BUSTECH 2018

The Eighth International Conference on Business Intelligence and Technology

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BUSTECH 2018 Editors

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BUSTECH 2018

Forward

The Eighth International Conference on Business Intelligence and Technology (BUSTECH 2018), held between February 18 - 22, 2018 - Barcelona, Spain, 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.

We take here the opportunity to warmly thank all the members of the BUSTECH 2018 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 2018. 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 2018 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope BUSTECH 2018 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 Barcelona provided a pleasant environment during the conference and everyone saved some time for exploring this beautiful city.

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Calculating Test Coverage for BPEL Processes With Process Log Analysis

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***Abstract*—Today more and more business processes are digitized by implementing them in specialized workflow languages like the Business Process Execution Language (BPEL) or Business Process Model and Notation (BPMN 2.0), which orchestrate services along the process flow. Because these process models are software artefacts of critical importance to the functioning of the organization, high quality and reliability of these processes are mandatory. Testing therefore becomes an important activity in the development process. Test Coverage Metrics have long been used in software development projects to assess test quality and test progress. Current approaches to test coverage calculation for BPEL either relies on instrumentation, which is slow, or is limited to vendor-provided unit test frameworks, in which all dependent services are mocked (unit tests), which limits the applicability of such approaches. Our approach relies on analyzing process event logs that are written during process execution. This approach does not require additional infrastructure and can be used in unit tests, as well as in system and integration tests. We found that our approach for measuring test coverage is not only more flexible but also faster than an instrumentation-based approach.**

Keywords–Test Coverage; Process Mining; BPEL; Event Log.

I. INTRODUCTION

Executable Business Processes, implemented with WS-BPEL or BPMN2, are used to automate business processes in large companies. They are software artefacts and can contain complex orchestration logic. With the increasing demand for fully digitized solutions, it is likely that more and more business processes are being implemented in these or similar orchestration languages.

Because business processes and as such their software implementations are very critical to the functioning and performance of organizations, it is mandatory to do good quality assurance in order to avoid costly problems in production [1]. It has been shown by Piwowarski et. al [2] that a) test coverage measurements are deemed beneficial by testers, although b) they are rarely applied because of being difficult to use, and c) that higher coverage values lead to more defects being found. These findings are supported by Horgan et al. [3], who linked data-flow testing metrics to reliability, and Braind et al. [4], who simulated the impact of higher test coverage. Furthermore, Malaiya et al. [5] and Cai & Lyu [6] have developed prediction models that can link test coverage with test effort and software reliability.

Quality Assurance, and thus test coverage calculation, are an ongoing activity because executable processes will evolve over time [7]. One way for continously measuring test quality is to measure test coverage as part of all ongoing testing activities. Test Coverage then serves as measurement of test data adequacy [8].

While approaches applicable for unit testing executable processes have been proposed by academia (e.g., [9], [10]) and developed by vendors for their respective process engines, there is no practical way to efficiently calculate test coverage for tests that are not controlled by a process testing framework. Also, approaches relying on instrumentation create significant additional overhead by a factor larger than 2.0 compared with the "plain" test case execution times [11] – which is far more than instrumentation approaches for "normal" programming languages, e.g., Java, impose.

For improving the guidance of quality assurance in software projects developing executable processes, an approach is required that can be used in non-unit test scenarios and is ideally faster and easy to set up. Within this paper, we propose a new approach based on analyzing process event logs, which are written by process engines regardless of whether testing frameworks are used or not. Our research goal is to calculate test coverage metrics more flexible and faster by leveraging processes' events logs.

The paper is structured as follows: First, the process modeling language BPEL is shortly explained in Section II before related work is presented in Section III. Our approach for mining test coverage metrics is described in detail in Section IV. For validating our approach, we conducted an experiment, which is presented in Section V. Finally, we conclude the paper and give an outlook on future work.

II. BACKGROUND ON BPEL

BPEL (short for WS-BPEL; Web Services Business Process Execution Language) is an OASIS standard that defines a modeling language for developing executable business processes by orchestrating Web services.

BPEL Models consist of *Activities*, which are divided into *Basic Activities* and *Structured Activities*. *Basic Activities* carry out actual work, e.g., performing data transformations or calling a service, while *Structured Activities* are controlling the process-flow, e.g., conditional branching, loops, etc.

Important *Basic Activities* include the *invoke* activity (which calls Web services), the *assign* activity (which performs data transformations), and the receive and reply activities (which offer others to call a process via service interfaces). Important Structured Activities are the *if*, *while*, *repeatUntil*, and

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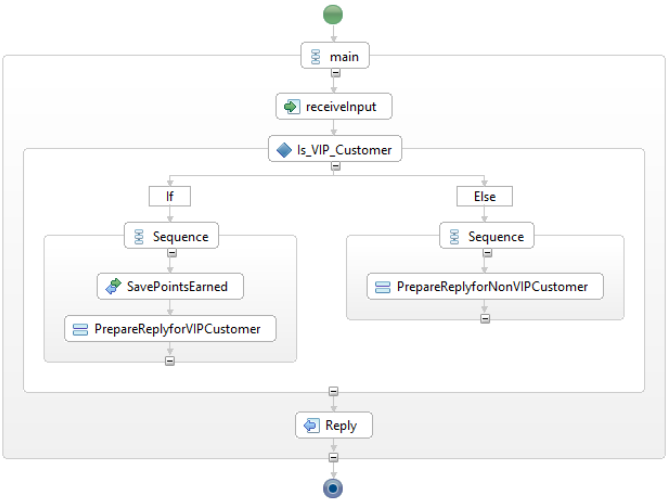

Figure 1. Sample BPEL Process for processing an Order.

forEach activities, which offer the same control-flow structures like their pendants in general purpose programming languages, and the *flow* activity, which allows process designers to build a graph-based model including parallel execution. For building the graph, BPEL offers *links* that can also carry conditions for modelling conditional branches.

For handling error conditions and scoped messages, BPEL provides different kinds of *Handlers*: *Fault Handlers* are comparable to try/catch constructs: Whenever a SOAP Fault is returned by an invoked service or is thrown by the process itself, the Process Engine searches for defined Fault Handlers. These may trigger *Compensation Handlers*, which can undo already executed operations. For receiving events asynchronously outside the main process flow, *Event Handlers* can be defined. These come in two flavors: *onEvent Handlers* for receiving SOAP messages, and *onAlarm Handlers* for reacting on (possibly reoccurring) times and time intervals.

BPEL does not define a graphical representation, like, e.g., BPMN2 does, but standardizes the XML format in which it is saved. Vendors have developed their own graphical representation. Within this paper we use the notation used in Eclipse's BPEL Designer. A process that will be used for examples in this paper is shown in Figure 1: A customer places an order ("receive input"). A check is made, whether the customer has VIP status or not. In case of a VIP customer, points are credited to the customer's account ("SavePointsEarned"). In both cases appropriate response message to the customer are prepared ("PrepareReplyFor…"), which is then sent back to the customer ("reply").

BPEL processes are deployed to a *Process Engine*, which has the responsibility for executing process instances and managing all aspects around process versioning, persistence, etc. The amount of data, which is persisted during process execution, is vendor-dependent and can be configured during the deployment of a process model in most engines.

BPEL has been designed to be extensible. Many extensions by both standard committees and vendors have been made. For example, BPEL4People allows to interact not only with services but also with humans during process execution.

III. Related Work

With the rise of BPEL, testing of these critical software artefacts became subject of many research projects. For example, Li et al. (BPEL4WS Unit Testing Framework [9]), Mayer & Lübke (BPELUnit [10]), and Dong et al. (Petri Net Approach to BPEL Testing [12]) published their ideas.

The BPELUnit framework was later extended by Lübke et al. [11] with test coverage measurement support. First, the metrics needed to be defined, which is not as straightforward as for other languages due to BPEL's different mechanisms for defining the process-flow. Consequently, three metrics were defined: **Activity Coverage**, **Handler Coverage**, and **Link Coverage**. Coverage Measurement was done by instrumenting the BPEL process: For tracing the execution, the process is changed prior to deployment. Additional service calls are inserted for every activity. The service calls send the current position ("Markers") to the test framework. Because of this the test framework knows which activities have been executed in the test run. However, the test framework needs to run while the instrumented processes are executed, which makes its use limited to automatic tests only. Also, the overhead introduced by many new service calls is considerable: The reported overhead is more than 100%, i.e., the test execution times are more than doubled. This is because every execution trace point needs to be send out of the process via a service call, which requires XML serialization and involves the network stack. This also makes the BPEL process much larger: The number of basic activities tripples for instrumenting all measurement points for calculating activity coverage alone. One advantage of the approach is that is only slightly dependent on the Process Engine being used: The changes to the BPEL process are completely standards-compliant. Only the new service for collecting the Markers needs to be added to the engine-specific deployment descriptor.

Process Engine vendors have also developed their own proprietary solutions: Test Cases are developed in the development environment of the process engine and can be executed from there or on a server. All services are mocked and the test frameworks simply inject predefined SOAP messages. Such test frameworks use a striped-down version of the process engine. This results in a mixture between simulation and test: The process engine uses the same logic but not all parts of its code are triggered because some features are disabled. Also, there is no possiblity of calling "real" services instead of mocks. While test coverage calculation is very fast, because the algorithms have access to internal engine data, its use is limited to unit test scenarios only. Examples of such vendor-provided test frameworks are Informatica's BUnit [13] and Oracle's BPELTest [14].

All in all, there is currently no approach available for BPEL processes that can be used to measure test coverage on code level with acceptable performance and the ability to be used in conjunction with manual tests and integration & system tests.

IV. Test Coverage Mining

This section will present the different steps that are performed for analyzing the process log in order to calculate test

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coverage.

A. Metric Calculation Process

For calculating test coverage, we use process mining techniques. Process Mining is concerned to build "a strong relation between a process model and 'reality'captured in the form of an event log" [15, p. 41]. By having the BPEL process model and all test cases available as event logs from the process engine, we are able to "replay" the event logs generated from the tests on top of the BPEL process model. Out of the many possible motivations to do a replay, our goal is to extend our model with frequency information [15, p. 43].

Accordingly, our approach is divided into three sub-steps, which are described in the following sections:

1) Build the BPEL Process Model Syntax Tree from its XML representation (BPEL Analysis),
2) Fetch the event log from the Process Engine (Data Gathering),
3) Replay the event logs on top of the BPEL Process and calculate coverage metrics (Mining).

B. BPEL Analysis

Within this step, the BPEL XML representation is read and the control-flow graph is being constructed as described by the block-based structured activities. For example, activities contained in *sequence* activity are chained together by control-flow links. The construction of the control-flow graph is the same as for the instrumentation approach to measuring BPEL test coverage [11] and thus takes the same time to build. The BPEL Models are accessible via the process engine's repository and can be extracted as part of the coverage mining.

C. Data Gathering

The case study project, which we could analyze, uses Informatica ActiveVOS [13]. ActiveVOS is a process engine fully compliant with the BPEL 2.0 and BPEL4People standards and stores all data (process models, process instances, process logs, ...) in a relation database. This allowed us to access and analyze the available data that can be mined for test coverage metrics. For different persistence settings ActiveVOS stores different lifecycle events for every BPEL activity, which include *ready to execute*, *executing*, *completed*, *faulting* and *will not execute*. In addition, there are two more event types for links (edges for graph-based modeling): *link evaluated to true* and *link evaluated to false*. Besides the event time, the event timestamp, the corresponding process instance, an internal activity or link ID is logged.

This means that all necessary data is available in order to reconstruct the process-flow and thereby calculating the test coverage metrics: For calculating activity coverage, all *completed*, *faulting* and *link evaluated* events need to be fetched for a given test run. All other event types can be ignored, which allows to use all engine settings except for "no logging." The underlying conceptual data model, as it is implemented in the ActiveVOS engine, is shown in Figure 2.

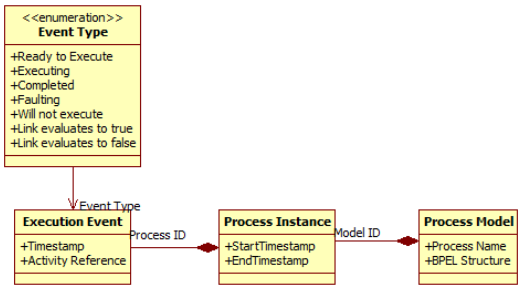

Figure 2. Conceptual Data Model of the Process Engine being used.

D. Replay & Metric Calculation

Test Coverage can be calculated with the data extracted in the previous steps. At first, all activities and conditional links in the syntax tree are marked as not executed. In the second step, all events are being applied to the syntax tree and all activities that have a corresponding *completed* or *faulting* event are marked as being executed. Also, conditional BPEL links for graph-based modeling are marked. However, every link can carry two different markers: one if the condition was true and another if the condition was false. Because links without a condition are excluded from the coverage metric, they are ignored from further analysis.

During this phase, loop activities can be marked as executed twice for calculating the branch coverage in later stages. This happens for most loops by setting this marker, if the loop is executed twice after each other. The only exception is the parallel *forEach* loop, in which the activity ID contains the number of the currently executed parallel branch. If a counter larger than one is encountered, the *forEach* activity is marked as executed twice.

The main problem in this step was to link events and activity nodes in the BPEL model. Because the activity IDs in the events are generated by the process engine and are not part of the BPEL model, it is necessary to first resolve the proprietary IDs to the activities. The generated activity IDs are in an XPath-like structure, which closely resembles the XML structure of the BPEL model. However, some cleaning and re-writing of these IDs is necessary, because they sometimes reference internal data structures and do not directly map to the BPEL activities. After re-writing the IDs, they can be converted to XPath expressions that directly point to the BPEL activity being executed. This step is highly specific to the process engine being used and needed reverse-engineering the format and construction rules for the proprietary IDs.

After all events have been applied to the syntax tree, the coverage metrics can be calculated. The easiest test coverage metric to compute is the Activity Coverage C_A metric: The syntax tree is traversed and all activities are counted which are marked (A_m) and which are not marked (A_u) as shown in equation 1.

$$C_A := \frac{|A_m|}{|A_m| + |A_u|} \tag{1}$$

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Similarily, Handler Coverage C_H can be calculated by searching the syntax tree for handlers that have been successfully executed.

Calculating Link Coverage C_L by process mining is easier than with instrumentation: In order to detect the different conditions on links, instrumentation needs to insert many new links and activities. However, with process mining, dedicated events are triggered whenever a link condition has been evaluated.

E. Example

To illustrate the replay of the event log on top of the process model we assume two test cases for the example BPEL process as shown in Figure 3. The first test case tests the VIP Customer.

As can be seen by the trace, the completion events are differently ordered than the definition in the BPEL process model: structured activities like a *sequence* or an *if* are completed after all their child activities have been completed. The replay algorithm needs to take this into account when replaying the event log against the process model.

Taking the event log for the first test case and replaying it on top of the BPEL process model yields the markings as illustrated in the center of Figure 3. Replaying the second test case yields the markings as shown on the right hand side of the same figure. With these two test cases, all basic activities are covered.

F. Comparison to Instrumentation

When we compare our approach to instrumentation (see Figure 4), there are many parts of the calculation that are similar or even the same. Instrumentation would initially load the BPEL process model and construct a syntax tree. However, it would then change the process model by introducing service calls that signal the internal process state to the test framework. During run-time these service calls are equivalent to log events. These events are replayed on the process model in both approaches. Thus, the main differences are that

- instrumentation needs to build the syntax tree prior to the test run and a service receiving all markers must be active during the whole test while process mining can perform all activities after the test run is completed,
- instrumentation needs to change the BPEL process model while process mining does not, and
- the events are collected in the instrumentation approach by signaling service calls instead of extracting all event logs with one database query like in our approach. For a test run, the instrumentation approach requires at least as many service calls for signaling the process state as the number of executed basic activities depending on the coverage metrics that shall be calculated.

