a date between 2000 and 2009, 4 companies

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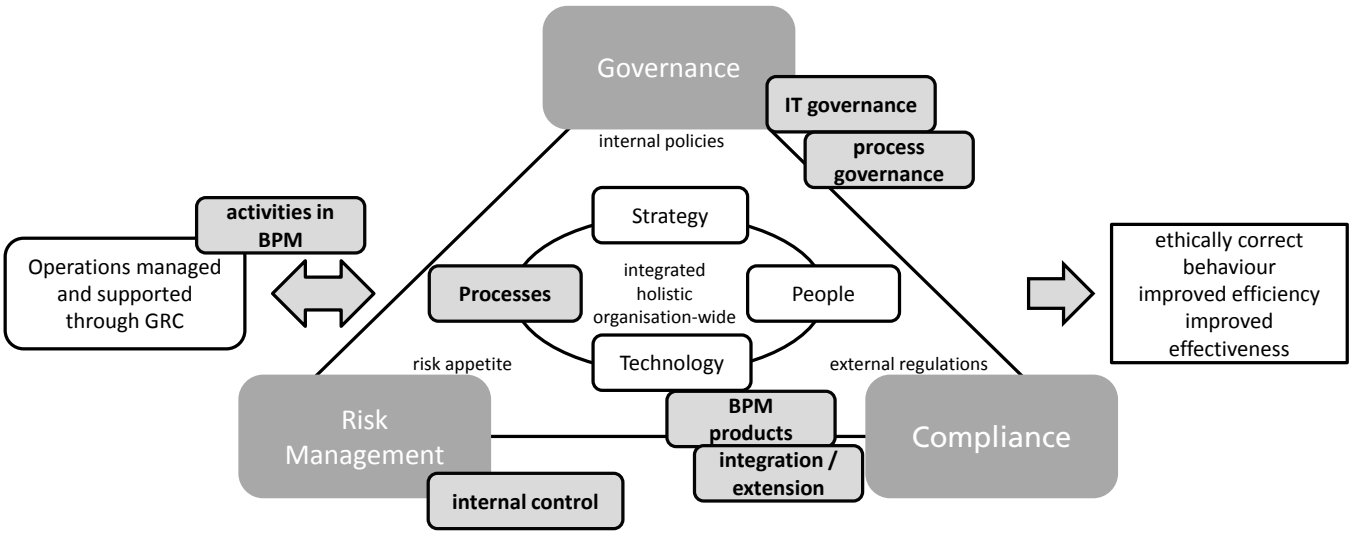

Figure 1. Framework for GRC with focus areas of survey (bolded, grey). Based on [12]

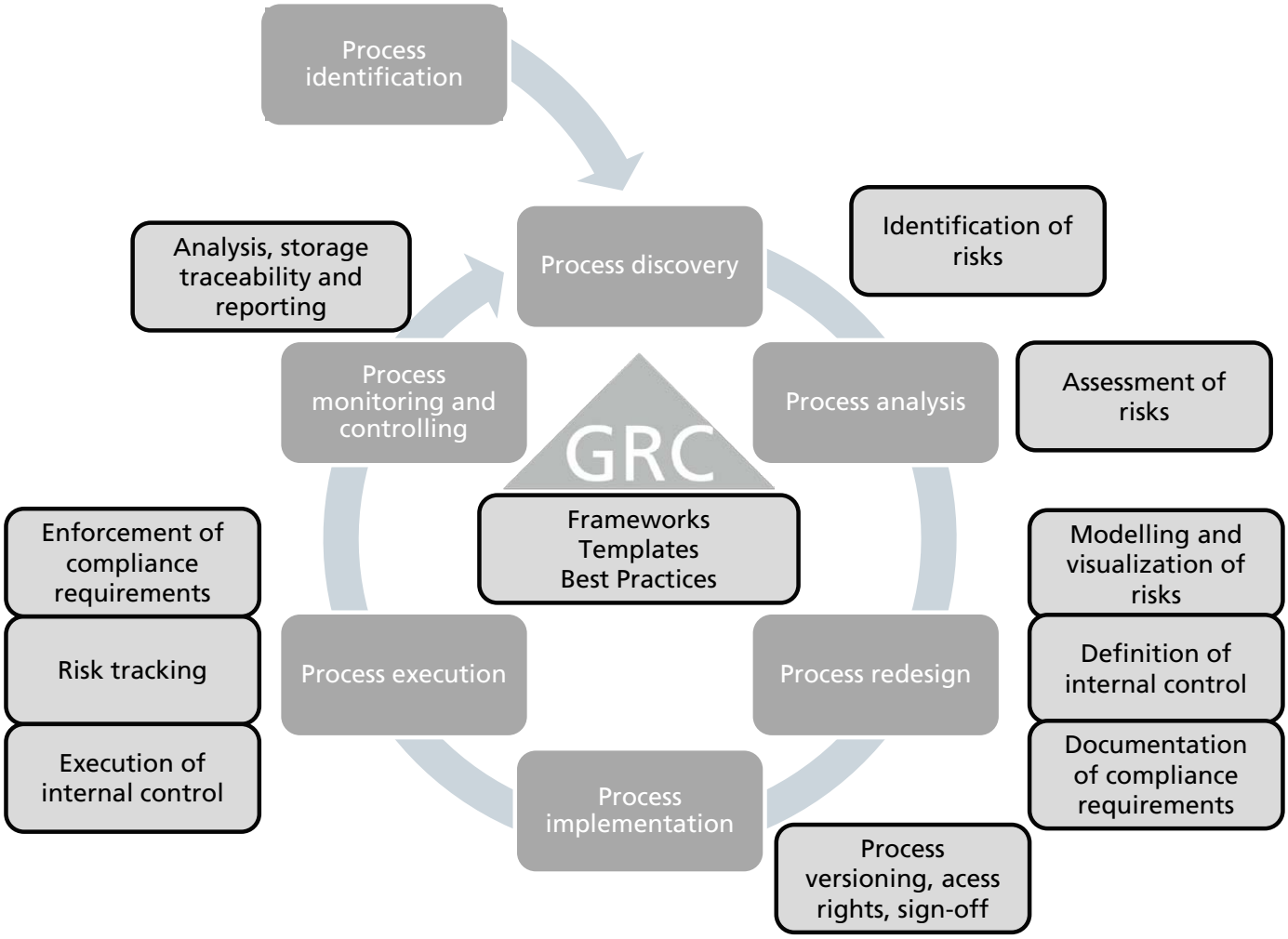

Figure 2. GRC activities in the process lifecycle. Based on [14]

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named a date 2010 or later. This indicates a rising demand for compliance functionality in business process management tools within the last 10 years.

B. Software tools

In this section, a general classification of the surveyed software tools is given to illustrate on which areas the software providers focus.

Regarding the BPM lifecycle (see Section V), all software providers support process discovery and process analysis. 9 providers support business process simulation. 11 providers support process execution, of which 7 provide a workflow engine. Process monitoring is supported by 9 providers.

Regarding tool classification, 3 software tools can be classified as process analytics tools, one can be classified as a workflow management system and 10 can be classified as business process management tools. It is to note that the bundling of software between providers varies. Some provide a single feature-rich solution, while others provide a collection of independent components that work together.

Looking at GRC, all software providers focus on all three areas. This indicates a trend to integrated GRC solutions.

In the survey, companies were allowed to indicate classes of business they focus on. However, no company named a special focus. This indicates that software tools are general purpose and not tailored to a specific industry.

C. Governance

To get the view of software providers on governance, we asked them for their definition of governance. Most providers see governance as a task for the enterprise as a whole, encompassing other topics besides process, e.g., organizational structure, roles, responsibilities and documentation. Governance is a leadership task, providing and enforcing rules and regulation frameworks as well as best practices.

Software components for governance encompass process organization (process versioning, access rights, sign-off, etc.), modeling and quality guidelines, modeling support and model checking, documentation and change management.

We identified the following software features as state of the art, which is supported by almost all software providers:

- Built in collections of best practices regarding modeling guidelines, etc.
- Creation and management of custom modeling guidelines
- Automated checking of process models using modeling guidelines
- Process portal or similar platform for collaborative business process management
- Support of management processes (e.g., sign-off)
- Version management of process models

As shown in Figure 2, Governance in BPM focuses on process design and implementation, aiding process modeling, collaboration and model management throughout the lifecycle. Governance also includes a knowledge management component, helping to communicate guidelines, templates and best practices.

Other features supported by some tools are:

- Process model templates and fragments enabling reuse
- Assisted modeling (automatic layout, model validation, etc.)
- Variant management of process models
- Governance dashboards
- Link of BPM and organizational structure

Several frameworks related to governance exist and may be used separately or in conjunction [15]. The following standards are most commonly supported by software providers:

- Control Objectives for Information and Related Technology (*COBIT*) [16] is supported by 8 of 14 providers
- Committee of Sponsoring Organizations of the Treadway Commission framework (*COSO*) [17] is supported by 4 of 14 providers
- Information Technology Infrastructure Library (*ITIL*) [18] is supported by 4 of 14 providers
- International Organization for Standardization (*ISO*) 9000/9001 is supported by 4 of 14 providers

Other supported standards include ISO 27001, ISO 31000, European Foundation for Quality Management (EFQM) model, Capability Maturity Model Integration (CMMI) and Software Process Improvement and Capability Determination (SPICE).

Several features to support these standards are included in most software tools:

- Checklists for requirements, etc.
- Reference process models
- Reference key performance indicators
- Linking of modeling elements to rules and requirements
- Linking of management processes to rules and requirements
- Support for reviews and audits

To summarize, all software providers focus on process governance, but link it to other areas of governance as well. The basic feature set is homogenous among the tools. Regarding governance frameworks the support varies among tools, indicating there is no dominant established governance standard, though a further investigation of industry sectors may give a clearer picture of standard proliferation.

D. Risk

Similarly to governance, we asked the software providers for a definition of risk management, showing a common view between all providers. Risk management is itself seen as a process by the software providers, including risk identification, assessment and management. Often used words include control and inspection measure. Aside from general risk management in the enterprise, providers emphasize the linking of risks to processes.

Software components for risk management include risk modeling and visualization, risk tracking and monitoring, risk analysis, documentation and reporting and risk control.

We investigated four areas of risk management to identify software features.

In the field of risk modeling and visualization, the following features are included in most software tools:

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- Risk modeling
- Linking of risks to process activities
- Linking of risks to other modeling elements
- Linking of risks to other objects (e.g., roles)
- Visualization of risks within process models
- Documentation of risks in a table
- Visualization of risks in a risk matrix [19]
- Hierarchical aggregation of risks

Other features supported by some software tools include other visualizations (e.g., heat maps, dashboards, customized reports and portlets), import and export of risks in external risk management systems, integration of risk and document management. This indicates three main activities. First, the risks are identified and modeled, then they are located within the process and finally they are visualized and documented.

In the field of risk tracking and monitoring, the following features are included in most software tools:

- Management of risk amounts and probability of occurrence
- Questionnaires to assist in risk tracking
- Monitoring of risks during process execution
- Triggering of risk management processes for certain risks

Other supported features by some software tools include risk monitoring dashboards, management of risk metadata (e.g., mandatory and optional information, assets, etc.) and link to response management.

In the field of risk analysis, documentation and reporting, the following features are included in most software tools:

- Creation of risk reports
- Audit-proof storage of reports
- Export of risk reports

Other supported features include risk visualization and analysis (in portals, cockpits, dashboards, etc.), creation of a data warehouse and export functionality of raw data.

All software tools include internal controls, which allow companies to control their risks by defining and implementing controls, audits, countermeasures, etc.

For the definition and documentation of internal controls, the following features are included in all software tools:

- Definition of controls
- Assignment of controls to risks
- Assignment of controls to processes
- Definition of roles for internal controls
- Visualization of controls within a process model

Most tools support Visualization of risks and controls in a risk control matrix. Additional features supported by some tools are the assignment of control tests and results to controls and integration of document management, organizational structure and response management.

11 of 14 tools support the execution of internal controls. The following features are supported by most of these tools:

- Performing controls in the process execution environment
- Scheduling and performing controls outside of the execution environment
- Audit-proof records of performed controls
- Analysis of performed controls

To summarize, risk management is supported throughout the process lifecycle, though some tools do not provide risk management support during process execution. All tools contain internal controls as an integral part of risk management in BPM.

E. Compliance

Similar to the other topics, we asked the software providers for a definition of compliance. All providers define compliance as conformance to rules and regulations. Aside from process compliance they mention other parts of the enterprise, e.g., personnel, culture, strategy, goals, responsibilities and components. Compliance is not seen as an isolated BPM topic, but as an encompassing task throughout the enterprise.

Compliance features can be divided in two categories. Definition of compliance requirements and checking of compliance requirements. It is to note that checking may mean both the enforcement of a requirement or the monitoring of a requirement, depending on the tool and the kind of requirement. For example, structural requirements to a process model can be enforced, while timing requirements during execution can only be monitored.

The following features regarding compliance requirement definition are included in most software tools:

- Definition of compliance requirements for business processes
- Management of requirement documents (regulatory texts, etc.)
- Linking of compliance requirements to documents
- Linking of compliance requirements to process steps
- Linking of compliance requirements to other elements
- Documentation of compliance requirements in a table
- Visualization of compliance requirements within process models
- Audit-proof record of compliance requirements and changes to them

Similarly to risk management, three main activities can be identified. Compliance requirements are derived from regulatory documents and defined, then located within the process or related artifacts and finally documented for further modification as well as for audits.

Regarding compliance checking, not all tools support automated compliance monitoring, which seems to be not part of the state of the art. However, most tools support compliance enforcement with the following features:

- Creation and processing of checklists for compliance requirements
- Templates and fragments for common compliance requirements
- Visualization of current compliance status
- Aggregated visualization of overall compliance status
- Generation of compliance reports

This shows that automated compliance enforcement is not state of the art, as manual compliance enforcement using

checklists is part of most tools. This may indicate both a lack of process automation as well as the difficulty of automated requirement checking. In our talks with users, they noted difficulties in defining precise compliance requirements from laws as well as in process automation, as processes are not yet fully documented [2]. Checklists can provide an interim solution to be compliant.

9 of 14 software providers offer a business rules engine, either as part of their tool or as a separate component. Business rules may be used to automatically monitor, enforce and document compliance requirements, but necessitate automated business processes.

8 of 14 software providers provide built-in rulesets for regulatory texts. 3 providers support Basel 2/3 [20], 3 providers support the SarbanesOxley Act of 2002 (SOX) [21]. Other rulesets are only supported by single providers. As no provider has named classes of business they specialize on, this may indicate a high level of customization in the compliance rulesets of their customers so built-in rulesets are of limited use.

To summarize, the definition of compliance requirements in the context of documents and business processes is supported by all software tools. Regarding compliance checking, the state of the art in compliance checking is more uneven. Some solution components help model compliant processes and check compliance manually (e.g., by checklists). For automated compliance checking, business rules engines are the prevalent solution.

VII. Conclusion and outlook

In this work, we summarized a survey of 14 BPM software providers active in the German market. This survey investigated the support of GRC in BPM tools.

Support of GRC in business processes is not only a mature research topic, but has also been incorporated in software tools. Software providers showed a common understanding of GRC, providing similar definitions for all three terms. Governance is supported by a homogenous feature set, indicating a proven approach in practice. Risk management is supported throughout the BPM life cycle with internal controls as an integral component. Definition of compliance requirements is supported uniformly, but compliance checking is realized more unevenly with business rules engines and checklists as the prevalent solutions.

Overall, the industry provides mature tools for handling GRC in business process management. While state of the art in industry can be a helpful indicator for scientific research, it alone does not suffice because the questions and constraints for industry and science are different. Examples are the questions of interoperability and integration, which were not covered by the survey.