Due to these structural differences, we expect our approach to be overall faster than the instrumentation approach: Making and answering many fine-grained service calls is time-consuming as outlined above. Being able to fetch all events from the Process Engine's event log at once should yield better performance. In addition, our approach does not slow down execution times of the executable processes itself because they behave as they are implemented and are not changed by an instrumentation process and their run-time behavior is not altered by introducing probes. This means that no additional error sources (e.g., by defects in the instrumentation) or different behavior (e.g., in parallel activities by instrumentation code) can occur.

G. Sample Implementation

We implemented a tool that performs the outlined test coverage calculation. The tool connects to the database of the process engine and extracts all relevant information. After the tests have been completed, the tool extracts the events for all newly created process instances. It expects that the tested processes have been configured appropriately to at least store the events for successfully and unsuccessfully completed activities.

The implementation is highly dependent on the process engine being used. The available process log data and its format is defined by vendors because it is not specified in any standard. As outlined in the previous section, a post-processing of the event log data is needed in order to properly resolve the referenced activities.

V. Experiment

In order to evaluate our approach, we conducted a small experiment that is described in this section.

A. Experiment Description & Design

For evaluating the practical applicability and the performance implications of our approach, we want to research the following two research questions:

RQ1: What is the associated overhead for mining process coverage?

RQ2: Is the associated overhead for mining process coverage less than for instrumentation-based coverage calculation?

For this we define a two factor/two treatments with-in group experiment design: The first independent variable is the coverage method (Instrumentation vs. Mining) and the second is the test suite size. Our dependent variable is the execution time of the measured test suites.

As subjects we used 4 BPEL processes, for which we could automatically – and thus unbiased – generated test suites of different sizes by using facet classification trees [16]. Two processes are taken from Schnelle [17] and two processes are taken from Terravis, which is an industrial project, which develops and runs a process-integration platform between land registers, notaries, banks and other parties across whole Switzerland [18].

B. Data Collection

For running the experiment we set up a process engine on a dedicated virtual server together with the required infrastructure, e.g., the tools for measuring test coverage.

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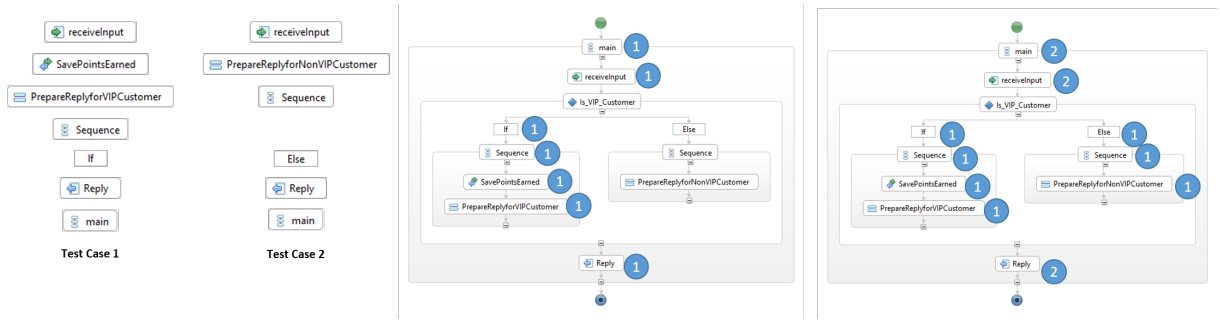

Figure 3. Event Logs for two Test Cases (Left), first Test Case replayed on BPEL Model (center) and both Test Cases replayed on BPEL Model (right).

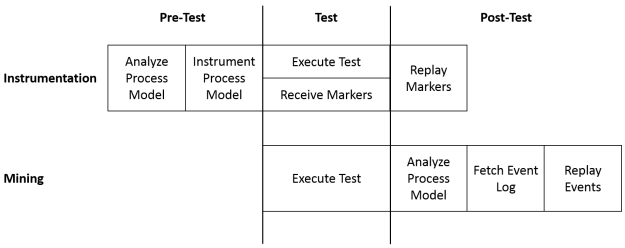

Figure 4. Comparison of Instrumentation and Mining.

Because the original BPELUnit tool for measuring test coverage [11] did not support vendor extensions and the deployment artefacts of the used process engine, we needed to re-implement the instrumentation tool with full support for all features, which are used by the industry project.

We measured the execution times by following the described process:

1) For every BPEL process, generate the test suites of different sizes,
2) For every test suite and for every calculation method, run 10x:
   a) Instrument the deployment unit (if necessary)
   b) Deploy the process,
   c) Run test suite,
   d) Wait for process log and calculate coverage (if necessary)

For every process, we generated random test suites with the sizes $n \in \{1, 5, 10, 25, 50, 75, 100\}$ if possible. The processes by Schnelle had only a smaller number of possible test cases, thereby the experiment could only use test cases with max. 25 and respectively 50 test cases.

We executed all test suites ten times in order to build mean values for all time measurements. All in all, 460 test suites runs were made for each coverage measurement method.

For all our test executions we used a virtual machine with 2 virtual CPUs and 4 GiByte of RAM running on Kubuntu with Informatica ActiveVOS 9.2 and MySQL.

C. Results

The mean execution times of our measurements (calculated in milliseconds) are shown in Table **??**. T or S indicate the process set (Terravis or Schnelle), 1 or 2 indicate which process, and I or L indicate the coverage measurement method (instrumentation or log analysis).

The mean value for the smallest test suites with only one test case are smaller for instrumentation than for log analysis. For all other chosen test suite sizes, log analysis performs faster.

TABLE I. TOTAL MEAN EXECUTION TIME (ms)

#TC	T1-I	T1-L	T2-I	T2-L	S1-I	S1-L	S2-I	S2-L
1	8532	7718	5138	4915	4544	3825	4029	4140
5	16240	10958	11736	6533	6646	4492	6553	4249
10	19523	12446	14356	7090	10567	5942	9737	5586
25	38262	19309	34086	11760	15856	6688	18290	7675
50	62288	27264	62589	17736	29584	9799	-	-
100	120720	48628	118413	28318	-	-	-	-

By subtracting the normal execution time of a test suite we derive the absolute overhead (calculated in ms) as shown in Table II. In general, the numbers for log analysis are much lower than for instrumentation and do not increase that much. The highest overhead for log analysis is 6519ms in contrast for up to 94287ms for instrumentation. The overhead is the largest for the first Terravis process (T1) for process log analysis while it is the largest for instrumentation with the second Terravis process (T2).

TABLE II. ABSOLUTE OVERHEAD OF COVERAGE CALCULATION

#TC	T1-I	T1-L	T2-I	T2-L	S1-I	S1-L	S2-I	S2-L
1	2565	1751	2054	1830	1872	1153	1549	1660
5	7288	2006	7124	1920	3562	1408	3562	1258
10	9447	2370	9100	1834	6722	2098	5792	1641
25	22580	3628	24808	2482	10741	1574	12672	2057
50	39707	4683	48003	3150	21637	1852	-	-
100	78611	6519	94287	4193	-	-	-	-

We calculated the relative overhead for the processes by dividing the absolute overhead by the normal test suite execution time as shown in Table III. While for larger test suites the relative overhead increases with instrumentation, it decreases for log analysis. Relative overhead of instrumentation ranges between 43% and 391%, while it ranges bwetween 16% and 68% for log analysis.

The measurements grouped by coverage calculation method and process for all test suite runs are shown in Fig-

TABLE III. RELATIVE OVERHEAD OF COVERAGE CALCULATION

#TC	T1-I	T1-L	T2-I	T2-L	S1-I	S1-L	S2-I	S2-L
1	0.43	0.30	0.67	0.59	0.71	0.43	0.64	0.68
5	0.78	0.23	1.55	0.42	1.16	0.46	1.19	0.42
10	0.94	0.24	1.73	0.35	1.75	0.55	1.48	0.41
25	1.44	0.23	2.68	0.27	2.10	0.31	2.26	0.37
50	1.76	0.21	3.29	0.22	2.73	0.23	-	-
100	1.93	0.16	3.91	0.17	-	-	-	-

ure 5. Test suites with more test cases expectedly take longer to execute. Log analysis is usually faster than instrumentation.

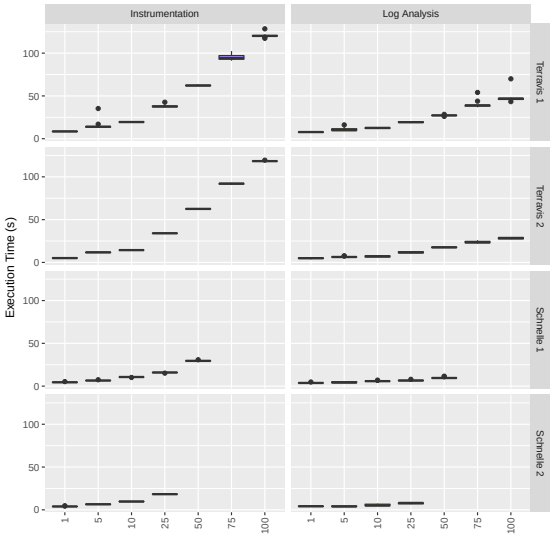

Figure 5. Overall Execution Times

The absolute and relative overhead of both coverage calculation methods are shown in Figure 6 and can be compared directly. Different colors indicate different processes. The absolute overhead shows clusters of overhead times that are associated with a test suite. As can be seen the values for both the absolute – and following from that – the relative overhead are higher most of the time for the instrumentation approach. Only in 13 of 460 measurements instrumentation was faster than log analysis. All of those measurements are concerned with test suites with only one test case.

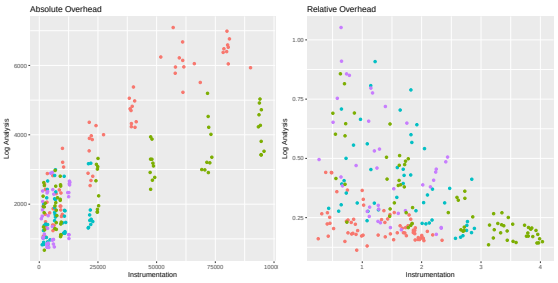

Figure 6. Coverage Measurement Overhead

In order to answer RQ2 we performed a paired, two-sided Wilcoxon hypothesis test with the null hypothesis H_0 being

TABLE IV. P-VALUES (TWO-SIDED, PAIRED WILCOXON TEST) FOR TEST SUITES WITH n TEST CASES AND FOR ALL TEST SUITES

Test Suite Size	p-Value
1	0.087 69
5	1.25×10^{-6} (***)
10	5.154×10^{-10} (***)
25	2.918×10^{-10} (***)
50	1.691×10^{-17} (***)
75	1.451×10^{-11} (***)
100	1.451×10^{-11} (***)
All	5.034×10^{-12} (***)

that no difference exists in the test suite execution times when using instrumentation or log analysis: Over all executed test suites, $p = 5.034 \times 10^{-12}$. However, we have seen that at least test suites with only one test case behaves differently from other test suites. Therefore, we blocked for the test suite size and derived the p-values as shown in Table IV. Values marked with (***) are less than 0.001 and thus highly statistical significant.

D. Interpretation

1) RQ1: Overhead of Log Analysis: Our measurements for the overhead of log analysisshow demonstrate that the absolute overhead increases and the relative overhead decreases with more test cases. The maximum absolute overhead of 6.5s for 100 test cases the performance penalty is little. This means that measuring approx. 92 test suites of such size would only impose a ten minute overhead (e.g., during nightly builds).

2) RQ2: Overhead of Log Analysis compared to Instrumentation: Our measurements clearly show that log analysis is significantly faster than instrumentation for non-trivial test suites, i.e. test suites with more than one test case. While the relative overhead of instrumentation increases with more test cases and reaches 391% (i.e., nearly quintuples the test suite execution time), log analysis imposes 68% overhead in the worst case of a small test suite but decreases to 16% for large test suites. For a further interpretation typical test case sizes in industry are needed in order to evaluate typical overhead ranges. If we suppose that a typical test suite consists of 25 test cases the relative overhead is between 24% and 55% for log analysis while it already is between 144% and 268% for instrumentation. This means that for any non-trivial test suite, log analysis brings a huge performance benefit when measuring test coverage.

E. Threats to Validity

As with every empirical research there are associated threats to validity. Because we could only use four BPEL processes for our experiment, the question of generalizability arises.

Since we research technical effects only, the findings should be generalizable to all BPEL processes that execute a minimum threshold number of activities or test cases. The p-value for rejecting the null hypothesis and accepting that log analysis is faster than instrumentation for a test suite size $t \geq 5$ is so low that we are confident that replications will find the same results.

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As long as the process engine stores all relevant events that are required for calculating the test coverage metrics, the log analysis can proceed. To our knowledge, all BPEL engines are able to write event logs that contain the required event types. For every newly supported BPEL engine, a new interpreter of these events needs to be developed. The analysis and replay components can be reused. However, as part of our study we also found that this is also true for instrumentation tools: While BPEL is standardized, its extensions and the deployment artefacts are not.

The presented numbers are only applicable to automated unit tests. While we think it is safe to generalize the absolute overhead to other test scenarios, we expect that the relative numbers to be different: Manual tests take longer for executing the same number of processes, because user interactions take time, which makes the process duration longer. Thus, we do not think that the relative overhead can be generalized to other test types.

VI. Conclusion & Future Work

Within this paper we presented a new approach to mine process event logs – which are usually already written when using a process execution engine – to calculate test coverage metrics of BPEL processes. Our new approach shows clear performance advantages over the instrumentation approach. Furthermore, the process mining approach can be used in other scenarios than the instrumentation approach: Because all activities for mining the test coverage are performed after the tests are run, it does not matter how the tests are run and when they were run. In contrast, coverage calculation needs a marker collection service running the whole time, which in practice is mostly only feasible during unit tests. Mining the process logs is completely independent of any test automation and can be used for automatic unit tests, automatic integration tests but also manual integration and system tests. The only drawback is, however, that the Process Engine needs to be configured to write the event log for all measured processes.

Although we have implemented test coverage mining for BPEL processes, the approach can be applied to other executable process languages as well: Process engine architectures are the same, e.g., BPMN 2.0 as the successor to BPEL defines other activities and is completely graph based. However, process engines executing BPMN 2.0 are also logging events for executed activities which can be replayed on top of BPMN 2.0 process models. Writing the process mining algorithm should be even simpler, because BPMN 2.0 defines process-wide unique identifiers for activities that are hopefully contained in the event log making reverse-engineering of vendor-specific identifiers obsolete.

While we have finished our research implementation, we want to optimize the implementation further and contribute it into the BPELUnit test framework. We hope to find further industry BPEL processes to apply our approach to and have a larger data set for evaluating performance – especially the use of other process engines is interesting and see whether all necessary event data is generally available.

Being able to calculate test coverage for non-unit tests also allows further research into executable process test methods: For example, experiments on the influence of different system testing approaches on test coverage.

References

[1] D. Lübke, Test and Analysis of Service-Oriented Systems. Springer, 2007, ch. Unit Testing BPEL Compositions, pp. 149–171.

[2] P. Piwowarski, M. Ohba, and J. Caruso, "Coverage measurement experience during function test," in Proceedings of the 15th International Conference on Software Engineering, ser. ICSE '93. Los Alamitos, CA, USA: IEEE Computer Society Press, 1993, pp. 287–301.