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Deciding Confidence for Identity Resolution in Closed and Open Universes of Entity Identity Information

Fumiko Kobayashi, John R. Talburt
Department of Information Science
University of Arkansas at Little Rock
Little Rock, AR, USA
fxkobayashi@ualr.edu, jrtalburt@ualr.edu

***Abstract*- Entity Identity Information Management (EIIM) systems provide the information technology support for Master Data Management (MDM) systems. One of the most important configurations of an EIIM system is identity resolution. In an identity resolution configuration, the EIIM system accepts a batch of entity references and returns the corresponding entity identifiers. However, these batch EIIM systems lack in providing easily accessible identity information. To address this, the EIIM system is extended with an Identity Management Service (IMS) [1] to decouple identity resolution from batch EIIM processing which allows it to move into an interactive realm. Due to the uncertainty of the information provided by the requester, the system may match the reference to many different Entity Identity Structures (EIS), and the identifier returned by the system may not be the correct one. To assist the client, the IMS provides a second output called a confidence rating. The confidence rating is a measure of the likelihood that the returned identifier is accurate. The confidence rating is related to the match score, but must also consider other factors including whether the entity identity information resides in a closed or open system. This paper discusses a model for generating confidence ratings based on an assessment of the differences between the match scores for competing EIS in either a closed or open universe. The paper also includes some preliminary results from experiments performed on a production IMS system supporting student MDM.**

Keywords- Entity Identity Information Management; Identity Resolution; Master Data management; Open Universe; Closed Universe; Confidence rating

I. INTRODUCTION

Identity Resolution (IR) is the process of determining if an entity reference refers to the same entity as one of the Entity Identity Structures (EIS) under management in an Entity Identity Information Management (EIIM) system. IR is sometimes called "entity recognition" because the system is being asked if the input entity reference can be recognized as one of the entities already under management.

ER is the process of determining whether two references to real-world objects in an information system are referring to the same object, or to different objects [2]. Real-world objects are identified by their attribute similarity and relationships with other entities. Some examples of attributes for person entities are First Name, Last Name, and Social Security Number (SSN). For place or location entities the attributes might be Latitude, Longitude, Description, or postal address. ER has also been studied under other names including but not limited to record linkage [3], deduplication [4], reference reconciliation [5], and object identification [6].

ER is a key task in data integration where different systems or data sources provide information for a common set of entities. ER has its roots in Customer Relationship Management (CRM) where it is often referred to as Customer Data Integration (CDI) [7]. The need for accurate and efficient ER is a necessity with the amount of data that is able to be collected and stored with current levels of technology. ER research is also driven by the need to share entity identity information across independently governed organizations in many areas such as education, healthcare, and national security.

Previous Information Quality (IQ) research [8] [9] has extended ER into the larger context of Entity Identity Information Management (EIIM) that includes the creation and maintenance of persistent data structures to represent the identities of external entities [2]. The overall goal of EIIM is to allow the ER system to achieve entity identity integrity, a state in which two conditions hold [10].

1. Each identity structures corresponds to one, and only one, real-world entity
2. Distinct identity structures correspond to distinct real-world entities.

Entity identity integrity is another way of stating the Fundamental Law of Entity Resolution [2] which requires that two entity references should be linked if, and only if, they are equivalent where equivalence means both reference the same real-world entity.

In the current model of EIIM, the configurations to maintain the EIS operate primarily in an offline batch mode. In general the EIIM model is focused on the processes necessary to achieve and maintain entity identity integrity of the EIS under management in systems Identity Knowledgebase (IKB). EIIM provides the tools to support the complete life cycle of identity information.

In the EIIM model, the only configuration that does not modify the IKB is the IR configuration. In an IR process each entity reference input into the system is resolved

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against a previously defined set of identities represented as some type of EIS. When the pre-defined identities represent master data of an organization such as employees, customers, or products, IR becomes an important component of Master Data Management (MDM). MDM and IR in a broad set of applications including business, health care, education, law enforcement, and the military. In a business context of MDM of customer information, IR is sometimes called "customer recognition" [2].

The IR operation is intended to provide access and use for information. The idea of decoupling IR from the batch EIIM system [1] allows more robust access to the entity identity information. The decoupling is done through an interactive Identity Management System (IMS) to interactively access the IKB maintained by the EIIM system.

In this paper, Section I introduces the terminology and concepts required to understand, define, and discuss the goals and approaches used in this research. In Section II, existing research and limitations addressed by this paper are discussed along with the importance of this research for business intelligence. Section III defines the specific problem addressed in this paper and the method used. In Section IV, the concept of candidate selection is explained and an extension to standard probabilistic scoring algorithms is defined which provides improved selection. Section V defines the differences between closed and open universes of information and how assumptions inherent in each universe alter the application of confidence rating for an EIS. In Section VI, the formula for calculation of and the method for applying δ (delta) are defined. Section VI also provides the final algorithms for calculating the confidence rating in closed and open universes of information. In Section VII presents the experimentation performed to gauge the accuracies of the new unique ratio (UR) score algorithm and the δ application. Section VIII concludes and summarizes the paper and proposes future research.

II. EXISTING RESEARCH

EIIM systems are designed in such a manner to provide a robust framework for the maintenance and management of entity information over time in a single batch system [11]. EIIM focuses mainly on the capture, update, and store phases on the CSRUD (capture, store and share, resolve and retrieve, update, and dispose) MDM lifecycle [9]. For practical use, the Resolve and Retrieve Phase is the most important of all the of the CSRUD MDM life cycle phases. Resolving an entity reference to its correct entity (EIS) is the primary use case for MDM. It's this resolve and retrieval that provides actual value to the client systems.

Quantifying the reliability of a resolved entity identifier is an important problem that is not addressed by EIIM. The reliability of identification will vary from inquiry-to-inquiry depending upon the depth, breadth, and context of the match to the EIS in then identity knowledgebase. In order to provide guidance to the inquiring client system, the IMS should compute a confidence rating for each inquiry providing the client system with an estimate of the likelihood a resolved entity identifier is correct.

This research provides methods that fill the void that was left in regards to design for the Resolve and Retrieve Phase of the CSRUD MDM life cycle. The increased accuracy of resolution and the confidence rating are vital for the area of Business Intelligence. This is because it provides a gauge when selecting meaningful and useful information from an IKB for business analysis purposes.

III. PROBLEM DEFINITION

There are many factors that contribute to the accuracy of an IMS. The main factor is the quality and reliability of the input reference. However, the number of input attributes provided, the domain of the information being searched, and others factors also have a bearing. While certain factors cannot be controlled, their impact on accuracy can be mitigated through observational testing and matching algorithms. This research focuses primarily on a model for calculating the confidence in the accuracy of the entity identifier returned by an IMS. The model takes into consider two broad categories of IMS, open universe IMS and closed universe IMS.

When IR is reconfigured into an interactive mode, the user still expects the system to provide the same type of results that a batch system provides. This expectation is that for every input, there should be one decisive identifier returned. The problem of determining the correct identifier to return revolves around two issues: the uncertainty of the user provided input and the universe of the entity identity information.

Imagine the situation in which the entity identity information comprises records with 14 attribute values. When a user provides a subset of these attributes values as input, the goal of the system is to provide the most accurate response possible. This is difficult to gauge when the user only provides a small percentage of the attribute values, i.e. in this situation, 3 or 4 attributes out of 14. In addition, there are no constraints or validations applied to the input data so it is often "dirty" input data. The issue of low-quality input data is further addressed through the introduction of the delta range discussed later.

Not only the entity identity information itself but also the universe in which that information resides is an important consideration. In this research, the concept of a closed and open universe have been applied to the entity identity information to allow for baseline assumptions to be made regarding model. These assumptions help determine the best response.

Through the application of the closed and open universe concept, this paper shows how it is possible to

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provide the requestor with an additional piece of information alongside the response that will allow them to know to which degree they can accept the response as fact. This is being referred to as the confidence rating.

The overall method performed in the research consists of four steps that must each be understood to accurately define a confidence. These are as follows:

1. Scoring and Candidate Selection
2. Universe Assumption application
3. δ (delta) application
4. Confidence application

Each of these is detailed in the next few sections.

IV. CANDIDATE SELECTION AND SCORING

In an ER system, it is impractical to perform matching on all the reference in an IKB against an input reference. To reduce the number of comparisons that are required custom indexing is used as a form of blocking [2]. This index allows the attributes values in the input reference to be used to quickly populate a candidate list [2] against which the more complex matching algorithms can be applied.