[3] J. R. Horgan, S. London, and M. R. Lyu, "Achieving software quality with testing coverage measures," Computer, vol. 27, no. 9, Sept 1994, pp. 60–69.

[4] L. C. Briand, Y. Labiche, and Y. Wang, "Using simulation to empirically investigate test coverage criteria based on statechart," in Proceedings. 26th International Conference on Software Engineering, May 2004, pp. 86–95.

[5] Y. K. Malaiya, M. N. Li, J. M. Bieman, and R. Karcich, "Software reliability growth with test coverage," IEEE Transactions on Reliability, vol. 51, no. 4, Dec 2002, pp. 420–426.

[6] X. Cai and M. R. Lyu, "Software reliability modeling with test coverage: Experimentation and measurement with a fault-tolerant software project," in The 18th IEEE International Symposium on Software Reliability (ISSRE '07), Nov 2007, pp. 17–26.

[7] D. Lübke, "Using Metric Time Lines for Identifying Architecture Shortcomings in Process Execution Architectures," in Software Architecture and Metrics (SAM), 2015 IEEE/ACM 2nd International Workshop on. IEEE, 2015, pp. 55–58.

[8] H. Zhu, P. A. V. Hall, and J. H. R. May, "Software unit test coverage and adequacy," ACM Comput. Surv., vol. 29, no. 4, Dec. 1997, pp. 366–427. [Online]. Available: http://doi.acm.org/10.1145/267580.267590

[9] Z. Li, W. Sun, Z. B. Jiang, and X. Zhang, "BPEL4WS Unit Testing: Framework and Implementation," in ICWS '05: Proceedings of the IEEE International Conference on Web Services (ICWS'05). Washington, DC, USA: IEEE Computer Society, 2005, pp. 103–110.

[10] P. Mayer and D. Lübke, "Towards a BPEL unit testing framework," in TAV-WEB '06: Proceedings of the 2006 workshop on Testing, analysis, and verification of web services and applications. New York, NY, USA: ACM Press, 2006, pp. 33–42.

[11] D. Lübke, L. Singer, and A. Salnikow, "Calculating BPEL Test Coverage through Instrumentation," in Workshop on Automated Software Testing (AST 2009), ICSE 2009, 2009, pp. 115–122.

[12] W. l. Dong, H. Yu, and Y. b. Zhang, "Testing bpel-based web service composition using high-level petri nets," in 2006 10th IEEE International Enterprise Distributed Object Computing Conference (EDOC'06), Oct 2006, pp. 441–444.

[13] Informatica. Bpel unit testing. [Online]. Available: http://infocenter.activevos.com/infocenter/ActiveVOS/v92/index.jsp?topic=/com.activee.bpep.doc/html/UG21.html (2016)

[14] Oracle. Oracle bpel process manager developer's guide: Testing bpel processes. [Online]. Available: https://docs.oracle.com/cd/E11036_01/integrate.1013/b28981/testsuite.htm (2007)

[15] W. van der Aalst, Process Mining – Data Science in Action. Springer, 2016.

[16] T. Schnelle and D. Lübke, "Towards the generation of test cases for executable business processes from classification trees," in Proceedings of the 9th Central European Workshop on Services and their Composition (ZEUS) 2017, 2017, pp. 15–22.

[17] T. Schnelle, "Generierung von bpelunit-testsuites aus klassifikationsbäumen," Master's thesis, Leibniz Universität Hannover, Fachgebiet Software Engineering, 2016.

[18] W. Berli, D. Lübke, and W. Möckli, "Terravis – large scale business process integration between public and private partners," in Lecture Notes in Informatics (LNI), Proceedings INFORMATIK 2014, E. Plödereder, L. Grunske, E. Schneider, and D. Ull, Eds., vol. P-232, Gesellschaft für Informatik e.V. Gesellschaft für Informatik e.V., 2014, pp. 1075–1090.

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The Moderating Role of Interorganizational Information Systems in Maximizing the Operational Performance of Dyadic Business Relationships: a Conceptual Model

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Abstract—**The objective of this study is twofold: first, to examine how the structure of a buyer-supplier relationship impacts the operational performance of the supplier involved in the dyadic relationship and second, to test the moderating impact of interorganizational information systems (IOS) usage (assessed through the dimensions of volume, diversity and depth) on the relationship between the structure of a buyer-supplier relationship and the operational performance of the supplier involved in the dyadic relationship. To do so, the marketing and IOS literatures are reviewed to propose a model and seven research hypotheses. Then, the methodology we intend to use to test our conceptual framework is explained. Lastly, the anticipated theoretical contributions and practical implications of the study are discussed.**

Keywords-dyadic business relationship strucutre; inter-organizational information systems; operational performance.

I. INTRODUCTION

Within the field of marketing, the structure of dyadic business relationships and its impact on the performance of each partnering firms is a key concern for practitioners and academics alike [1][2]. The structure of a dyadic business relationship can be defined as the patterned or regularized aspects of exchange between two business counterparts [3]. To date, most studies on this specific concern have focused on the political impact (i.e., cooperation, satisfaction, trust and commitment) while neglecting the economic impact (i.e., cost, speed, quality and reliability) of dyadic business relationship structures [4]. Among the few researchers that have empirically investigated the economic impact of the structure of buyer-supplier relationships, Bonner and Calantone [5] have shown that certain structures provide economic value to buyers. To date, however, no study has yet to investigate whether certain dyadic business relationships structures also provide economic value to suppliers. To partially address this gap in the marketing literature, the first objective of this study is to complement Bonner and Calantone [5] pioneering work by examining how the structure of a buyer-supplier relationship impacts the operational performance of the supplier involved in the dyadic relationship.

Within the field of information systems (IS), numerous authors have demonstrated that interorganizational information systems (IOS) – defined as computer networks that support information exchanges across organizational boundaries [6] – can add economic value to business relationships. For example, Saeed et al. [7] demonstrated that IOS can provide either sourcing leverage or process efficiency, depending on IOS functionalities used. In addition, other IS researchers have discussed the possible symbiosis between IOS usage and the structure of business relationships [2][6][8][9][10]. For example, Malone et al. [9] relied on the transaction cost paradigm in their prediction that the evolution of computer-aided buying and selling would disrupt conventional marketing and distribution patterns. According to these authors, by reducing coordination costs, IOS would increase organizations' reliance on markets rather than hierarchies. A couple of years later, Clemons et al. [8] refuted Malone et al.'s [9] theory by demonstrating that the transaction economies of scale, learning curve effects, and other factors related to IOS use favor a move toward long-term relationships with a smaller set of suppliers (i.e., the "move to the middle" hypothesis). Yet, while conceptually very convincing, no study has empirically validated these propositions. To partially address this gap in the IS literature, the second objective of this study is to complement previous IOS studies by testing the moderating impact IOS usage on the relationship between the structure of a buyer-supplier relationship and the operational performance of the supplier involved in the dyadic relationship.

The rest of this article is organized as follows. First, in Section 2, the literatures on the structure of business relationships and IOS usage are reviewed. Based on these theoretical underpinnings we then present our research model and related hypotheses in Section 3. This is followed, in Section 4, by a discussion of the methodology that will be used to validate our research model. Lastly, Section 5 concludes the article by presenting the anticipated theoretical

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contributions and practical implications of the study, as well as its limits and future research avenues.

II. THEORETICAL BACKGROUND

Taking into account the objective of this study, this section reviews the literatures on the structure of business relationships and IOS usage to propose a sound theoretical background.

A. Structure of a Business Relationship

Traditionally, conceptualizations of the structure of a business relationship have been anchored on two different approaches: an economic approach and a behavioral approach [10]. By applying microeconomic theory and industrial organization analysis, the economic approach is essentially "efficiency" oriented, focusing on costs, functional differentiation and channel design [10]. Williamson [11] is a key contributor to this approach. He asserted that firms organize their exchanges in order to minimize transaction costs and that the ensuing transaction forms may vary according to the degree to which exchange partners maintain decision-making autonomy. Discrete transactions are located at one extreme while highly centralized hierarchical transactions are at the other. Hybrid transactions, such as joint ventures and alliances, are located in between. His pioneering work was among many studies that rely on microeconomic factors to explain the structure of business relationships. On the other hand, the behavioral approach, which is anchored in social psychology and organization theory, is essentially "socially" oriented, and focuses on power and conflict phenomena [10]. Macneil [12] is a key contributor to this approach. Based on a set of contracting norms, he defined the concept of relational exchange on a continuum ranging from discrete to relational. Subsequently, Kaufmann and Stern [13] made an initial attempt to comprehensively operationalize contracting norms, which led the way to more empirical investigations to assess the structure of business relationships according to such norms.

More recently, several authors have combined the economic and behavioral approaches to examine the structure of business relationships, its antecedents and its outcomes [1][10][14][15]. These authors argue that both approaches should be used simultaneously, as interaction effects between economic and behavioral elements may influence the outcome of the exchange [14]. Stern and Reve [10] were the first to adopt this combined approach to study the structure of business relationships. Later on, Boyle et al. [1] proposed a framework anchored on both economic and behavioral elements to demonstrate that communication strategies, captured through communication frequency and content, differ significantly from one channel configuration to the next.

Out of the numerous studies that used the economic approach, the behavioral approach or a combination of the two, three dominant paradigms have emerged to characterize the structure of business relationships: transaction cost, relational marketing and political economy [16]. Of these three paradigms only the latter (political economy) integrates aspects from both the economic and behavioral approaches, making it the most suitable to study the complex business relationship structures present in today's economy [1][14]. Accordingly, numerous authors have adopted the Political Economy Paradigm (PEP) to study business relationships [1][10][14]. Amongst these authors, it is certainly Robicheaux and Coleman [16] who have proposed the most comprehensive framework to characterize and asses the structure of business relationships. Within their framework, the structure of a business relationship is assessed along two continuous axes: decision-making structure and operational integration. The former represents the degree to which the decision-making structure is clannish or bureaucratic (i.e., the polity structure), while the latter represents the degree to which the exchange relationship within a channel dyad is discrete or integrated (i.e., the economy structure). Four measures, namely centralization, formalization, participation and shared paradigm, are proposed to assess the decision-making structure (polity) while the level of operational integration (economy) can be captured through four other variables: joint actions, assistances, monitoring and information exchange. To complement their major contribution to the field, Robicheaux and Coleman [16] also proposed sets of antecedents and outcomes related to the structure of business relationships.

B. Conceptualization of IOS usage

Early studies on IOS usage, such as Venkatraman and Zaheer's [17] empirical work, relied on a single dichotomous variable to assess IOS usage. However, the appropriateness of such a measure was rapidly challenged since the issue from a management's perspective is typically not one of use or non-use, but rather one of how and how much use [18]. To address this issue, researchers rapidly arrived to the conclusion that they needed continuous (rather than dichotomous) variables to assess IOS usage.

Later, two distinct approaches were adopted to develop continuous IOS use variables. The first relied on unidimensional measures to assess IOS usage. Among the numerous authors promoting this approach, we note Wang et al. [19], who conceptualized IOS usage along the dimension of virtual integration, defined as the extent to which trading partners use IT to support the processes related to collaborative operation execution and collaborative process planning and control. The second approach relied on multidimensional measures to assess IOS usage. Authors who favored this approach include Keen [20], who proposed a framework describing the usage of IOS along two dimensions: reach and range. According to this author, reach determines the locations that the system can access and to which it can link, while range is defined as the kind of information that can be seamlessly and automatically shared across the system and services.

More recently, some researchers have combined IT implementation models [21] and the diffusion of innovation theory [22] to propose unidimensional measures to assess IOS usage at different phases of the technology assimilation process. For example, Zhu et al. [23] used a

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three-stage approach to assess firms' e-business assimilation. The first stage, e-business initiation, was measured by an aggregated index capturing whether the firm had used the Internet for each of the seven value chain activities proposed. The second stage, e-business adoption, was assessed by aggregating the seven adoption items. Finally, e-business routinization was measured by the extent of organizational use of e-business to support value chain activities.

To conclude this section, it is important to note that most of the conceptualizations of IOS use proposed to date, whether unidimensional or multidimensional, were inspired by Massetti and Zmud's [24] approach to EDI measurement, which comprised four facets: (1) volume, which assesses the extent to which a firm's document exchanges are handled through EDI connections; (2) diversity, which captures the extent to which different types of documents are handled though EDI connections; (3) breadth, which assesses the extent to which a firm has developed EDI connections with each of its trading partners; and (4) depth, which captures the extent to which a firm's business processes are intertwined with those of its trading partners through EDI connections. Depending on the context of the research, one or more dimensions of this scheme have been used to assess firms' usage of different types of IOS, including EDI [25], SCM systems [26] and IOS in general [27].

III. CONCEPTUAL FRAMEWORK

Taking into account that this research focuses on the economic aspects of dyadic business relationships, we build on the theoretical background presented above to propose a research model that first considers the direct impact of the structure of a buyer-supplier relationship on the operational performance of the supplier involved in the dyadic relationship (Figure 1). Operational integration, which is one of the two axes proposed by Robicheaux and Coleman to assess the structure of a business relationship, represents the degree to which an exchange relationship within a business dyad is discrete or integrated [16]. In a discrete relationship, the exchange pursues self-interest vigorously without any consideration of future exchange [28], whereas in an integrated relationship, the distinct and interdependent organizational components of the partners involved in the channel dyad constitute a unified whole [29]. The four variables proposed by Robicheaux and Coleman [16], namely joint actions, assistances, monitoring and information exchange, are used to measure the level of operational integration between the partners (i.e., buyer and supplier) involved in a dyadic relationship. Joint actions capture the extent to which the partners are involved in each other's operations [30]. The assistance assesses the position taken by the supplier toward assisting the buyer [31]. Monitoring captures the ex-ante and ex post control or supervisory actions taken by the buyer over the supplier [32]. Finally, information exchange assesses the bilateral expectation that the partners will proactively provide information to each other [33].

A multidimensional view is also adopted to test the moderating effect of three IOS usage variables, namely volume, diversity and depth, on the relationship between the predictor and criterion variables. The fourth facet from Massetti and Zmud's [24] conceptualization of IOS usage, breadth, is not considered, as this research focuses on dyadic relationships. Volume of IOS usage assesses the extent to which the supplier's activities with the buyer are supported by IOS use. Diversity of IOS usage assesses the number of e-business functionalities adopted by the supplier to support its activities with the buyer [34]. Depth of IOS usage assesses the extent to which the supplier's processes are intertwined with those of its buyer through IOS use [30].

A. The Impact of the Strucuture of a Buyer-Supplier Relationship on Operational Performance of the Supplier Involved in the Dyadic Relationship

Several studies have highlighted or demonstrated the positive impact that an integrated exchange relationship can have on the operational performance of the partners involved. Indeed, integration between supply chain partners can improve manufacturing productivity [35], generate economies of scale and scope [11], reduce shipment discrepancy levels [36] and speed up product development, delivery and payment [29]. Furthermore, operational integration between partners, as assessed through assistances, monitoring, information exchange, continuity expectations and flexibility, decreases purchasing costs [30].

In regards to the particular facets of operational integration proposed by Robicheaux and Coleman [16], numerous researchers have demonstrated that joint actions between a buyer and a seller can improve the performance of the parties involved [36]. For example, Cannon et al. [36] confirmed the importance of joint actions to improve relationship performance under both low and high levels of environmental uncertainty. Based on this premise, we posit our first hypothesis (H1): *Joint actions between the partners involved in a dyadic relationship will positively impact the operational performance of the supplier involved in the relationship*.

Several authors have demonstrated that when a seller/buyer offers assistance to a buyer/seller, the buyer/seller is likely to interpret such actions as a manifestation of commitment by its business counterpart, which may be the basis of trust [5][37]. And, given that trust and commitment have been found to directly and indirectly influence exchange performance or organizational performance [38], it is likely that supplier's assistance to the buyer will positively impact the supplier's operational performance. Based on this premise, we posit our second hypothesis (H2): *Supplier's assistance to the buyer will positively impact the supplier's operational performance*.

The buyer's monitoring of the performance of the supplier is also an important means of assessing the health of a relationship. Indeed, in addition to showing that buyer's monitoring of the supplier positively impacts the buyer's performance [39], the literature also shows that buyer's monitoring of the supplier also positively impact the supplier's performance by enticing him to improve its activities and processes [40]. Based on this premise, we posit our third hypothesis (H3): *Buyer's monitoring of the supplier*

will positively influence the supplier's economic performance.

Finally, past marketing and supply chain management studies have shown that effective interorganizational information sharing can enhance the performance of a supply relationship [41][42]. For example, as stated by Paulraj et al. [41, p. 49], when "buyers and suppliers share important information relating to materials procurement and product design issues, they are more likely to (1) improve the quality of their products, (2) reduce customer response time, (3) reduce the costs of protecting against opportunistic behavior, and (4) increase cost savings through greater product design and operational efficiencies". Based on this premise, we posit our fourth hypothesis (H4): *Information exchange between the partners involved in a dyadic relationship will positively impact the operational performance of the supplier involved in the relationship*.

B. The Moderating Impact of IOS Usage

Various mechanisms facilitating the operational integration among supply chain partners have been identified in the management literature [42]. As noted by Barki and Pinsonneault [29], these mechanisms include standardizing work, standardizing output, standardizing skills and knowledge, standardizing norms, direct supervision, planning, and mutual adjustment. It has also been demonstrated that the introduction and usage of an IOS eases the implementation of these mechanisms, which, in turn, facilitates the operational integration between supply chain partners [26].

In regards to the particular facets of IOS usage proposed by Massetti and Zmud's [24], various authors have demonstrated that unless IOS volume reaches a sufficient level, it is unlikely that the reengineering of associated business processes will provide significant benefits [24]. Indeed, a high volume of IOS usage will allow a firm to fully exploit the key mechanisms facilitating operational integration that were initially implemented through the adoption of the IOS. Based on this premise, we posit our fifth hypothesis (H5): *The impact of (a) joint actions between the partners, (b) supplier's assistance to the buyer, (c) buyer's monitoring of the supplier and (d) information exchange between the supplier on the supplier's operational performance will be greater when the volume of IOS usage is high than when the volume of IOS usage is low*.

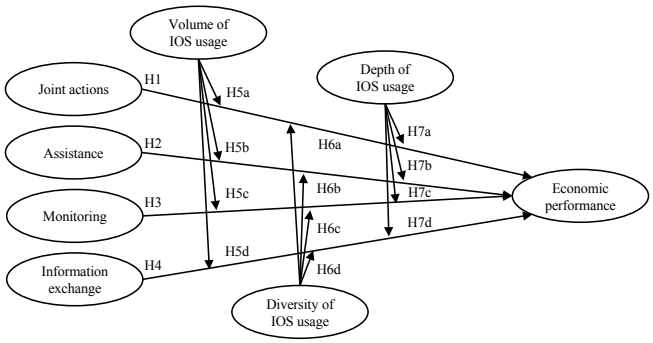

Figure 1. Research Model.

Also, the greater the variety or diversity of documents exchanged through IOS, the more automated and standardized the document's generation, transmission and reception processes become [24]. By automating and standardizing document exchange, IOS diversity also optimizes other mechanisms that facilitate operational integration such as mutual adjustments and planning [27]. Thus, high diversity of IOS usage will allow a firm to implement a wide range of mechanisms facilitating operational integration. Based on this premise, we posit our sixth hypothesis (H6): *The impact of (a) joint actions between the partners, (b) supplier's assistance to the buyer, (c) buyer's monitoring of the supplier and (d) information exchange between the supplier on the supplier's operational performance will be greater when the diversity of IOS usage is high than when the diversity of IOS usage is low*.

Lastly, establishing integrated IOS links (or greater depth) through the redesign of business processes and the establishment of unique information exchange routines increases procedural specificity between the partners involved [7]. Furthermore, IOS depth automates and shortens the time required to exchange information [25], which in turn may allow for the implementation of other mechanisms that facilitate operational integration such as direct supervision planning and mutual adjustment. Thus, greater depth of IOS usage will allow a firm to implement a wide range of mechanisms facilitating operational integration. Based on this premise, we posit our seventh hypothesis (H7): *The impact of (a) joint actions between the partners, (b) supplier's assistance to the buyer, (c) buyer's monitoring of the supplier and (d) information exchange between the supplier on the supplier's operational performance will be greater when the depth of IOS usage is high than when the depth of IOS usage is low*.

IV. METHODOLOGY

As our research is still in progress, this Section explains the methodological framework we have devised, but not yet used, to test our research model. More precisely, we present our unit of analysis as well as our intended research setting, data collection procedures, survey instrument and data analyses procedures.

A. Research Setting

This study explores the structure of business relationships from the perspective of the supplier. Hence, the unit of analysis of this research is the supplier's relationship with a particular buyer. The up-to-date list of manufacturing firms from the greater Montréal area maintained by a local government agency (CRIQ) will constitute this study's sample frame. In addition, the sample frame will be limited to manufacturing firms active in four industrial sectors: (1) machinery manufacturing (NAICS 333); (2) computer and electronic product manufacturing (NAICS 334); (3) electrical equipment, appliance and component manufacturing (NAICS 335); and (4) transportation equipment manufacturing (NAICS 336). Two reasons justified this choice. First, the adoption level of IOS in these four sectors is among the highest (Forester Research 2011).

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Second, previous studies have demonstrated the validity of these sectors in the study of business relationships [15][30].

B. Data Collection

Data will be collected by the mean of an online survey. We will follow the key informant approach and collect data from one sales professional at each supplier because specialists in this boundary role are most likely to be knowledgeable about study constructs [35]. Prior to answering the online survey, respondents will be asked to focus on an important buyer relationship for a major product manufactured by their company. To maximize this study's response rate, the diffusion of the survey will be based on four key elements: (1) a respondent-friendly questionnaire; (2) a five-contact strategy (in the form of five different e-mails to be sent to sales professionals); (3) a personalized correspondence; and (4) two incentives (i.e., a tailored benchmark report and a chance to win an electronic gift card of a 500$ value on Amazon). To ensure the anonymity of our respondents all collected data will be anonymized.

C. Survey Instrument

The survey instrument will comprise measures adapted from the literature. Measures tied to the structure of the dyadic business relationship (Joint actions [43], Assistance [38], Monitoring [32], and Information exchange [33]) will be adapted from marketing studies while those related to IOS usage (volume of IOS usage [34], diversity of IOS usage [44] and depth of IOS usage [24] will be adapted from IS studies. In addition, the measure to assess the operational (or economic) performance of the supplier will be adapted from the work of [26]. All measures are available upon request to the authors.

D. Data Analyses

The analysis of our data comprises four steps: (1) assessing the unidimensionality and convergent validity of the constructs; (2) assessing the internal consistency of the constructs; (3) assessing the discriminant validity of the constructs; and (4) testing our research hypotheses via a hierarchical regression model. For the last step, consistent with standard practice for analyzing models with interaction effects [45], variables will be entered in blocks in the hierarchical regression model. First, we will include the variables of joint actions, assistances, monitoring and information exchange into the model and assess their impact of operational performance. Then, we will enter the IOS usage variables into the model and asses their impact on operational performance. Finally, we will enter the interaction variables into the model and asses their impact on economic performance.

V. CONCLUSION

The objective of this study was twofold. First, to examine how the structure of a buyer-supplier relationship impacts the operational performance of the supplier involved in the dyadic relationship. Second, to test the moderating impact of IOS usage on the relationship between the structure of a buyer-supplier relationship and the operational performance of the supplier involved in the dyadic relationship. Accordingly, this research is likely to yield important theoretical contributions and practical implications despites certain limitations.

A. Theoretical Contributions

This study should make two important theoretical contributions to the marketing and IS literatures. First, this research will be the first to empirically test a key sub-set of Robicheaux and Coleman's [16] framework to characterize and assess the structure of business relationships. Second, this study will link past findings from marketing and IOS studies and show that IOS can help maximize the economic value of supplier involved in buyer-supplier business relationships.

B. Practical Implications

From a practical standpoint, the present research anticipated results should allow managers to identify the key marketing activities (i.e., joint actions, assistance, monitoring and information exchange) that foster economic value in dyadic business relationships. Also, this study should help managers maximize the economic value they derive from their dyadic business relationships by revealing the key role that IOS play in this context.

C. Limits and Future Research Avenues

There are two main limitations to this study. First, the research model will be tested with data collected from a small sample, which evidently limits the scope and generalizability of our results. To alleviate this issue, future researches could test our research model with manufacturing firms pertaining to other industries and/or localized in other regions of the world. Second, we did not investigate the impact of IOS ownership in the context of dyadic business relationships. Future research should focus on this important variable since several studies have shown that benefits tied to IOS usage are often skewed in favor of the IOS owner [7].

REFERENCES

[1] A. Boyle, F. R. Dwyer, R. A. Robicheaux, and J.T. Simpson, "Influence strategy in marketing channels: Measures and use in different relationship structures," J. Marketing Res., vol. 29, pp. 462–473, November 1992.

[2] B. Chae, H. R. Yen, and C. Sheu, "Information Technology and Supply Chain Collaboration: Moderating Effects of Existing Relationships Between Partners," IEEE Trans. Eng. Manag., vol. 52, no. 4, pp. 440-448, 2005.

[3] I. Geyskens, J.-B. E. M. Steenkamp, and N. Kumar, "A meta-analysis of satisfaction in marketing channel relationships," J. Marketing Res., vol. 36, no. 2, pp. 223-238, May 1999.

[4] J. P. Cannon and C. Homburg, "Buyer-supplier relationships and customer firm costs," Journal of Marketing, vol. 65, no. 1, pp. 29-43, 2001.

[5] J. M. Bonner and R. J. Calantone, "Buyer attentiveness in buyer-supplier relationships," Ind. Market. Manage., vol. 34, no. 1, pp. 53-61, 2005.

[6] V. Choudhury, "Strategic choices in the development of interorganizational information systems," Inf. Syst. Res., vol. 8, no. 1, pp. 1-24, 1997.

[7] K. A. Saeed, M. K. Malhotra, and V. Grover, "Examining the impact of interorganizational systems on process efficiency

and sourcing leverage in buyer-supplier dyads," Decis. Sci., vol. 36, no. 3, pp. 365-396, 2005.

[8] E. K. Clemons, S. Reddi, and M. C. Row, "The impact of information technology on the organization of economic activity: The 'move to the middle' hypothesis," J. Manage. Inf. Syst., vol. 10, no. 2, pp. 9-35, 1993.

[9] T. W. Malone, J. Yates, and R. I Benjamin, "Electronic markets and electronic hierarchies," Commun. ACM, vol. 30, no. 6, pp. 484-497, 1987.

[10] W. L. Stern and T. Reve, "Distribution channels as political economies: A framework for comparative analysis," J. Marketing, vol. 44, no. 3, pp. 52-64, 1980.

[11] O. Williamson, The Economic Institutions of Capitalism, New York: Free Press, 1985.

[12] I. R. Macneil, The New Social Contract: An Inquiry into Modern Contractual Relations, New Haven, CT: Yale University Press, 1980.

[13] P. J. Kaufmann and L. W. Stern, "Relational exchange norms, perceptions of unfairness, and retained hostility in commercial litigation," Journal of Conflict Resolution, vol. 32, no. 3, pp. 534-552, 1988.

[14] J. J. Mohr and J. R. Nevin, "Communication strategies in marketing channels: A theoretical perspective," J. Marketing, vol. 54, no. 4, pp. 36-51, 1990.

[15] J. B. Heide and G. John, "Alliances in industrial purchasing: The determinants of joint action in buyer-supplier relationships," J. Marketing Res., vol. 27, no. 1, pp. 24-36, 1990.

[16] R. A. Robicheaux and J. E. Coleman, "The structure of marketing channel relationships," J. Acad. Market. Sci., vol. 22, no. 1, pp. 38-51, 1994.

[17] N. Venkatraman and A. Zaheer, "Electronic integration and strategic advantage: A quasi experimental study in the insurance industry," Inf. Syst. Res., vol. 1, no. 4, pp. 377-393, December 1990.

[18] G. E. Truman, "A discrepancy-based measurement approach for data integration," working paper IS-95-24, Stern School of Business, New York University, 1995.

[19] E. T. G. Wang, J. C. F. Tai, and H. L. Wei, "A virtual integration theory of improved supply chain performance," J. Manage. Inf. Syst., vol. 23, no. 2, pp. 41-64, 2006.

[20] P. G. W. Keen, Shaping the Future: Business Design through Information Technology, Cambridge, MA: Harvard Business Press, 1991.

[21] T. H. Kwon and R. W. Zmud, "Unifying the fragmented models of information systems implementation," in Critical Issues in Information Systems Research, R. Boland and R. Hirscheim, Eds., Chichester, UK: Wiley, 1987, pp. 88-97.

[22] E. M. Rogers, Diffusion of Innovations, New York: Free Press, 1985.

[23] K. Zhu, K. L. Kraemer, and S. Xu, "The process of innovation assimilation by firms in different countries: A technology diffusion perspective," Manage. Sci., vol. 52, no. 10, pp. 1557 1576, 2006.

[24] B. Massetti and W. R. Zmud, "Measuring the extent of EDI usage in complex organizations: Strategies and illustrative examples," MIS Quart., vol. 30, no. 3, pp. 331-345, 1996.

[25] P. Hart and C. Saunders, "Emerging electronic partnerships: Antecedents and dimensions of EDI use from the supplier's perspective," J. Manage. Inf. Syst., vol. 14, no. 4, pp. 87-112, 1998.

[26] M. Subramani, "How do suppliers benefit from information technology use in supply chain relationships?," MIS Quart., vol. 28, no. 1, pp. 45-73, 2004.

[27] L. Chi, C. Holsapple, and C. Srinivasan, "Competitive dynamics in electronic networks: A model and the case of interorganizational systems," International Journal of Electronic Commerce, vol. 11, no. 3, pp. 7-49, Spring 2007.

[28] J. B. Heide, "Interorganizational governance in marketing channels," J. Marketing, vol. 58, pp. 71-85, April 1994.

[29] H. Barki and A. Pinsonneault, "A model of organizational integration, implementation effort, and performance," Org. Sci., vol. 16, no. 2, pp. 165–179, March–April 2005.

[30] A. W. Joshi and R. L. Stump, "The contingent effect of specific asset investments on joint action in manufacturer-supplier relationships: An empirical test of the moderating role of reciprocal asset investments, uncertainty, and trust," J. Acad. Market. Sci., vol. 27, no. 3, pp. 291 305, 1999.

[31] T. G. Noordewier, G. John, and J. R. Nevin, "Performance outcomes of purchasing arrangements in industrial buyer-vendor relationships," J. Marketing, vol. 54, no. 4, pp. 80-93, 1990.

[32] R. L. Stump and J. B. Heide, "Controlling supplier opportunism in industrial relationships," J. Marketing Res., vol. 33, no. 4, pp. 431-441, 1996.

[33] J. B. Heide and A. S. Miner, "The shadow of the future: Effects of anticipated interaction and frequency of contact on buyer-seller cooperation," Acad. Manage. J., vol. 35, no. 2, pp. 265-291, 1992.