Once the candidate list is selected, the matching is applied in the form of a scoring algorithm. Scoring is the process of assigning a numerical value (normalized between 0 and 1) that predicts the probability that a reference in the IKB matches the input reference. The score is expensive in terms of processing but can be run on all of the references that were specified as possible matches by the index. After scores are calculated for each reference, any scores that meet the predefined threshold can then be used as the final set on which confidence is calculated.

In an interactive IR system, it was found that standard score algorithms [12] were not suitable. For more accurate score generation, the algorithm needs the ability to use attribute data that exists in the candidate list to skew the final results. To accomplish this, the unique ratio (UR), a basic profiling statistic, was found to provide large gains in accuracy when factored into the score algorithm.

The idea behind the modified score algorithm is that in a result set, exact matches with a higher unique ratio (UR) should hold a higher weight than an exact match with a low unique ratio (UR). A unique ratio is calculated as:

$$UR_i = \frac{UC_i}{RC} \quad (1)$$

Where

- UC = number of unique attribute values in a given attribute (inclusive of blanks)
- RC = record count in the candidate set

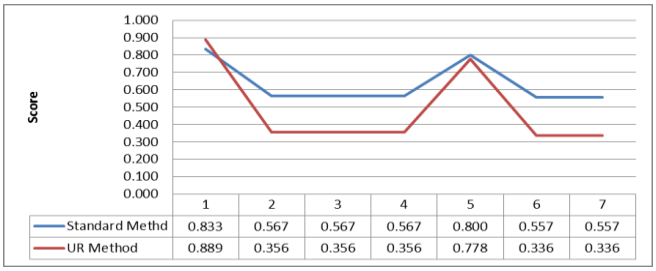
The following is the modified score algorithm with the UR factored in:

$$URScore(\mathrm{IR}, \mathrm{CR}) = \frac{\sum_{i=1}^{n} LED(IR_i, CR_i) * UR_i * AF_i}{\sum_{i=1}^{n} UR_i * AF_i} \quad (2)$$

The attribute flag (AF_i) is calculated for each reference that is processed by the system. The attribute flag stores a simple Boolean value (1 or 0) and is calculated for each attribute as:

$$AF_i = \begin{cases} 1 \; if \; i \neq \emptyset \\ 0 \; if \; i = \emptyset \end{cases} \quad (3)$$

The purpose of this modified score algorithm is to value unique differences in a search over repetitive values. It can only be applied to the final result set to allow the optimal result to be selected. The algorithm uses the result set values as a group to skew the final calculation instead of allowing the records to be valued independently.



	1	2	3	4	5	6	7
Standard Methd	0.833	0.567	0.567	0.567	0.800	0.557	0.557
UR Method	0.889	0.356	0.356	0.356	0.778	0.336	0.336

Figure 1. UR vs. Standard Scoring.

Figure 1 shows the results of a request that has 7 references in the final candidate list. This shows how the UR score method more clearly classifies matches (or possible matches) from other false positives by widening the gap in their match score results.

Figure 1 shows that the Standard Method placed both EIS 1 and 5 into the same bucket. When the UR score algorithm was applied however, the gap in the scores for EIS 1 and 5 became profound enough that they now fall within 2 separate buckets. This clearly labels EIS as the winner.

V. UNIVERSE OF ENTITY IDENTITY INFORMATION

In terms of entity identity information, the universe defines the type of information that is being accessed. That is, if the entity identity information is in a controlled environment in which the data entering the system is known, or if the entity identity information being entered into the system has little or no oversight beyond structure. These two types of entity identity information are classified into closed universe information and open universe information respectively. Depending on which a set of entity identity information falls into, a certain level of assumption can be applied to the data to assist in the decision making.

A. *Closed Universe*

In an Interactive IR system, a closed universe defines a set of entity identity information in which the requestor can be certain that the entity they are searching for exists within

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the IKB and that the entity is unique. This means that the following assumptions can be applied to entity identity information that falls within this category:

- The record being searched for is known to exist within the universe
- There is always one and only one perfect match
- The data and EIS are controlled and updated only by an knowledge expert

Due to the type of data, these assumptions are valid and allow for leaps to be taken in the assignment of a final confidence rating. Specifically, with these assumptions it can be inferred that even if the top score generated is very low, it is still the best match and could be assigned a high confidence rating.

An example of a closed universe could be that of a university enrollment system. In such a system, a professor could be certain that a student attending their class will exist in this universe and that there should only be a single entity for that student. If the professor needs to look up information on said student, they should have confidence that the entity identity information retrieved from their search should be the entity they are looking for.

This means that for professor's class A, and student registration system B:

$$A \subseteq B \tag{4}$$

B. *Open Universe*

In an Interactive IR system, an open universe defines a set of entity identity information in which the requestor is uncertain if the entity they are searching for exists. The following assumptions can be made regarding entity identity information that falls within this category:

- The contents of the entity identity information in the open universe contain no oversight or restrictions beyond the particular layout of the attribute data.
- An entity may or may not be present when searching.

These two assumptions introduce doubt to the user of the information as they cannot be certain that any results they receive are the correct result. These assumptions and the corresponding doubt require confidences in an open universe to endure an additional consideration. A hard cut off for confidences is applied in the form of a threshold. This means that unlike the closed universe, if the top score is very low, no assumption can be made and this reference will be assigned no confidence.

An example of an open universe could be that of a criminal IKB. Many organizations could contribute information to the IKB ranging from local to federal level. However, even though the IKB contains vast amounts of information, when information of a suspect is being processed through the system there is no guarantee that the information exists within the IKB. If information is found, it may consist of multiple records that match the search criteria but aren't actually the correct EIS.

In both closed and open universe, the overall goal is to mitigate some of the uncertainty in results provided to the requestors. This can be accomplished through a confidence rating.

VI. CONFIDENCE RATING

A confidence rating is the primary focus of this research. It is a numerical value between 0 and 1 that is returned to a requestor along with the final match result for the request. The confidence rating informs the requestor of the likelihood that the match result was the correct EIS for the request. The confidence rating can be used by the requestor to either accept the response or make another request providing more information. As noted previously, the main difference between determining confidence in a closed and open universe is the threshold that is applied to the open universe under which no confidence can be assigned to a reference.

The calculation of a confidence rating is the last step of reference selection in an interactive IR system but in order to accurately calculate the confidence rating a δ (delta) calculation must be applied to account for uncertainty in the selection.

A. *δ (delta)*

A naïve approach to confidence rating calculation is to simply assign a confidence of 1 to the top match scored value. However, there is not always a single top scored candidate. Also depending on the universe model, it is not always reasonable to assume the top score is the best match. From this insight, it was decided to build "buckets" and assign the match scores to the buckets.

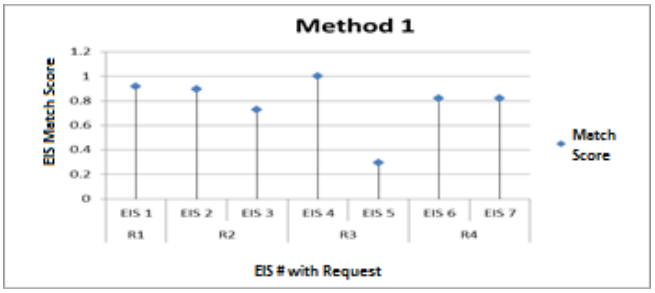

Figure 2. Methods 1 – Buckets.

The information is Figure 2 is as follows:

- Every dot represents an EIS
- Each EIS noted has at least one matching record
- Rows represent a corresponding score

In this method, the EISs in the highest bucket were selected as the candidate and assigned a confidence as a ratio of the number of EIS.

$$M1Con = \frac{1}{EC} \tag{5}$$

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In the Method 1 Confidence (M1Con) calculation, EC is the count of EIS in the top used bucket. However, this is inefficient because an EIS with a match score of 99.9% would be assigned the same confidence as a match score of 90.2% with no regard to the number of attributes or other considerations.

This problem can be addressed by applying a δ (delta) value. The δ is a number used as a sliding window (bucket) for the top candidate selection when calculating confidence.