[34] P. Hadaya, "Benchmarking firms' operational performance according to their use of Internet based interorganizational systems," Benchmarking, vol. 16, no. 5, pp. 621-639, 2009.

[35] J. E. Ettlie and E. M. Reza, "Organizational integration and process innovation," Acad. Manage. J., vol. 35, no. 4, pp. 795-827, 2001.

[36] J. P. Cannon, R. S. Achrol, and G. T. Gundlach, "Contracts, norms, and plural form governance," J. Acad. Market. Sci., vol. 28, no. 2, pp. 180-194, 2000.

[37] J. H. Dyer and W. Chu, "The Determinants of Trust in Supplier-Automaker Relationships in the U.S., Japan, and Korea," Journal of international business studies, vol. 31, no. 2, pp. 259-285, 2000.

[38] J. A. Siguaw, P. M. Simpson, and T. L. Baker, "Effects of supplier market orientation on distributor market orientation and the channel relationship: The distributor perspective," J. Marketing, vol. 62, no. 3, pp. 99-111, 1998.

[39] P. D. Cousin, B. Lawson, and B. Squire, "Performance measurement in strategic buyer-supplier relationships: The mediating role of socialization mechanisms," Int. J. Oper. Prod. Manag., vol. 28, no. 3, pp. 238-258, 2008.

[40] P. K. Dey, A. Bhattacharya, and W. Ho, "Strategic supplier performance evaluation: A case-based action research of a UK manufacturing organization," Int. J. Prod. Econ., vol. 166, pp. 192-214, 2015.

[41] A. Paulraj, A. A. Lado, and I. J. Chen, "Inter-organizational communication as a relational competency: Antecedents and performance outcomes in collaborative buyer–supplier relationships," J. Oper. Manage., vol. 26, pp. 45-64, 2008.

[42] S. Glouberman and H. Mintzberg, "Managing the care of health and the cure of disease – Part II: Integration," Health Care Management Review, vol. 26, no. 1, pp. 70-84, 2001.

[43] M. Bensaou and N. Venkatraman, "Configurations of interorganizational relationships: A comparison between U.S. and Japanese automakers," Manage. Sci., vol. 41, pp. 1471 1492, 1995.

[44] M. T. Frohlich and R. Westbrook, "Demand chain management in manufacturing and services: Web-based integration, drivers and performance," J. Oper. Manage., vol. 20, no. 6, pp. 729 745, 2002.

[45] L. Aiken and S. West, Multiple Regression: Testing and Interpreting Interactions, Newbury Park, CA: Sage, 1991.

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Enablers of Business Process Transformation Success in Japan:

How Super-ordinate Groups Achieve Effectiveness?

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***Abstract*— The aim of this paper is to present the analysis result of research that focuses on the enablers of business process transformation in Japan. It has been said for some decades that the overall quality and efficiency of production lines in Japan are superior to many other countries. However, the overall business processes, including work of back offices throughout all industries, are not always efficient. According to the Organisation for Economic Co-operation and Development (OECD), labor productivity in Japan ranks 22nd out of 34 countries. Ministry of Economy, Trade and Industry (METI) mentions that the scope of information system integration is rather narrow in Japan, compare to many other countries. In addition, about 70% of firms have aimed at drastic process change but only 30% have attained it. Dealing with these issues, the authors conducted a survey and identified the enablers of Business Process Transformation (BPT) focusing on "super-ordinate" firms.**

Keywords-business process transformation; success factor; IT utilization stage.

I. INTRODUCTION

It has been said for some decades that the overall quality and efficiency of production lines in Japan are superior to other countries. The word "KAIZEN (continuous improvement)" has become a word that is used not only in Japan. However, the overall business processes including the work of back offices throughout all industries are not always efficient [1][2], and labor productivity in Japan ranks 22nd out of 34 countries according to the Organization for Economic Co-operation and Development (OECD) [3]. Long working hours are a serious issue in Japan. Firms in Japan are trying to make their business processes more efficient by using Information Technology (IT). The objective of IT investment may differ in each firm; however, there are various tendencies according to region, industry and so on. As for the regions, Higano mentioned that Japanese firms tend to spend much more, in percentage terms, on improving the operational efficiency of their business compared to firms in Western countries, but the results do not seem to be satisfactory because the contribution of IT capital services to value added growth in Japan is lower than in Western countries [4]. There are many methodologies for business process orientation including business process re-engineering (BPR) or business process integration (BPI) [5]. However, it is difficult to achieve effectiveness by conforming to an ideal or to picture-perfect models. Data from the survey conducted by the authors show that 72.9% of the respondents (managers of information systems, business planning, or internal audit divisions) stated that the policy of their BPR was "drastic BPR," but only 28.4% had attained it [6].

In this paper, we present the analysis result of research that focused on the enablers of business process transformation (BPT), focusing on what the "super-ordinate" firms do to achieve effectiveness considering the unique situation in Japan. In the subsequent section, we review related studies with the category of business process orientation and the unique situation of firms in Japan considered for BPT success. Section 3 describes our research model of BPT success and the analysis results of the survey. The differences seen between "super-ordinate" firms and other firms are discussed in Section 4. Finally, Section 5 concludes this work and mentions about our future work.

II. RELATED STUDIES

In this section, we will look through the related studies about business process orientation, and the unique situation of firms in Japan should be considered for BPT success.

A. Studies about business process orientation

Studies related to business process orientation can be roughly classified into several groups: methodologies [7][8], tools [9][10], the effectiveness of business process integration including critical success factors (CSF) [11] [12][13], etc. As for CSF, some researchers mention that culture is also one of them [14][15]. Takei et al. mentioned that some CSF of Enterprise Resource Planning (ERP) vary in different regions or countries, while some CSF are common to many countries [16]. For instance, BPR is not so important in developing countries because they are making new business processes and do not need re-engineering. The CSF of business process orientation including BPT can be considered to vary in different countries.

B. The unique situation of firms in Japan should be considered for BPT success

・**Scope of the information system.** One of the reasons why business process transformation is not efficient in Japan may be the scope of information system integration [17]. Figure 1 shows the result of a survey about the IT implementation

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stage conducted by the Ministry of Economy, Trade and Industry (METI) in Japan. The "IT utilization stage" is defined as follows [17]:

- Stage 1: The information system is implemented.
- Stage 2: The information system is optimally utilized within a department or section within a firm.
- Stage 3: The information system is optimally utilized within an enterprise (expanded beyond departments or sections).
- Stage 4: The information system is optimally utilized among enterprises (including suppliers or customers).

The fact that about 70% of the firms in Japan (that is much lower compare to many of Western countries) are in stage 1 or stage 2 can be considered one of the reasons for the difficulty in implementing ERP systems in Japan, and for the low effectiveness of IT investment in Japan. Behind this, there is the culture of "TATEWARI", which is a kind of vertically-segmented administrative system organization which takes a "silo approach" in Japan. In the TATEWARI type of organization, each section does not interfere with other departments, and everyone works hard only within the organization that they belong to.

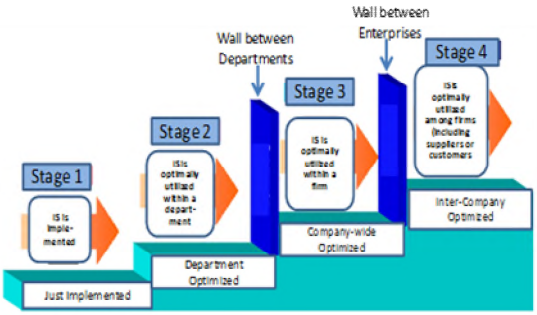
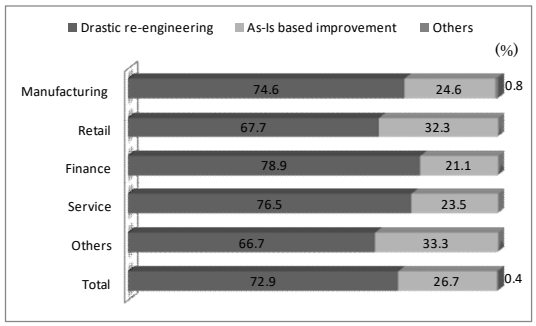


Figure 1. IT utilization four stages (Source: METI 2010)

· **Improvement but not drastic**. Data from the survey conducted by we show that 72.9% of the respondents (managers of information systems, business planning, or internal audit divisions) stated that the policy of their business process transformation was "drastic transformation," but only 28.4% had attained it [6] (Figure2).

- Planned (n=243)



- Actual (n=240)

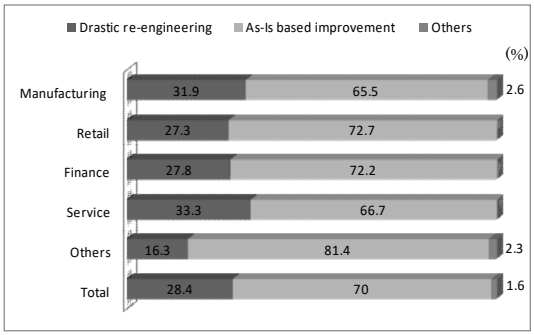


Figure 2. Business process transformation policy (Planed and Actual)

· **Outsource**. Figure 3 shows the ratio of IT investment by software type [18]. Japanese firms rely far more on system engineers of outsourcing services, compared to the United States. Some of the reasons for this situation are related to employment conditions in Japan (Figure 3).

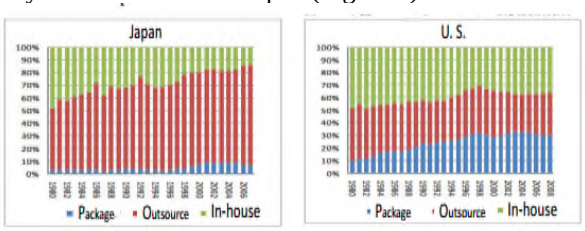


Figure 3. Difference in IT Investment Ratio by Software Type (Source: Motohashi 2010, in Japanese)

As we mentioned above, it seems to be important to seek ways to achieve effectiveness though BPT considering the unique situation in Japan. In the following sections, we describe the analysis result of the survey that we conducted.

III. Analysis of BPT Success

To address the issues mentioned in the previous section, we conducted a new survey. In this section, we describe the analysis result concerning enablers of BPT success.

A. *Conceptual research framework and hypotheses*

Enabler items are considered to consist of BPT management, executing drastic transformation, and wide-scope transformation. Figure 4 is a conceptual model for analysis.

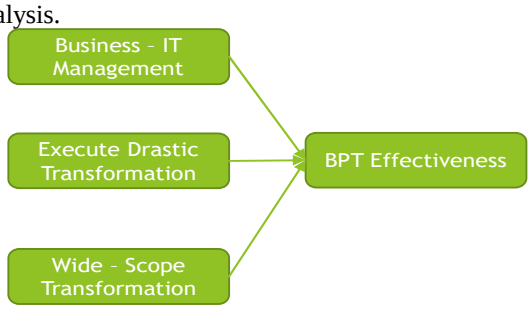


Figure 4. Conceptual model

The major hypotheses for the analysis are as follows:

Hypothesis 1 (H1): BPT management level has a positive impact on BPT effectiveness.

It is hardly surprising that BPT management is important for achieving BPT effectiveness. We defined research items for BPT management considering the unique situation of firms in Japan: "business executives' involvement in IT strategy", "communication between business and IT section", "motivation for improvement", "business - IT alignment function", "clear rules for cross-department decisions", "evaluation criteria for external resources"

Hypothesis 2 (H2): Planning and executing drastic transformation has a positive impact on the BPT effectiveness.

As mentioned in the previous section, many firms in Japan failed to realize drastic BPT (realized only As-is based improvement finally), and that is considered one of the reasons why such firms have Japan is hardly achieved effectiveness by BPT which focuses on business efficiency.

Hypothesis 3 (H3): Wide- scope transformation has a positive impact on BPT effectiveness.

As mentioned in the previous section, many firms in Japan are at a lower stage of IT utilization, and that is considered as one of the reason why firms in Japan is hardly achieve their effectiveness by BPT that focuses on business efficiency.

B. Overall Research Results

For the survey, 413 samples were gathered from the internet in March 2015. Table 1 shows the profile of the survey data. In next section, we describe the result of their analysis of BPT success.

TABLE I. PROFILE OF SURVEY DATA

Industry	Frequency	Percentage
Manufacturing	153	37.05%
Distribution	38	9.20%
Finance	18	4.36%
Service	150	36.32%
Others	54	13.08%
Total	413	
Posision (※count duplicate for conccurent post)	**Frequency**	**Percentage**
Manager of Business PlanningDivision	95	13.34%
Sttaff of Business Planning Division	53	7.44%
Manager of IT Division	91	12.78%
Staff of IT Division	103	14.47%
Manager of IT User Division	187	26.26%
Sttaff of IT User Division	135	18.96%
Chief Executive Officer	25	3.51%
n.a.	23	3.23%
Total	712	
Annual Sales (Yen)	**Frequency**	**Percentage**
Above 1000T	29	2.66%
Between 700B - 1T	12	6.54%
Between 400B - 700B	23	14.04%
Between 100B - 400B	11	7.02%
Between 70B - 100B	14	5.57%
Between 40B - 70B	27	6.54%
Between 10B - 40B	58	3.39%
Under 10B	188	45.52%
n.a.	51	12.35%
Total	413	
Number of Employees	**Frequency**	**Percentage**
Above 10,000	54	9.93%
Between 7,000 - 10,000	15	10.65%
Between 4,000 - 7,000	19	19.61%
Between 1,000-4,000B	41	13.08%
Between 700 - 1,000	42	4.60%
Between 400 - 700	44	10.65%
Between 100 - 400	81	10.17%
Under 100	115	27.85%
n.a.	2	0.48%
Total	413	

Business – IT management level and BPT effectiveness. The multi regression result of IT management level of super-ordinate firms (target variable: BPT effect) are shown in Table 2. Predictor variables "business executive's involvement in IT strategy", "communication between business and IT section", "motivation for improvement", "evaluation criteria for external resources" had positive and significant impacts on BPT effect. The item "business - IT alignment function" was not significant, and "clear rules for cross-department decisions" had a negative impact. Clear rules for cross-department decisions may reinforce the "TATEWARI" culture which is considered one of the obstructive factors to wide-ranging BPT.

TABLE II. MULTI REGRESSION RESULT (TARGET VARIABLE: BPT EFFECT)

Predictor Variable	Coefficients	F-value	p-value
Involvement of business management in the IT strategy decision process	0.2017	20.7115	**
Communication between Business and IT section	0.1147	5.4192	*
Motivation for Innovation /Improvement	0.1849	12.8373	**
Business - IT alignment function	0.0900	3.0136	-
Clear rules for cross-department decisions	-0.0978	3.8994	*
Evaluation criteria for external resources	0.1930	25.9699	**
Constant	1.0737	62.7238	**
Overall model		53.3488	**

*: P<0.05, **: P<0.01

Drastic BPT level and effectiveness. The multi regression result of drastic BPT level and BPT effectiveness is shown in Table 3. The drastic BPT level is as follows:

- Level 4: Planned and able to execute drastic BPT.
- Level 3: Planned drastic BPT but could not execute it (could execute As-is based improvement).
- Level 2: Planned as-is based improvement and executed drastic transformation.
- Level 1: Planned and executed as-is based improvement.

TABLE III. REGRESSION RESULT (TARGET VARIABLE: BPT EFFECT)

Predictor Variable	Coefficients	F-value	p-value
BPT Drastic Level	0.2050	16.3841	**
Constant	2.7773	382.5463	**
Overall model		16.3841	**

*: P<0.05, **: P<0.01

As we had expected, the BPT drastic level has a positive significant relationship with BPT effect. Figure 5 shows the cross-tabulation result displayed as a bar chart. High level firms tend to achieve effectiveness.

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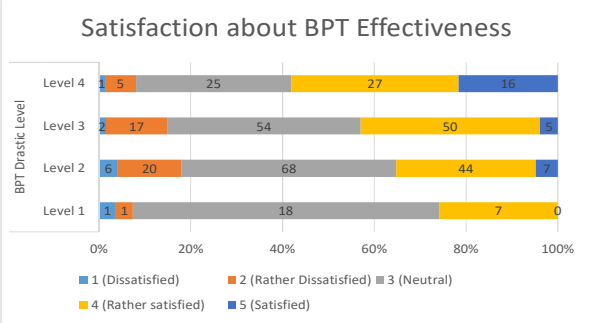

Figure 5. Drastic BPT level and BPT effectiveness

Wide-scope and BPT effectiveness. The regression result of IT utilization stage (target variable: BPT effect) are shown in Table 4, and Figure 6 shows the cross-tabulation result displayed as a bar chart.

TABLE IV. REGRESSION RESULT (TARGET VARIABLE: BPT EFFECT)

Predictor Variable	Coefficients	F-value	p-value
IT Utilization stage	- 0.0797	2.5379	0.1120 -
Constant	3.5359	670.3786	**
Overall model		2.5379	**

*: P<0.05, **: P<0.01

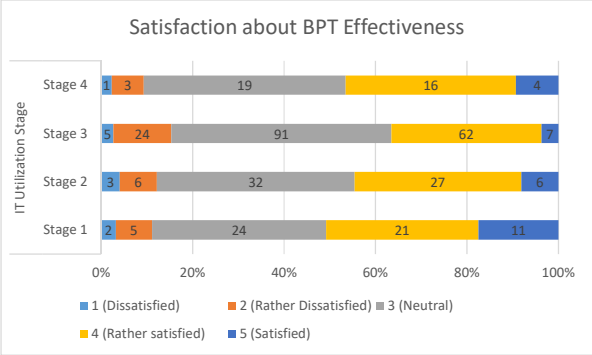

Figure 6. IT Utilization stage and BPT effectiveness

The p-value was 0.112 and this was not smaller than 0.05. In that sense, we can say we cannot find a significant relationship between "IT utilization stage" and BPT effect. However the p-value is 0.112, it is nearly at the 10% level of significance. (It is sometimes considered that <10% is significant, rather than <5% is significant). The coefficient value of this item is negative. That means wide-ranging BPT projects seldom achieve their goal. Figure 7 shows the IT utilization stage ratio. There are about 50% of stage 4 and 3 firms, but this is still far less than in Western countries.

The reason why the item "IT utilization stage" shows a negative impact on BPT effect may be that many firms in Japan achieve only a small effect by targeting small scope of the organization.

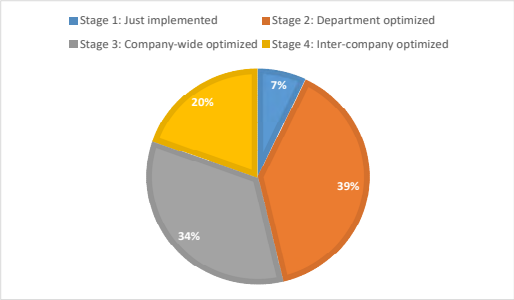

Figure 7. IT Utilization stage ratio

Summary of overall analysis. Figure 8 is the summary of overall analysis. Most of the BPT items have a positive impact on BPT effectiveness. Executing drastic BPT has a positive impact on BPT effectiveness, but only 18 % of the firms have been able to execute the drastic BPT that they had planned. Wide – scope BPT has a positive impact on BPT effectiveness, but many of the firms that have wide–scope transformation have not achieved effectiveness.

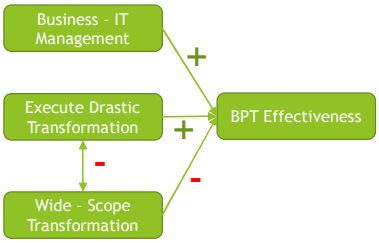

Figure 8. Summary of overall analysis

In addition to the result mentioned in 3.2.3, there some issues are founded from the survey as follows:

- The firms where the IT utilization stage is high do not tend to achieve BPT effectiveness.
  - METI mentioned that most firms in Japan are at a lower stage, and that is one of the reasons EISs in Japan are not efficient. However, even firms at higher stages do not always achieve BPT effectiveness.
- The firms whose IT utilization stage is at a high level do not always achieve a BPT effect which is IT contribution on business efficiency.
- Although about 50% of the firms have planned drastic transformation, only 37% of the firms above have been able to implement such transformation (2015).
  - It has progressed from the survey conducted in 2008 (30% of the firms could implement drastic transformation), but the percentage (37%) is still behind other countries.

C. How do "super-ordinate firms" achieve their effectiveness?

Addressing the issues that relationship between drastic BPT and wide-scope BPT is negative but this negative relationship can be thought the one of the reason of low efficiency of business processes in Japan, we tried to

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analyze that how do "super-ordinate firms" achieve their BPT effectiveness.

Definition of "super-ordinate firms". We defined "super-ordinate firms" as follows:

- Drastic BPT Level: Level 4 (Planned drastic BPT and could execute it)
- IT utilization Stage: Stage 4 (IS is optimally utilized among firms) or 3 (IS is optimally utilized within a firm.)

The reason why we defined "super-ordinate firms" as above is that "super-ordinate firms" are overcoming their drawbacks and achieving the BPT effectiveness.

IT management level of "super-ordinate firms". The multi regression result of IT management level of super-ordinate firms (target variable: BPT effect) are shown in Table 5.

TABLE V. REGRESSION RESUL (TARGET VARIABLE: BPT EFFECT)

Predictor Variable	Super-ordinate firms (n=30)			Other firms (n=378)		
	Co-efficients	F-value	p-value	Co-efficients	F-value	p-value
Involvement of business management in the IT strategy decision process				0.2075	19.0905	**
Managements' will to change business process according to business environmental change	0.5796	16.8674	**			
Communication between Business and IT section				0.1162	5.1579	*
Motivation for Improvement				0.1737	10.6313	**
Business - IT alignment function	0.2185	2.3347	0.1391	0.0888	2.6973	0.1015
Clear rules for cross-department decisions				-0.1027	3.8186	0.0515
Evaluation criteria for external resources	0.2528	5.1090	*			
Provision for IT Risk	-0.1996	2.8360	0.1046			
Constant	0.4745	1.0711	-	1.1368	65.4518	**
Overall model			**			**

*: P<0.05, **: P<0.01

There is a significant, positive relationship between the following items and BPT effect; "Managements' will to change business process according to business environmental change" and "Evaluation criteria for external resources". There is a positive relationship between "Business - IT alignment function" and BPT effect, its p-value is about 0.13, which can be said to be rather significant (because sometimes up to around 0.1 is considered as significant). This multi regression result of "super-ordinate firms" is quite different from that of other countries. For the group of other firms, the items which have a positive significant relationship with BPT effect are "Involvement of business management in the IT strategy decision process", "Communication between Business and IT section" and "Motivation for Improvement".

Meeting style of "super-ordinate firms". The multi regression result of IT management level of super-ordinate firms (target variable: BPT effect) are shown in Table 6. The following items have a positive impact on BPT effect: "System users' division leads the meeting" and "Meeting is held at IT division's office". For the meeting style, we could not find any difference between super-ordinate firms and other firms by item, but the coefficient values were different.

TABLE VI. REGRESSION RESULT (TARGET VARIABLE: BPT EFFECT)

Predictor Variable	Super-ordinate firms (n=26)			Other firms (n=274)		
	Coefficients	F-value	p-value	Coefficients	F-value	p-value
System users' division has the key role at the meeting.	0.2731	3.6525	0.0685 -	0.1868	12.7846	0.0000 **
Meeting is held at IT division's office.	0.4882	13.2862	0.0014 **	0.0981	4.0598	0.0449 *
Informal meeting about BPT is held in coffee lounge etc.				0.0970	2.2612	0.0245 *
Constant	0.5756	0.5997	0.4466	2.0858	10.8761	0.0000 **
Overall model			0.0019 **			0.0000 **

*: P<0.05, **: P<0.01

What is difficult about BPT? The multi regression results as regards what is difficult about BPT of super-ordinate firms and other firms (target variable: BPT effect) are shown in Table 7. As for the super-ordinate firms, the answer of the question "It is difficult to estimate the BPT effectiveness of each division" has a positive impact on BPT effectiveness. That means the "super-ordinate" firms are good at estimating the BPT effectiveness of each division (5: No (=Do not feel difficulty), 4: Rather no, 3: Neutral, 2: Rather no, 1: No) . It seems this makes sense, because the adjustment of each division's requirements can be considered as one of the critical issues of wide-scope transformation.

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TABLE VII. REGRESSION RESULT (TARGET VARIABLE: BPT EFFECT)

Predictor Variable	Super-ordinate firms (n=26)			Other firms (n=274)		
	Coefficients	F-value	p-value	Coefficients	F-value	p-value
It is difficult to estimate the BPT effectiveness of each division.	0.2909	3.2105	0.0844			
It is difficult to determine the business process standardization scope of the BPT project.				0.1061	2.6425	0.1050
It is difficult to adjust system users' requirements and IT feasibility.				-0.0955	2.2245	0.1368
Constant	2.6670	38.1676	0.0000 **	3.2901	572.541	0.0000 **
Overall model		3.2105	0.0844			0.2343

5: No (=Do not feel difficulty), 4: Rather no, 3: Neutral, 2: Rather no, 1:No
*: P<0.05, **: P<0.01

On the other hand, as for the other firms, the answer of the question "It is difficult to adjust system users' requirements and IT feasibility" has negative impact on BPT effectiveness (5:No (=Do not feel difficulty), 4:Rather no, 3: Neutral, 2:Rather no, 1:No) . That means, for the other firms, difficulty of adjusting system users' requirement and IT feasibility is lowering BPT effectiveness.

IV. DISCUSSION

Some differences were seen between "super-ordinate" firms and other firms in some categories.

The items that show positive or negative impact on the BPT effect are listed below.

- Super-ordinate firms
  - (+)Managements' will to change business process according to business environmental change.
  - (+)Business - IT alignment function.
  - (+)Evaluation criteria for external resources.
  - (-)Provision for IT risk.
  - (+)System users' division has a key role at the meeting.
  - (+)Meeting is held at IT division's office.
  - (+)It is not difficult to estimate the BPT effectiveness of each division.
- Other firms
  - (+)Involvement of business management in the IT strategy decision process
  - (+)System users' division has a key role at the meeting.

"Managements' will to change business process according to business environmental change" and "Business - IT alignment function" are the items discussed at CSF of business process orientation (BPR, BPI, BPT). They can be considered the common enablers of BPT success. On the other hand, "Evaluation criteria for external resources", "It is not difficult to estimate BPT effectiveness of each division" and negative impact of "Provision for IT Risk" can be considered as items fitting the unique situation of firms in Japan.

Having "evaluation criteria for external resources" as an enabler, firms can manage outsourcing resources, which have more weight in Japan. Having "It is not difficult to estimate BPT effectiveness of each division" as an enabler, a firm can adjust the requirement of the divisions and avoid conflict. Not having "provision for IT risk" means taking IT risks (preparing for IT risk) must be an enabler to achieve the effectiveness of new technology.

Figure 9 shows operating income on sales by "super-ordinate" firms and other firms. "Super-ordinate" firms look a little superior to other firms. They will be considered to achieve much greater effectiveness by continuing their transformation using their enablers.

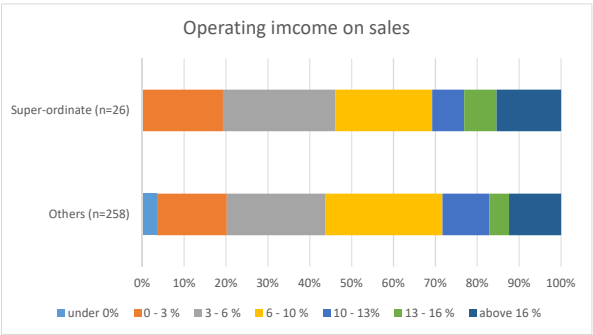

Figure 9. Operating income on sales

V. CONCLUSION AND FUTURE WORK

The aim of this paper was to present the analysis result of research that focuses on the enablers of business process transformation in Japan. At the time we constructed the conceptual research framework and hypotheses, enabler items were considered to consist of BPT management, executing drastic transformation, and wide-scope transformation which helps to achieve BPT effectiveness. However, from the research results, executing drastic transformation and wide-scope transformation seemed to be

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conflicting items. Then, we focused on the group that we had defined as “super-ordinate firms”, and a difference was seen between “super-ordinate” firms and other firms in some categories.(e.g., managements' will to change business process according to business environmental change, business - IT alignment function, evaluation criteria for external resources, system users’ role.) These items can be considered as the enablers of BPT for Japanese firms. The item “evaluation criteria for the external resources” must be important for many firms, not limited to Japanese firms. However, Japanese firms rely far more on system engineers of outsourcing services, compared to the United States. That means, evaluation criteria for the external resources must be one of the crucially important items for the Japanese firms. The enablers we had mentioned in this paper would help the firms in Japan who are struggling to realize drastic transformations. For the future research, we plan to delve more deeply into these enabler items, by interviews. Trust can be considered one of the key factors of business transformation effect [19]. So, we are planning to focus on the process of developing trust in business process transformation, and will analyze the differences between the super-ordinate firms and other firms.

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REFERENCES

[1] M. Hojo, “Recent Issues in the Japanese Labor Market (in Japanese)”, Journal of international studies, School of Internationa Studies, Kwanse University, 2017.

[2] Organizsation for Economic Co-operation and Development (OECD), OECD Compendium of Productivity Indicators 2016.

[3] Japan Productivity Center Cabinet Office Japan, Rodoseisansei no Koksai Hikaku 2016 Nenndoban (International Comparison of labor productivity 2016, in Japanese) .
http://www.jpc-net.jp/intl_comparison/intl_comparison_2016.pdf.

[4] T. Higano, “IT ni Yoru Work Style Henkaku (Work Style Innovation, in Japanese)”, IT Solution Frontier 2009.11, Nomura Research Institute, 2009, pp. 16-19.

[5] A.Khosravi, “Business process rearrangement and renaming: A new approach to process orientation and improvement”, Business Process Management Journal, vol. 22 Issue: 1, Emerald Group Publishing Limited, 2005, pp. 116-139.

[6] K. Iizuka, T. Okawada, M. Tsubone, Y. Iizuka and C. Suematsu, C., “Issues about Inter-organizational Process Flow Adjustment in Business Process Modeling”, Enterprise and Organizational Modeling and Simulation, Selected Papers, vol.53, LNBIP, Springer, 2013.pp. 24-41.

[7] M. Zairi, “Business Process Re - engineering and Process Management: a Survey of Current Practice and Future Trends in Integrated Management”, Management Decision, vol. 33 Issue: 3, MCB UP Ltd., 1995, pp. 3-16.

[8] S. Mohapatra and A. Choudhury, “Readiness Framework for Business Process Re-engineering”, Strategic Change, John Wiley & Sons Ltd, Volume 25, Issue 5, September 2016, pp. 509–524.

[9] P. Bradley, J. Browne, S. Jackson and H. Jagdev, “Business Process Re-engineering (BPR) — A study of the Software Tools Currently Available”, Computers in Industry, Volume 25, Issue 3, March 1995, pp. Elsevier B.V.,pp. 309-330.