By applying δ, like confidences could be assigned to close scored references even if they fall within different fixed buckets. To illustrate this concept, Figure 3 shows that δ=A would assign equal confidence ratings to EIS 1 and 4, δ=B would assign equal confidence ratings to EIS 1, 4, and 7, and δ=C would assign equal confidence ratings to EIS 1, 2, 4, and 7. This leads to the question of how to determine a δ in a systematic and accurate way.

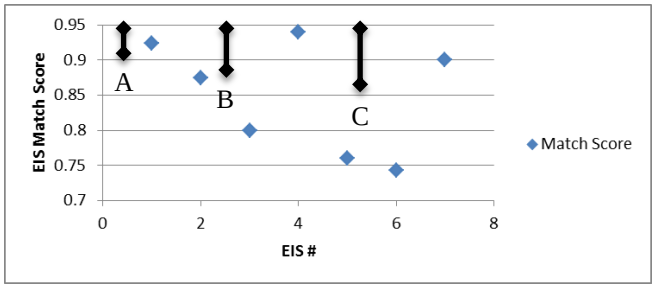

Figure 3. δ (delta) Range.

The method for calculating δ is based on the number of input attributes. The value of δ varys based on the attribute count of the IKB and the attributes contained in the request being made. This is to accommodate requests of different sizes and accuracies, i.e. if a user only provides 2 attributes, the δ would be larger as not enough information was provided to generate an accurate response. For a user that provides 12 attributes (out of 20) the δ should be much smaller as the user provided more information and gets a more accurate decision from the system. The formula for δ is as follows:

$$\delta = 0.1 * \frac{\frac{B}{A * A - 1} + (A - 1) * 0.8}{B * 2 + A} \quad (6)$$

Where:

- A= total attribute count for a given IKB
- B= Total attribute count for a given input request into the IKB

When δ is calculated for every combination of request attribute count and total attribute count and then plotted, the resulting is a δ curve which visually illustrates the expectations for δ values. Figure 4 shows the δ curve for an IKB consisting of 99 attributes.

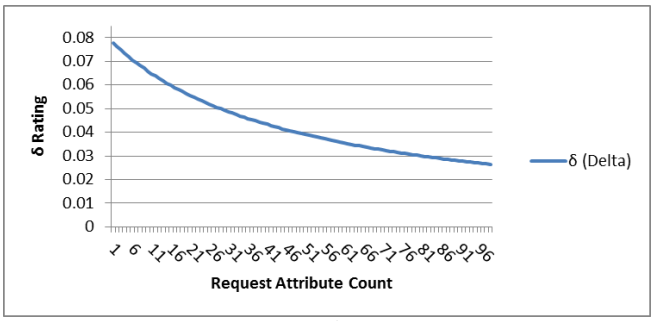

Figure 4. δ Curve.

Once the δ is calculated for a request, it can be applied to more accurately group references when calculating the confidence rating.

B. *Calculating the Confidence Rating*

The last step in the process is to calculate the confidence rating for the result based on the information compiled in the previous steps. In a closed universe, this is done by the following:

1. Select the EIS that has been assigned the highest score based on the UR score function
   a. Use this as the upper bound of the δ range
2. Subtract the calculated δ from this score value.
   a. Use this as the lower bound of the δ range.
3. Count the number of EIS that meet the following
   Upper Bound≥EIS Score≥Lower Bound
   a. Assign this count to variable EC
4. Assign a confidence equal to 1⁄EC to each of the EIS that fall within the δ range
5. Return the EIS identifier and the corresponding confidence rating for the EIS with the highest score value to the requestor.

In an open universe, the threshold for confidence must be considered. The following is the modified method:

1. Compare the highest UR score (urs) to the threshold
   a. If urs<threshold
      i. Assign a confidence rating of 0 to top scored EIS and return the EIS identifier and confidence to requestor.
   b. If urs≥threshold
      i. Select the EIS that has been assigned the highest score based on the UR score function
         1. Use this score as the upper bound of the δ range
      ii. Subtract the calculated δ from this score value.
         1. Use this as the lower bound of the δ range.
      iii. Count the number of EIS that meet the following
         Upper Bound≥EIS Score≥Lower Bound
         1. Assign this count to variable EC

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iv. Assign a confidence equal to 1/EC to each of the EIS that fall within the δ range
v. Return the EIS identifier and the corresponding confidence rating for the EIS with the highest score value to the requestor.

VII. EXPERIMENTATION

The testing of the modified rating algorithm in a closed universe was done on real data for a student identity system management system. This data consisted of approximately 1 million EIS each containing 39 attributes. From this data three random sets of EIS were pulled making 3 closed universes consisting of 100, 200, and 1,000 EIS. A truth set for each of these was created and each of the search results was compared against this for accuracy.

On each of these three IKBs, 840 searches were performed and the resulting EIS and its confidence were checked against the truth set. These 840 searches consisted of 70 requests for 1 to 12 attributes per request. The reason for this was to identify the point at which accuracy gains stopped outweighing the need for additional attributes.

It is important to note that in an ER system, match decision are applicable if and only if the attributes used for the decisions are classified as identifying attributes. For the data tested, 12 of the 39 attributes were selected for testing once they were identified as information that could be used to accurately identify a match.

The results were recorded for each set of 840 searches and then the results were averaged to generate an accuracy estimate for each attribute level for each IKB. The averages are shown in TABLE I.

TABLE I. ALGORITHM ACCURACY AVERAGES

Attribute Count	**Cluster Count**			
	100	200	1000	Average
1	11.429%	7.143%	1.429%	6.667%
2	14.286%	10.000%	7.143%	10.476%
3	21.429%	22.857%	21.429%	21.905%
4	30.000%	28.571%	37.143%	31.905%
5	47.143%	45.714%	58.571%	50.476%
6	84.286%	87.143%	84.286%	85.238%
7	94.286%	94.286%	91.429%	93.333%
8	95.714%	94.286%	92.857%	94.286%
9	97.143%	95.714%	95.714%	96.190%
10	97.143%	95.714%	95.714%	96.190%
11	98.571%	97.143%	97.143%	97.619%
12	98.571%	98.571%	97.143%	98.095%

When these averages are graphed as shown in Figure 5, it is evident that the accuracy of the algorithm grows as more attribute values are provided. This result was expected.

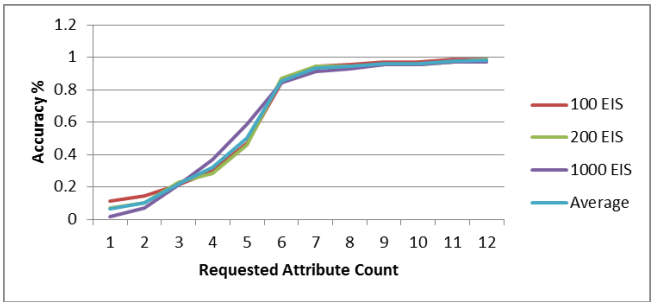

Figure 5. Algorithm Accuracy.

The validation of the modified rating algorithm is that with 6 attributes, no matter the size of the universe, the algorithm made an accurate decision returning the correct EIS 89% of the time.

VIII. CONCLUSION/SUMMARY

It was found that once Identity Resolution is moved into the interactive realm, additional complications are encountered during processing which requires a more accurate method of deciding a singular "best match". This best match is expected by the user of the system as they assume an interactive IR system should return results comparable to that of a batch system. With the introduction of a confidence rating, the system can provide the requestor with the most confident EIS in relation to the candidate list of matches for a request. The confidence rating is a relative measure from the initial match score.

During testing, it was found that the domain of the information must be considered as confidences should act differently in both and closed and open universes due to accepted assumption about the two realms of entity identity information. To address this issues a modified score algorithm was created to utilize the data contained in the final match set to augment the final scores and provide a more accurate confidence decision. Through this modified score algorithm in conjunction with the δ range, it was identified that there is a threshold on data at which the accuracy will peak beyond 90%. Depending on the number of identifying attributes in the IKB, this number may vary but for the experimentation done it required was 40% of the attributes to be provided to achieve accuracy of 90% or above.

The experimentation performed during this research showed that the system was able to determine the correct match with a high level of accuracy. The accuracy of the UR Score provided an almost 10% gain is accurate selection when compared to other standard scoring algorithms. When the UR Score was combined with the δ range, the resulting confidences were determined to accurately represent the trustworthiness of a returned EIS. This increase in accuracy and the ability to rate and return a confidence has many

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applications in the Business Intelligence domain. These including that of increased trust in the results of business analysis performed on entity identity information requested from an IMS system.

Future research into the confidence rating will focus on an open universe. The expanded research will consider the use of neural networking and other graph theory concepts to approve selection amongst match candidates.

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Big Data: Opportunities and Challenges

Omar Al-Hujran, Rana Wadi, Reema Dahbour, Mohammad Al-Doughmi
Department of Management Information Systems
Princess Sumaya University for Technology
Amman, Jordan
Emails: o.hujran@psut.edu.jo; rwadi.91@gmail.com; dahbour.reema@gmail.com; hashem_m_doughmi@live.com

Mutaz M. Al-Debei
Department of Management Information Systems
The University of Jordan
Amman, Jordan
Email: m.aldebei@ju.edu.jo

***Abstract*—The concept of Big Data has become a reality due to our capability to create and collect digital data at an extraordinary rate. Despite its significance, the concept of Big Data is still largely overlooked and underestimated. Drawing on seven case studies of service providers and customers from different countries, this study contributes to the existing body of knowledge by comprehensively addressing the opportunities and challenges of Big Data.**

Keywords-Big Data; Innovations; Technology; Challenges and Opportunities; Jordan.

I. INTRODUCTION

The rapid emergence, prevalence and potential impact of Big Data has sparkled a significant amount of interest amongst Information Systems/Information Technology (IS/IT) industry and research. The concept of Big Data has come true due to the inescapable significance of our capability to create and collect digital data at an extraordinary scale. Big Data has been around since 2005, when the term Big Data has been adopted from O'Reilly media. The increasing number of people, devices, and sensors that are now connected by digital networks (i.e., Internet of Things) has generated a vast amount of data. Data is generated from online transactions, social networking interactions, emails, clickstream, logs, search queries, sensors, global positioning satellites, roads and bridges, and mobile phones [16]. The amount of data that is produced each day already exceeds 2.5 Exabyte [11]. In addition, the bidirectional telecommunications capacity is growing by almost 30% per year and the globally stored information is increasing by more than about 20% per year [7][27]. Accordingly, the great potential of Big Data for both academics and practitioners has become clear. In the business world, companies are leveraging Big Data technologies for effective decision making, efficient business operations, and maximum business impact [10][26]. For example, business could use Big Data to improve their offers, mange risks, and know their customers better [5]. According to McKinsey report [10], government administration in developed economies could save more than $149 billion in operational efficiency improvements alone by using Big Data. In short, Big Data solutions provide managers with the ability to make informed decisions that are based on evidences rather than making arbitrary decisions which are largely dependent on their intuitions and subjective judgments.

Although there is currently no single universally accepted definition of the term, Manyika et al. [10] define Big Data as "datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze data". In other words, Big Data is an advanced information technology that allows users to capture, communicate, aggregate, store and analyze massive amounts of data. However, the value of Big Data largely depends on what types of software tools are available, what sizes of datasets are common in a particular industry, and their use in general (i.e., the way one is using it along with purposes).

Despite the rapid emergence of Big Data technologies, empirical research in this domain is still quite limited [1]. In addition, many organizations are still not aware about Big Data analytics along with their capabilities, benefits, and also challenges. An empirical research conducted by Russom [15] showed that only 28% of respondents understand the concept of Big Data and have name it, most of them (around 85%) being from developed countries. Moreover, despite the numerous advantages of Big Data, its implementation and adoption in developing economies is still very limited and surrounded by a variety of challenges. Therefore, the main objective of this research is to examine and shed light on the current state and the future prospects of Big Data in developing countries.

The rest of the paper is structured as follows. In section two, we provide a comprehensive theoretical background and literature review of the Big Data concept. Thereafter in section three, the research methodology including data collection and analysis methods are discussed. In section four, the results of the study are presented and discussed. Finally in section five, the research conclusions are presented and recommendations for theory and practice are offered.

II. BACKGROUND

There has not been a commonly accepted definition in regards to Big Data. However, as mentioned earlier, the literature usually reports that Big Data should include datasets with sizes beyond the ability of commonly used software tools to capture, manage, and process the data

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within a tolerable elapsed time. Many researchers have defined Big Data via its three main characteristics and aspects that go beyond the capability of the current database management systems. These characteristics are Volume, Velocity and Variety, also known as 3Vs [4][9][11][15]. Volume refers to the size of the data such as terabytes (TB), petabytes (PB), and zettabytes (ZB), Velocity means how frequently the data is generated, and Variety represents the different types of data sources; for example, data could be unstructured social networking data, web logs data, sensor readings, streamed video and audio, or mobile generated data [11]. Recently, Kaisler et al. [8] added "Value" as a fourth characteristic of Big Data. Value measures the usefulness of Big Data in decisions-making [2].

Although Big Data was a serious problem just a few years ago, now it is considered as business opportunity. Using Big Data gives organizations a competitive advantage to differentiate themselves from others, and this can help them uncover people's hidden behavioral patterns and even emphasis on their intentions [15]. It can also eliminate the gap between what people want to do and what they actually do in addition to how they interact with others and their environment, which helps directly in decision-making. Previous research also showed that data-driven decision making is associated with higher productivity, profitability and market value. Indeed, companies that use data-driven decision making may enjoy 4% higher productivity, 6% greater profitability, and 50% higher market value [20]. In addition, Big Data analytics can positively impact product development, market development, operational efficiency, customer experience, and market demand predictions [3][15]. With the rapid explosion of data, governments can also benefit from Big Data by creating a system that collects and analyzes vast amount of data coming from different sources to help them in tracking criminals, preventing money laundering as well as improving homeland security [1]. McKinsey Global Institute [10] argued that five new kinds of value might come from Big Data:

1- Creating transparency in organizational activities that can be used to increase efficiency.
2- Enabling more experimentation to discover needs, expose variability, and improve performance.
3- Segmenting populations in order to customize actions.
4- Replacing/supporting human decision making with automated algorithms.
5- Innovating new business models, products, and services.

However, while Big Data can yield extremely useful information, it also presents new challenges with respect to how much data to store, how much this will cost, whether the data will be secure, and how long it must be maintained. Big data also presents new ethical concerns. In fact, one of the major challenges of Big Data is preserving individual privacy [12][16]. In their study, Agrawal et al. [1] also identified many technical challenges associated with Big Data. These technical challenges include scalability (i.e., data volume is scaling faster than compute resources), heterogeneity (i.e., data comes from different sources), lack of structure (i.e., data must be carefully structured as a first step in -or prior to- data analysis), error-handling (i.e., data cleansing and error correction), timeliness (i.e., the larger the data set to be processed, the longer it will take to analyze), and visualization (i.e., present results in powerful visualizations that assist interpretation). Big Data adoption is also facing several other managerial and organizational challenges. These managerial and organizational challenges include inadequate staffing skills, lack of business support [15], organization culture, and resistance to change [11].

III. METHODOLOGY

The present section explains the methodology used in collecting and analyzing data for the purpose of achieving the objectives of the current study. Given the scarcity of empirical research in the area of Big Data adoption and the need to obtain rich data, the study was considered exploratory in nature, and therefore, a case study approach was considered appropriate [17]. Case studies are useful for exploring areas where existing knowledge is limited [6] and are also valuable in generating an understanding of a particular situation [17]. Our research method involves seven case studies representing Big Data solution providers (i.e., Informatica, Huawei, Rabaie Analytics Group) and Big Data potential customers (i.e., EMP, A leading e-commerce startup company in Jordan, Aramex, E-Arabia) (see Table 1). The decision to use the perspectives of these two different groups was based on the belief that service providers could offer a better understanding of the benefits and challenges of adopting Big Data based on their own interaction with, and feedback from their clients, while customers that had adopted Big Data solutions could provide us with information regarding benefits and challenges they experienced. Interviewees were senior decision-makers with adequate experience in assessing Big Data solutions.