[10] H. S. B. Jayatilake, A. S. Withanaarachchi and S. Peter, “Possibility of Applying Industry 4.0 as a Business Process Re-engineering Tool: Case Study from an Apparel Production Plant”, Proceedings of the International Research Symposium on Pure and Applied Sciences (IRSPAS 2016), Faculty of Science, University of Kelaniya, Sri Lanka. 2016, p 84.

[11] P. Trkman, “The Critical Success Factors of Business Process Management”, International Journal of Information Management, Volume 30, Issue 2, April 2010, Elsevier B.V.,pp. 125–134.

[12] K. Iizuka, Y. Iizuka and C. Suematsu, “Consideration of the Business Process Re-Engineering Effect: Business Flow Notation Structure and the Management Perspective”, Reichert M., Reijers H. (eds) Business Process Management Workshops. BPM 2015. Lecture Notes in Business Information Processing, vol 256. Springer, 2016, pp. 323-333.

[13] M. N. Haviv, “Understanding Critical Success and Failure Factors of Business Process Reengineering”, International Review of Management and Business Research, Volume 2, Issue.1, March 2013, pp. 1-10.

[14] G. Hall, J. Rosenthal and J. Wade, “How to make reengineering really work”, Harvard Business Review, November-December, 1994, pp. 119-131.

[15] J. Peppard and D. Fitzgerald, “The Transfer of Culturally-Grounded Management Techniques: the Case of Business Process, reengineering in Germany.” European Management Journal Volume 15, Issue 4, 1997,pp.446-460.

[16] Y. Takei, R. Nagase and K. Iizuka, “Consideration on Achieving Effectiveness by Using ERP Systems: From the Analysis of Satisfaction Structure, International Symposium on Business Management (ISBM),2014, pp.1035-1053.

[17] Ministry of Economy, Trade and Industry (METI), IT Keieiryoku Sihyo wo Mochiita IT no Rikatuyou ni Kansuru Genjou Chousa (Current Status Survey on IT Utilization Stage Evaluated by IT managerial Capability Index, in Japanese), 2010.

[18] K. Motohashi, IT to Seisansei ni kansuru jisshou bunseki (Anallysis on relationship between IT and Productivity, in Japanse), Institute of Economy, Trade and Industry,2010.

[19] K. Iizuka and C. Suematsu, “Structure of the Trust: Seeking the Real Effectiveness of Business Process Transformation Projects”, International Social Sciences & Technology Conference (ICTECH) 2017, pp. 1-5.

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Automated Analysis of Patient Experience Text Mining using a Design Science Research (DSR) Approach

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***Abstract*— Online forums of hospitals are a common method of collecting patient feedback on the healthcare received. The feedback data obtained are often free text and large which may make a manual analysis of the data difficult and time-consuming. An approach to automatically analyse patient experience data would be beneficial for the hospital staff in several ways. In this paper, a Design Science Research (DSR) paradigm based framework is proposed that is used for our ongoing research in developing solutions with an aim for an automated approach to analyse patient experience data using natural languages processing techniques such as Sentiment Analysis, Topic Modelling, and Dependency Parsing. The framework design proposed provides a three-stage iterative process wherein at each iteration the patient feedback is deeply analysed based on the outcomes obtained from the preceding ones. This iterative approach facilitates the development of a strong, effective patient feedback analysis system.**

Keywords-patient experience; sentiment analysis; text mining; topic modelling; DSR

I. INTRODUCTION

Understanding patient experience enables hospitals to identify their weaknesses in providing healthcare. It provides opportunities for them to reflect on their functioning and thus, make efforts towards addressing the limitations in relation to the service provided. Further, understanding the patient experience can also contribute towards making the hospital processes more efficient, which in turn will lead towards better utilisation of resources and the addressing of patient concerns.

The National Health Service (NHS) provides health care within England, Scotland and Wales and is a public health service established shortly after the Second World War and caters for all residents of the UK. The NHS describes patient experience as a core dimension of good quality care [1]. It is an imperative task for the NHS to measure patient experience in order to monitor and improve health care performance, enhance strategic decision making and record progress for health care organisations [2].

An effective method of collecting a patients' feedback is to provide an online forum, where they can anonymously provide their views on the health care service they have received on a website feedback form at their own convenience. In 2008, the NHS created a website called *NHS Choices* that invites patients to leave their feedback about their experience with the healthcare providers of the hospital, which they can do using two approaches. One method is to provide ratings to a given hospital on different metrics on a scale of 1 to 5 stars. Moreover, in addition to rating their visit on different metrics, they can also leave feedback in the form of comments in the comments section of the website. Thus, the NHS has a large database of patient feedback covering most hospitals across the United Kingdom (UK). The number of comments and feedback across the database runs into the hundreds of thousands.

The process of collecting patient feedback via website source provides the healthcare professionals easy and convenient access to patient feedback data that can be used for analysis purposes. The hospital administration and researchers can use the feedback database to identify the strengths and weaknesses of their healthcare service and further employ them to address the identified issues.

Online reviews are generally written as free text and do not adhere to any structure or format. This makes analysing and understanding the patient experience more challenging than when dealing with closed questions, as the possibilities regarding the feedback content are endless. Techniques, such as keyword searching can help in searching for topics in patient feedback; however, this does not recognise positive and negative feedback. To address the challenge of analysing a large patient feedback database, automated methods would enable the analysis process to be more sustainable and time effective. The recent advancements in information analysis technologies, such as text mining and natural language processing, has resulted in them being widely applied to analyse the user experience of products by various companies.

In the last few years, studies have applied sentiment analysis approaches for analysis of patient experience data. Studies such as [6] and [7] applied SVM, decision trees, and Naive Bayes approaches of Sentiment Analysis and were able to classify patient comments into complaints/praise attributed to specific staff as well as feedback about other aspects, such as access, wait time, privacy, facilities, etc. In [8], the authors analysed the patient experience data provided by US hospitals on Twitter. They assessed tweeted reviews for over 2,000 US hospitals and identified those related to patient experience. Their preliminary results showed that the patient experience present on the tweets did not match that

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regarding the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) ratings. However, there are limited studies that have explored how such language processing methods could be utilised to analyse patient experience.

In this paper, the ongoing research on applying natural language processing to provide a framework with an aim for automated analysis of a patient experience is introduced. The methodology that is being used in the ongoing research is explained in detail in Section II. Section III describes our developed framework for the research followed by conclusion in Section IV.

II. THE DESIGN SCIENCE RESEARCH (DSR) PARADIGM

The Design Science Research (DSR) methodology is currently being used for our research. The DSR paradigm is a widely popular research approach in Information Systems (IS) research. It is referred to as a problem-solving paradigm because it aims at building "artefacts" that are aimed at addressing a problem. The artefacts address the problems or enhance existing solutions and are important tools for arriving at research outcomes and reviewing them to decide how the artefact adopted can be further utilised [3]. The DSR process follows a systematic procedure in which the artefacts are developed with systematic creation, capturing, and communication of knowledge from the design process. DSR uses an iterative process, whereby the artefacts are reconstructed at each iteration and thus, can be described as a continuous learning process that enhances the artefacts quality incrementally [4].

Vaishnavi & Kuechler developed a methodology for DSR as shown in Figure 1 [5]. The model puts more emphasis on the process of contributing to knowledge. The DSR process here is based on the knowledge built and comprises five main stages: *Awareness of Problem*, *Suggestion*, *Development*, *Evaluation*, and *Conclusion*.

The *awareness of problem* aims at understanding the problem in the context of the application using various resources available. The outcome of this process leads to the development of the *suggestion* of the research project. In the *suggestion* phase, various insights into the application domain are obtained during this phase and the specifications for the solutions are acquired which leads to the development of a tentative design. In the *development* stage, the first artefact is developed. The *evaluation* phase focuses on evaluating the performance of the developed artefact, the outcomes of which may be used to further improve the artefact design and performance.

In our research, the aim is to develop an automated analysis of patient feedback to identify their sentiment and opinions about the healthcare service. The DSR methodology is well suited for us to achieve this, as DSR is an iterative process and our artefact developed will be a three stage iterative process wherein at each iteration the patient feedback is deeply analysed based on the outcomes obtained from the preceding ones. This iterative approach facilitates the development of a strong, effective automated patient feedback analysis system. In the following section, the DSR methodology based framework of our research is presented.

III. A DSR BASED FRAMEWORK FOR AUTOMATED PATIENT EXPERIENCE ANALYSIS

To develop a patient feedback analysis system that can potentially automate the process, the five-phase design process steps mentioned in Figure 1 is adapted and used as the DSR approach for the study. The study will be carried out in three iterations and the adapted DSR approach enables the identification of the problem in each iteration, finds a solution, develops and evaluates the performance of the solution methodically and hence, is suitable for the research goals. The DSR methodology of our study is illustrated in Figure 2.

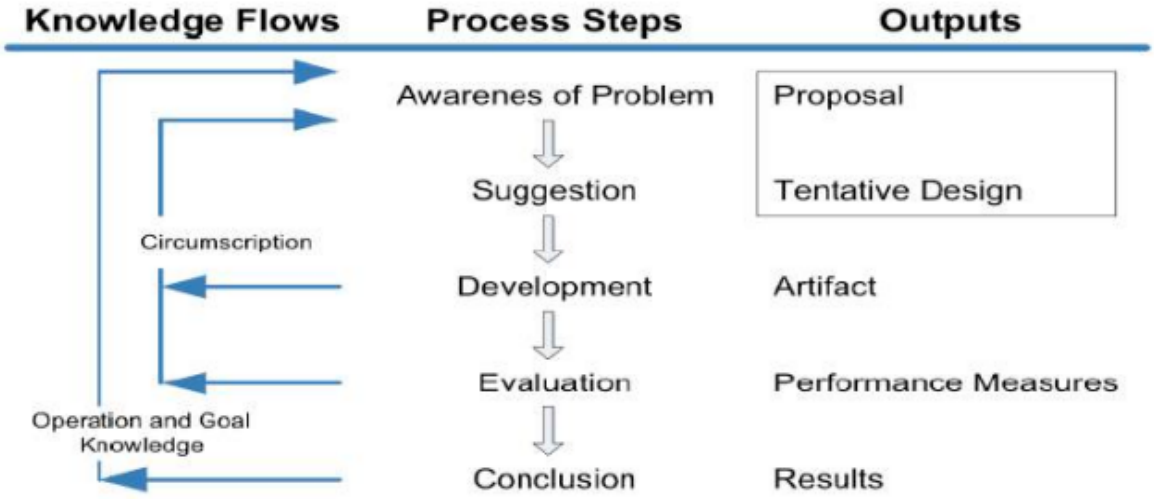

Figure 1. Design Science Research Phases (Kuechler, Park and Vaishnavi, 2007)

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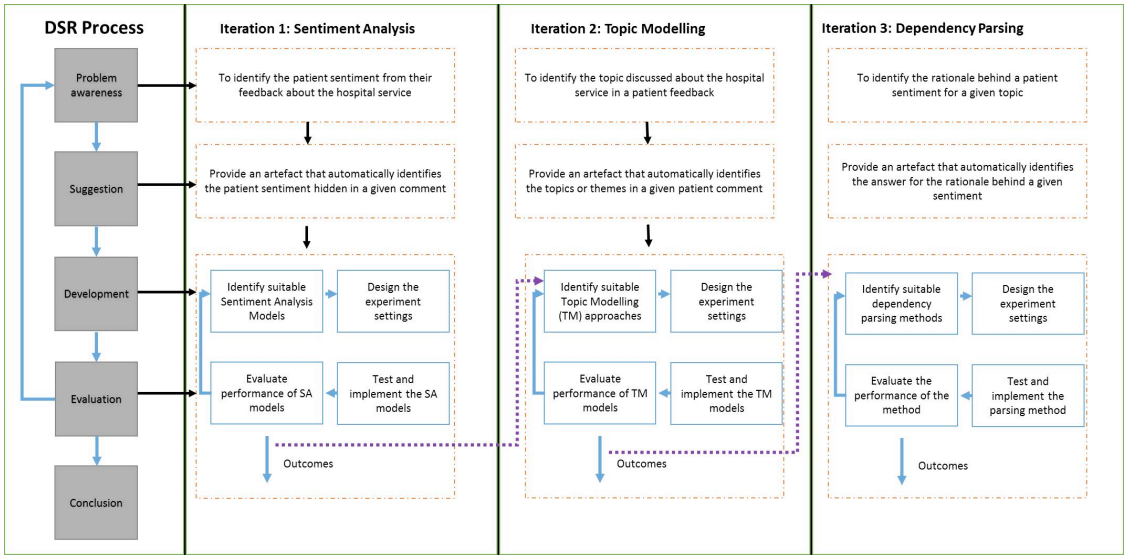

Figure 2: The proposed DSR based framework for automated analysis of patient experience data

A. *Iteration One: Sentiment Analysis of Patient Feedback Data*

The first iteration of our ongoing research is to apply Sentiment Analysis (SA) approaches to the *NHS Choices* patient feedback database. The aim of this iteration is to find the sentiment of the patient feedback in their comments provided on NHS hospitals on the NHS website. The sentiment identification is performed by the application of Sentiment Analysis approaches that analyse and classify a comment into positive or negative sentiment based on its contents.

It can be seen that the problem is the need to identify the patient sentiment from the comments obtained for each NHS hospital from the NHS Choices website. The suggestion is to develop an artefact that can automatically or semi-automatically identify the patient feedback or sentiment in the comment as positive or negative. To develop this artefact, there are several sub-steps. The first is to identify suitable Sentiment Analysis (SA) models from the literature research that can identify the sentiment in the comment. The next sub-step is to design the experiment settings where the SA models are implemented on the feedback database. This involves identifying the processes for cleaning and preparing the database for the analysis, tools and technology required to implement the SA models.

The next step is to evaluate the outcomes of the SA model implementation. The evaluation is an analytical approach in this iteration, whereby it is focused on the accuracy of the SA model in identifying the correct sentiment in the patient feedback. If the sentiment identified by the SA model matches the ground truth sentiment, then the SA model is said to be accurate. The outcomes of this iteration will be used for the second iteration of the study.

B. *Iteration Two: Topic Identification from Patient Feedback*

The next iteration of the study is to identify topics in the given patient feedback. The aim is to understand what specific area of the healthcare service the patient has discussed in their feedback, such as the maternity department, parking facilities or the waiting period in the hospital. In Figure 2, it can be observed that the DSR framework for iteration two is more or less similar to the iteration one approach. The problem in this iteration is to identify the topic being discussed by the patient in their feedback about the hospital on the NHS website. Therefore, in line with the problem, the artefact aimed at providing a model that can potentially automatically identify the topics or themes being discussed by the patient in a given comment.

To develop the artefact, the Latent Dirichlet Allocation (LDA) Topic Modelling (TM) approach will be used. After the TM approach is implemented, and then the topics and themes for each patient comment are automatically identified. This reveals which topics are being discussed in the patient feedback. The next step is to identify the sentiment for each topic identified in the patient comment. To achieve this, the sentiment identified for each comment from the SA models from iteration one is used i.e. for each comment, the identified sentiment is mapped to the relevant topics to obtain a sentiment score for that topic across the patient feedback database. A difference in iteration two when compared to iteration one during the development stage is that the iteration two study requires the outcomes of the SA model obtained from the first iteration, i.e. second iteration of the study is dependent on the previous iteration.