TABLE I. A LIST OF INTERVIEWEES

Interviewee	Position and institution	Time
Interviewee 1	Senior Software Developer at Informatica	45 min
Interviewee 2	Chief Marketing Officer (CMO) of Huawei Technologies	45 min
Interviewee 3	Manager at Data Aurora Rebai Analytics Group	30 min
Interviewee 4	Senior Consultant at E-Arabia	45 min
Interviewee 5	Computer Engineer at warehousing department in Aramex	40 min
Interviewee 6	Engineering Program Director a leading startup e-commerce company located in Jordan.	50 min
Interviewee 7	CIO at Emerging Market Payments (EMP).	35 min

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A. Case Studies Description

- *Big Data Solution Providers*

Informatica: Located in the heart of Silicon Valley, Informatica provides data integration software and services that enable organizations to gain a competitive advantage in today's global information economy by empowering them with timely, relevant and trustworthy data for their top business imperatives. We interviewed a senior software developer at Informatica to provide us with insights about the uses of Big Data in developed countries as well as the opportunities and challenges facing the implementation of that technology in the region.

Huawei Technologies: Huawei is a leading global Information and Communication Technology (ICT) solutions provider. Through its dedication to customer-centric innovation and strong partnerships, it has established end-to-end capabilities and strengths across the carrier networks, enterprise, consumer, and cloud computing fields. They are committed to creating maximum value for telecom carriers, enterprises and consumers by providing competitive ICT solutions and services. Its products and solutions have been deployed in over 170 countries and regions, serving more than one third of the world's population.

Rabaie Analytics Group: Rebaie Analytics group is a boutique "data" consultancy organization which provides a range of services for vendors, companies, civil society organization, governments and citizens to make their "data" an aurora of innovation, competition and productivity. They help vendors on their product and marketing direction and messaging and they help clients in vendor-neutral selection of Big Data technologies and advise on Big Data strategy and architecture. They also build data auroras that focus on data visualization, analysis, crowdsourcing, and collaboration. Data auroras aid organizations in harnessing various information streams in real time, analyzing their data seamlessly and their sharing their story to the world.

- *Big Data Solution Customers*

Emerging Market Payments (EMP): EMP Middle East, previously Visa Jordan Card Services, was founded in 1991 by Visa and a group of Jordanian banks to ensure high quality Visa acceptance and processing in the country. Based in Amman, Jordan, EMP Middle East is run by a highly experienced management team and more than 70 employees. The company serves more than 20 banks and 18,000 merchants in Jordan and the surrounding region. EMP Middle East also operates Jordan's national ATM switch, JoNET, and a state-of-the-art card personalization facility.

A leading e-commerce startup company: The Company was established by experts at leading firms in the fashion and e-commerce industry. Seasoned shoppers and experienced ecommerce engineers joined forces to bring their passion, expertise and the latest offerings to fashion lovers in the Middle East. The Jordan based company claims to use the most advanced technologies in the industry to offer their customers a comfortable, enjoyable and secure shopping experience anyplace/anytime. Their back office harnesses the latest innovations in the industry, allowing them to customize and personalize their offers to best suit the needs of their customers.

Aramex: Aramex is a leading global provider of comprehensive logistics and transportation solutions. Established in 1982 as an express operator, the company rapidly evolved into a global brand recognized for its customized services and innovative multiproduct offering. In January 1997, Aramex became the first Arab-based international company to trade its shares on the NASDAQ stock exchange. After five years of successful trading, Aramex returned to private ownership in February 2002 and continued to expand and excel as a privately owned company, establishing global alliances and gaining stronger brand recognition. In June 2005, Aramex went public on the Dubai Financial Market (DFM) as Arab International Logistics (Aramex) with its shares traded under ARMX. Today, Aramex employs more than 13,900 people in over 354 locations across 60 countries, and has a strong alliance network providing worldwide presence. The range of services offered by Aramex includes international and domestic express delivery, freight forwarding, logistics and warehousing, records and information Management solutions, e-business solutions, and online shopping services.

E-Arabia: E-Arabia is a startup e-commerce company. It is a platform that helps start-up e-commerce companies in hosting their e-commerce solutions as well as integrating their solutions with online payment companies, and logistical companies (e.g., Aramex, DHL, FedEx).

B. Data Collection and Analysis

Data collection took place between April 2014 and June 2014 and was primarily personal face-to-face semi-structured interviews, a technique well suited to exploratory research. This is because it allows expansive discussions to illuminate factors of importance [17]. Seven direct face-to-face semi-structured interviews have been conducted. Face-to-face interviewing may be appropriate where depth of meaning is important and where a research is primarily focused on gaining insight and understanding. A set of research questions were formulated in an attempt to meet the main objectives of this research. Questions were compiled from validated instruments in the literature to represent each construct and wording was modified to fit the Big Data context. Major questions directed to interviewees were related to the concept and role of Big Data and its impacts on businesses. The interviews were recorded, transcribed, edited and qualitatively analyzed. Data were consolidated through brainstorming sessions, informal conversations, discussions and field notes of daily observations. Accordingly, a picture of the current situation

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concerning the opportunities and challenges of Big Data can be formed.

The length of each interview was approximately 45 minutes. Participants were freely expressing their opinions, seeking answers and suggesting solutions. On the other hand, other sources of secondary data such as brainstorming sessions, informal conversations, and reports have been also combined altogether to supplement data. The compelling reason for using an interview as the main methodology was completely based on the qualitative nature of the theories and their complexity related to represent a suitable research analysis. The interview questions count to 25 questions as a net total count. The 25 questions were distributed in a maneuver that accommodates for covering almost all the ideas concerning the study's main objectives. Having all interviews in hands, the transcribed data of the seven interviews went through preparation and editing processes to make it ready for the analysis. The resulted textual data was then aggregated with the hand notes of the researchers and the combined content was qualitatively analyzed. The analysis procedure has been performed using NVIVO 10.0 software. NVIVO is a computer assisted qualitative data analysis package, settled by QSR International [21]. This software offers a set of functions that support the coding and recovery of text. Another remarkable privilege is that it assists researches to write down memos during the analysis process [22]. In an attempt to conquer reliable and informative knowledge out of the interviews, each single interview has skilfully created a transcript that was saved in a distinct word processor document. This has enabled sustaining fertility of the interviews data. Afterwards, all documents were imported in NVIVO for reading, analysis and coding. The main objective of the analysis was to transform data into findings, but more importantly was to make a sense out of it. During the analysis, recurring ideas, patterns of beliefs, and salient themes were extracted with relevant quotations that demonstrated support for these themes. The emerging themes were then examined based on their intensity, depth, and specificity with the phenomenon of interest, with additional emphasis given to comments that were frequently repeated or refuted by the interviewees [23].

IV. RESULTS AND DISCUSSION

Big opportunities can be considered as an essential factor in influencing the decision of adopting Big Data [3][5]. In recent years, Big Data has become a major topic in the field of ICT. Novel digital technologies such as Big Data are transforming the ICT industry and the way companies can operate. It is evident that Big Data generates business opportunities. By analyzing Big Data, organizations can capture new facts about their customers, partners, products, services, and operations and then use that information for business advantage [15]. For example, businesses can use such information to develop new products and services, improve decision making, optimize operations, and reduce costs [10]. However, businesses and policy makers need to address considerable issues in order to realize the full potential of Big Data. This section covers the extracted themes that were derived from the analyses of data; each theme converses an issue related to Big Data adoption.

A. Underestimating the Value of Big Data

Over the past two decades, Big Data analytics and technologies have become increasingly important in both the academic and the business communities [24]. Findings of this study revealed that Big Data and business analytics exploitations by Jordanian companies are still at the very infancy stage. According to the interviewees, both start-up and leading enterprises are not fully aware of Big Data and business analytics technologies along with their benefits and outcomes. Despite their general lack of awareness, we have observed that some organizations in Jordan have implemented some sort of business analytics including Database Management Systems (DBMS) and Google analytics. The value that can be derived from Big Data analytics differs from what traditional data analytics can offer. Some of the leading Jordanian companies are using traditional data analytics. According to the interviewee 4, "We are currently using Google analytics, because it is familiar and gets the job done." While interviewee 5 stated, "we use Structured Query Language (SQL) server analysis services to build statistical and analytical reports and dashboards for the business owners in order to help them in the management process". Accordingly, it seems that most of Jordanian companies do underestimate the value derive from unstructured data.

What can be established from our interviews with well-established enterprises as well as startup companies based here in Jordan that there are no serious steps or plans for fully utilizing Big Data technologies in the near future. Most of Jordanian companies are still using traditional technologies mainly for automating business processes. Generally speaking, we have realized that there is a lack of interest in implementing business analytics in general and Big Data in particular. Interviewee 6 stated that "there is no need to implement Big Data to start-up enterprises since most of the data we use is structured and we barely use unstructured data". The aforementioned statement by Interviewee 6 also indicates that they are some sort of misunderstanding and misconception about big data technologies.

B. Misconception About Big Data and its Actual Size

In an IBM study [15], it has been discovered that over half of all defendants contemplate their datasets that are between one terabyte and one petabyte to be Big Data. This includes more than three-quarters of midsize companies. However, it has been established that size alone does not matter; Big Data is also about an extraordinary diversity of data types, delivered at various speeds and frequencies [15]. Big Data is defined as "any dataset that cannot be managed

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by traditional processes and tools, any line that outlines "big" and "small" data is arbitrary because the key characteristic is that the data has a greater volume than the current data ecosystem can manage" [13]. This theme has a wide misapprehension, the Jordanian interviewees believed that "Big Data" refers to having "large datasets" and almost all argued that "they do not have large amounts of information nor they deal with large amounts of unstructured data". Interviewee 2 further commented that Big Data refers to "Any company with lots of information and questions." Interviewee 1 referred to it as "Applications that require data analysis with large volumes on continuous stream of data." Indeed, the aforementioned statements clearly highlight the misunderstanding concerning the size of data required for Big Data. On the other hand, interviewee 3 who clearly illustrates the issue of size in Big Data stated that, "when it comes to size of the data, we often tell our clients that it is not about the size of data you have, rather it is about the value that can be extracted from your data. Even with few megabytes, organizations now mash-up datasets and tell interesting stories with data. Some clients have terabytes of data and others have megabytes. You can start small and start playing with the tools and move on".

C. Corporate Culture is Critical

Novel technologies (e.g., social media, cloud computing, mobile computing and Big Data) are transforming the ICT industry and the way companies across all markets and industries can operate (European Commission, 2013). Previous research on IS/IT indicated that culture is one of the critical factors for implementing new innovations [1][14][25]. This research also finds that corporate culture is a significant organizational factor that impacts the adoption and implementation of Big Data. This issue has been explicitly expressed by the majority of interviewees. For example, interviewee 2 argued that "corporate culture influences are significant! The industry expression is "we don't know what we don't know" is all too true. Many, marketing professionals in particular, see Big Data as a "Harry-Potter like" magic solution. However, at an average cost of $10m USD, the CEO and board expect to see a return." Interviewee 1 also explained that, "The corporate culture has huge influence not only on Big Data adoption but also on any novel IT initiatives. Chances are significantly higher to succeed in adopting Big Data in a given company if it enjoys a culture that supports technological innovations". Similarly, interviewee 7 stated that, "the technology is there and available and many leading organizations have the capabilities to impersonate all these new technologies. To me the big challenge comes in the people and culture. So we humans became major players in the data-driven plan".

D. Security, Privacy and Ethical Concerns

Security has been emphasized as one of the main issues in Big Data adoption literature [16][19]. What can be derived from all the interviews is that security is the number one concern when implementing Big Data. Privacy is another huge concern, and one that increases in the context of Big Data [1]. Another literature perspective adds, "We, however, face many challenges, such as legal, privacy, and technical issues regarding scalable data collection and storage and scalable analytics platforms for security" [19]. Thus, securing both data and communication is really vital for Big Data providers and consumer. Our investigation exposed that there are huge concerns about data privacy and security risks. This presents many challenges for widespread adoption of Big Data in Jordan and in developed countries. There are many remarks in respects to this theme came from our interviewees. For example, interviewee 3 clarified that, "Big questions to be asked when it comes to Big Data revolve around privacy and security. Do you know how your data is being used? Do you trade-off your data in order to get a better experience and have more fun?". Interviewee 1 also explained that "security and privacy are the main priorities", interviewee 1 agreed with interviewee 3 by saying "Security and privacy are part of the main challenges when implementing Big Data".

Policy makers have long struggled to draw the line for ethical data use, the discussion has historically revolved around the definition of "sensitive data." Yet, any attempt to exhaustively define categories of sensitivity typically failed, given the highly contextual nature of personal information [16]. With the rise of Big Data technologies, business innovators are thrilled about the prospective benefits they are able to generate from the design and development of a wide range of new products and services based on the size, variety, and velocity of information available raises new questions [18]. Some of those questions are about the implications of the acquisition, storage, and use of large quantities of data about people's attributes, behavior, preferences, relationships, and locations [18]. Ethical concern is the most sensitive topic, when we discussed with interviewee 2 about his thoughts about the risk of unauthorized use of data by Big Data providers, he commented, "It is a big risk…providers may sell your data to advertisers. This may result in an unwanted intrusion to your life by others; a one big reason I advocate "permission-based marketing." Interviewee 3 commented, "Unfortunately, there are no clear ethical standards in the world of Big Data although this is much needed now."

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Around the world today, there is an overwhelming demand for tools that could help organizations in accessing, analyzing, governing, and sharing information. This study is concentrating on understanding the current state of Big Data in developing countries, particularly Jordan in comparison to developed world. Drawing on seven case studies of service providers and customers from different countries around the

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globe, this study contributed to the existing Big Data literature by addressing the complex and multidimensional nature of innovation adoption. Findings of this study indicated that there are many promised benefits of Big Data technologies such as better decisions making and hence improve every aspect of businesses, for example those related to cost reduction, sales improvement, gaining competitive edge, and ultimately improving business profit margins. However, many technical, organizational and environmental challenges described in this study must be addressed before this potential can be fully realized. These challenges include security, privacy and ethical concerns, lack of awareness and misconceptions about Big Data amongst Jordanian leading enterprises, lack of experts in the field, corporate culture, resistance to change, and other technological issues, such as complexity in data modeling and integration approaches.

B. Recommendations and Implications

- Awareness and Literacy

The lack of awareness about Big Data in Jordan exposed an important need for extensive workshops and conferences to fulfil this significant gap as well as to emphasize on the benefits and the importance of riding the Big Data wave as it is the way to future. Furthermore, the need to stress on the importance of pursuing the study of data sciences and analytics amongst high school students and undergraduates considering continuing their education since data scientists are huge assets to any developing country as well as the need to include Big Data courses in business and ICT majors in Jordanian universities to ensure the planting of seeds to a fruitful future of Big Data in Jordan.

- Integration

There is a deep need for an intermediary to facilitate and assist in the implementation of Big Data in organizations and integrating Big Data with the rest of the business processes and technologies. There should be more motivation for Big Data startups to be established to help in this aspect so more companies would adopt Big Data.

- Security, Privacy and Ethical issues

Big Data environment should be aligned with organizational security and privacy requirements. Security measures need to be implemented so as to ensure the privacy of information.

- Customer Alignment in Strategic Plans of Jordanian Companies

The lack of focus on the customer needs and desires in Jordanian companies has been noticeable where the use of Customer Relationship Management (CRM) tools were limited and performance was mainly measured strictly by revenue figures, whereas the core of successful Big Data implementation is always keeping the customer in mind and always caring for what is best for the customer. The need for the customer alignment with business models and strategic plans is crucial to the success of Big Data in companies.

- Need For More Data-Driven Decision Making in Jordanian Companies.

For IT experts, data is a valuable currency or resource like gold or money that will open opportunities that no one has ever thought of, due to the fact that the insight you can get from your market through data are immeasurable. The stress of the need for more data-driven decision-making cannot be stated enough as it will revolutionize the direction and future of companies.

Our future plan is to conduct further studies supported with more interviews and surveys in the area of Big Data so we can keep up to date with the latest improvement regarding Big Data technologies. In addition, with the help of our MIS department, we are planning to organize the first Big Data workshop or conference that will gather professionals from the Jordanian market with IT specialists from around the world to help us in raising awareness about Big Data in the Jordanian market.

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