The evaluation of the topics identified in iteration two involves both analytical and observational evaluation. The former refers to when the sentiment score for each topic is computed based on the sentiment scores found from the

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iteration one. The observational part of the evaluation pertains to when the topics are identified by the TM method. The topics are bags of words that are likely to belong to a particular theme and they need to be manually analysed in order to assign a label to each of them. This is achieved by involving NHS experts to observe each topic's elements and provide a label for each category.

The outcomes of iteration two will be disseminated by representing the topics identified using data visualisation approaches in the R programming environment to make them accessible to hospital staff. Finally, the topics identified by the TM approach in iteration two will be used for further study and analysis in iteration three for the Dependency Parsing investigation aimed at identifying the rationale behind the patient sentiment.

C. Iteration Three: Rationale Identification of Patient Sentiment

In the third iteration, the aim is to identify the rationale behind a particular sentiment of the patient in a given comment or review. In other words, the purpose is to find out why the patient is happy or unhappy about a particular topic in a given comment. The problem being addressed in this iteration of the study is to find the possible reason behind a patients' sentiment for a particular topic in a given comment. To achieve this, the artefact developed will implement a Natural Language Processing method called Dependency Parsing. This identifies the keywords in a given comment that could potentially summarise the patient feedback for a given topic in the comment. Specifically, this is achieved by extracting a "noun-adjective" pair for each topic in a given comment and this pair are expected to provide the keywords in the comment that indicate the reason behind the patients' happiness or unhappiness about the healthcare service provided.

Similar to the previous two iterations, once the suitable Dependency Parsing methods are identified and the implementation environments are finalised, the experiment settings are created and implemented. For this iteration, the R programming environment will be utilised and the openNLP and coreNLP methods available in the literature will be adopted. Further, similar to how iteration two was dependent on the outcomes of the iteration one, iteration three is also dependent on those from the two preceding iterations. This is because the "noun-adjective" pair that is extracted to summarise the patient comment is performed on a per topic basis. In other words, for each topic, the reason behind the patient sentiment is identified. In particular, the unigram topics identified from the TM method are used for Dependency Parsing in this study.

The evaluation of the topics identified in iteration three is both analytical and descriptive. The analytical evaluation refers to when the Dependency Parsing methods implemented automatically analyse the feedback data and identify a noun-adjective pair from the comments. The descriptive part of the evaluation pertains to the noun-adjective pair identified providing a summary of the patient comment on a given topic. Thus, it potentially describes the patient comment by a pair of words.

Similar to iteration two, the outcomes of iteration three will be disseminated via visualisation techniques. In this visualisation, the users will be able to list all the comments for a chosen topic and then for each comment, they will be able to visualise the most salient noun-adjective pair that potentially summarises the comment for the given topic, either negatively or positively.

Thus, it can be noted that the DSR approach is deemed suitable to design a framework for our study as it provides a systematic approach to formulating the problem, identifying potential solutions, implementing and testing the solutions and finally, evaluating and disseminating the outcomes. The iterative approach is a strong aspect of the DSR method and is particularly suitable for the current study as each part of the study is dependent on the outcomes of its predecessor study.

IV. CONCLUSION

The DSR method is an iterative process that enables the development of an artefact for solving a problem. It is suitable for our research, as the main goal is developing an artefact for analysing patient experience automatically. Our artefact will be developed in three iterations and each successive iteration study is dependent on the outcomes of the previous iteration. This approach would enable us to develop an effective framework to analyse the patient experience data and can be beneficial to hospitals to assess their performance in achieving high patient satisfaction.

REFERENCES

[1] S. LaVela and A. Gallan, "Evaluation and measurement of patient experience," Patient Experience Journal, vol.1, no. 1, pp. 28-36, 2014.

[2] A. Coulter, L. Locock, Z. S. and J. Calabrese, "Collecting data on patient experience is not enough: they must be used to improve care," BMJ: British Medical Journal, p. 348, 2014.

[3] K. Peffers, T. Tuunanen, C. Gengler, M. Rossi, W. Hui, V. Virtanen and J. Bragge, " The design science research process: a model for producing and presenting information systems research," In Proceedings of the first international conference on design science research in information systems and technology , 2006.

[4] S. Gregor and A. Hevner, "Positioning and presenting design science research for maximum impact," MIS quarterly, vol. 37, no. 2, pp. 337-355, 2013.

[5] V. Vaishnavi and W. Kuechler, Design Science Research methods and Patterns: Innovating Information and Communication Technology, New York: 1st edn. Taylor & Francis Group., 2007.

[6] F. Alemi, M. Torii, L. Clementz, L. and D.C. Aron, 'Feasibility of real-time satisfaction surveys through automated analysis of patients' unstructured comments and sentiments', *Quality Management in Healthcare,* 21(1), pp. 9-19, 2012.

[7] F. Greaves, D. Ramirez-Cano, C. Millett, A. Darzi, and L. Donaldson, 'Machine learning and sentiment analysis of unstructured free-text information about patient experience online', *The Lancet,* 380, pp. S10, 2013.

[8] C. Lees, 'Measuring the patient experience', *Nurse researcher,* 19(1), pp. 25-28, 2011.

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Requirement-Driven Architecture for Service-Oriented e-Learning Systems

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***Abstract*—The continuous evolving of Technology Enhanced Learning (TEL) requirements, more specifically Functional Requirements, increases the complexity of TEL software system since such requirements cannot be met by one TEL/e-learning solution. In addition to the traditional Virtual Learning Environments/Learning Management Systems capabilities, such Functional Requirements include: video streaming, plagiarism checker for students' submissions, e-portfolio, etc. Therefore, combining various e-learning software systems, solutions, or tools seems more realistic. However, a limited effort has been done to investigate and control the impact of combining different solutions on the quality, i.e., Non-Functional Requirements (NFRs), of the overall e-learning software system. This paper proposes a new approach to elicit, precisely specify, and manage NFRs for TEL software systems. To meet these capabilities (i.e., Functional Requirements and Non-Functional Requirements), this paper also proposes a flexible service-oriented architecture for e-learning systems. The proposed list of NFRs is comprehensive and can be customized to various e-learning systems to meet stakeholders' requirements. Moreover, the proposed architecture needs to be further developed to test its impact on TEL software systems in real scenarios.**

Keywords-Technology Enhanced Learning; e-learning; architecture; Non-Functional Requirements; Software architecture; SOA; Web Services.

I. INTRODUCTION

The continuous rise of using eLearning in higher education increases the complexity of e-Learning/Technology Enhanced Learning (TEL) Software Systems [1]. On one hand, there is a continuous demand for various supplementary capabilities, more specifically Functional Requirements, that cannot be met by one TEL/ e-learning software system only. For instance, in addition to the traditional Virtual Learning Environments (VLE) capabilities, various supportive capabilities are required (e.g., video streaming, plagiarism checker for students' assignments, e-portfolio, etc. Therefore, combining various e-learning software systems, solutions, or tools seems more realistic. On the other hand, a limited effort has been done to investigate the impact of combining different solutions on Non-Functional Requirements (NFRs) of the overall e-learning service or software system. Such Non-Functional Requirements include performance, reliability, availability, recoverability, etc.

Literature evidence shows that Non-Functional Requirements are not properly managed over the Software Development Life Cycle (SDLC) [2]. This applies to NFRs elicitation, specification, documentation, and evaluation. One of the potential reasons behind this is related to the nature of applying TEL solutions in higher education institutions as they focus on Functional Requirements at the expense of Non-Functional Requirements. Also, there is a lack of literature evidence on how NFRs are elicited and specified. Most of the e-learning systems evaluation is performed against the Functional Requirements only (e.g., [3] and [4]). Moreover, NFRs subtle nature makes them challenging to elicit in advance, and most likely to be approached iteratively along software development life cycle [5]. NFRs are very important to software architecture; they are also known as Architecturally Significant Requirements because they have a measurable impact on the architecture of software system [6] [7].

Therefore, this paper investigates the current approaches to manage, more specifically elicit and specify, NFRs over TEL software development life cycle. NFRs management refers to the process of eliciting, specifying, communicating, and controlling Non-Functional Requirements over software development life cycle [8]. Since, NFRs are persistent, rarely changed, this paper focuses on the early stages of NFRs management process. These stages include NFRs elicitation, specification, and communication. Then, it proposes a flexible architecture for e-learning solutions to meet the early-identified NFRs. The rest of this paper is organized as follows. Section II summarizes related work; Section III proposes a new approach to elicit and specify NFRs for TEL systems; Section IV proposes a service-oriented architecture for e-learning software systems; Section V concludes the paper with future research directions.

II. RELATED WORK

There exist different e-Learning/TEL Software Systems, where some of them are: (i) *open source*, such as: Moodle [3], Atutor [9], Sakai [10], and Ilias [11] or (ii) *propriety*, such as: Blackboard [12] and Desire2Learn [13]. Such systems are known as Learning Management Systems (LMSs) or Virtual Learning Environments (VLEs). The current LMSs/VLEs cannot support architectural flexibility, to different extents, due to their monolithic design [14]. LMSs evolved from black box systems, known as first generation LMSs, towards more modular architectural approach, known as second generation LMSs [14]. Much of this evolution was due to the standardization initiatives, such as: Sharable Content Object Reference Model (SCORM) and IMS Global Learning Consortium Learning Design (IMS LD), which allow good level of interoperability between different LMSs, their components, and third-party plugins/tools. For instance, IMS Learning Tools

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Interoperability (LTI) is used by many e-learning tools to align or map their configurations with LMS configurations. Meanwhile, various architecture-oriented improvements on Atutor LMS have been introduced [9]. Similarly, more modular structure has been considered in the case of Sakai LMS, especially in relation to service orientation [15]. This has increased the scalability and extendibility of the current LMSs via plugins deployment.

However, such structure is not sufficiently agile. New requested plugin needs planning and deployment procedures and might have impact on systems performance or other related NFRs. In addition, the recent move towards cloud-based e-learning solutions, especially Software as a Service (SaaS), made it more challenging for the current e-learning systems to effectively exchange assets and efficiently co-exist with each other (e.g., sharing hardware resources). Hence, the next section will present a comprehensive and consistent approach to elicit, specify, and communicate NFRs in relation to TEL solutions to consider them later to design a flexible architecture for TEL systems.

III. NON FUNCTIONAL REQUIREMENTS IN TEL

In the light of the above discussion, a good starting point for architecting e-learning solutions is to thoroughly consider its NFRs in a consistent way. Our approach is inspired by one of the most reliable approaches to elicit NFRs, which is the Quality Attribute Workshop (QAW) approach [16], developed by Carnegie Mellon University Software Engineering Institute. Simply, this approach refers to engaging system stakeholders, or their representatives, early in the life cycle to discover the driving Non-Functional Requirements of software system through a series of workshops. Unlike QAW structure that has a rigid structure and lacks the base definitions for NFRs, we opt for a flexible structure for our proposed approach. The structure of the proposed approach must address the following phases: (i) *induction phase*, to introduce the approach to stakeholders, or their representatives, and explain the rationale behind it and who is doing what, (ii) *business view phase*, to introduce high-level Functional Requirements for the proposed solution, (iii) *architecture view phase*, to present the proposed solution architecture at a high-level including useful details (e.g., hardware, certain technologies, etc.), (iv) *architectural drivers phase*, to summarise the key drivers of the proposed solution, which could be high-level capabilities, organizational concerns, etc., (v) *scenario phase*, to divide the audience into groups to brainstorm real scenarios for using the systems, and to validate them, and link them with NFRs, and finally (vi) *precisely specify TEL software system NFRs* based on the NFRS template introduced later in this section (i.e., Tables I and II). Precise specifications of NFRs means to pick up the definition listed in Table I or II, and to add certain parameters to the definition as explained later.

The proposed phases could be conducted as separate workshops, meetings, interviews or other potential formats, which can be better decided by organisational business analysts. Also, phases can be merged together or divided into two or more depending on the context factors that include: the scale of the TEL software system, nature of stakeholders, their technical background and interest, etc. The key role of the business analyst team is to maximise the benefits of stakeholders' engagement to get accurate enough NFRs specifications. One of the central steps here is to avoid natural language-based specification as this may lead to subtle requirement specifications, which cannot be measured. To do so, we opt for a standard-based approach based on ISO 25010 Systems and Software Quality Requirements and Evaluation: (i) *Product Quality (PQ) Model* that measures the static qualities of a certain software system, depicted in Figure 1, and (ii) *Quality in Use (QiU) Model* that measures the dynamic qualities of a certain software system when it is applied in a particular context [17], depicted in Figure 2. Both models have a set of precisely defined list of qualities that can be easily customised to be smart enough for architecting e-learning solutions. In this context, smart means: specific, measurable, achievable, resource and time bound. Also, using a standard coherent set of precisely defined quality characteristics is appropriate for negotiation with industries, especially in Service Level Agreements for SaaS solutions.

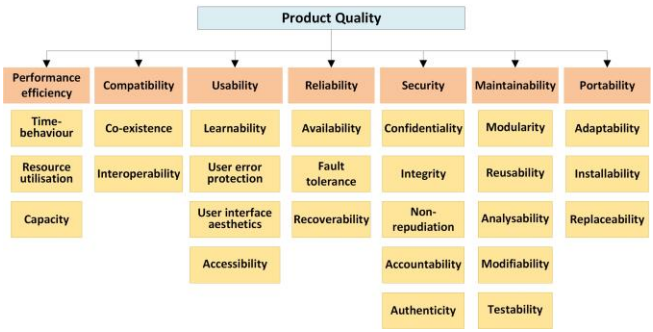

Figure 1. System-related Non-Functional Requirements

The above-depicted NFRs are organised as characteristic (e.g., compatibility) and sub-characteristics (e.g., co-existence and interoperability). The former provides a general definition that does not need to be smart, while the latter (i.e., sub-characteristics) needs further customisation to be smart NFRs. All the above-mentioned product quality-related NFRs are defined [18] in Table 1 below. For readability purpose, different background colour has been given to characteristics (e.g., performance efficiency), while sub-characteristics (e.g., time-behaviour) background colour is white.

TABLE I. SYSTEM-RELATED NON-FUNCTIONAL REQUIREMENTS

Characteristic/ Sub-characteristic	**Definition**
Performance efficiency	performance relative to the amount of resources used under stated conditions.
Time-behaviour	degree to which the response and processing times and throughput rates of a system, when performing its functions, meet requirements.
Resource utilisation	degree to which the amounts and types of resources used by a system, when performing its functions, meet requirements.
Capacity	degree to which the maximum limits of a system parameter meet requirements
Compatibility	degree to which a system or component can exchange

	information with other systems or components, and/or perform its required functions, while sharing the same hardware or software environment.
Co-existence	degree to which a system can perform its required functions efficiently while sharing a common environment and resources with other products, without detrimental impact on any other product.
Interoperability	degree to which two or more systems or components can exchange information and use the information that has been exchanged.
Usability	degree to which a system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
Learnability	degree to which a system can be used by specified users to achieve specified goals of learning to use the product or system with effectiveness, efficiency, freedom from risk and satisfaction in a specified context of use.
User error protection	degree to which a system protects users against making errors.
User interface aesthetics	degree to which a user interface enables pleasing and satisfying interaction for the user.
Accessibility	degree to which a system can be used by people with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use.
Reliability	degree to which a system or component performs specified functions funder specified conditions for a specified period of time.
Availability	degree to which a system or component is operational and accessible when required for use.
Fault tolerance	degree to which a system or component operates as intended despite the presence of hardware or software faults.
Recoverability	degree to which, in the event of an interruption or a failure, a system can recover the data directly affected and re-establish the desired state of the system.
Security	degree to which a system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization.
Confidentiality	degree to which a system ensures that data are accessible only to those authorized to have access.
Integrity	degree to which a system or component prevents unauthorized access to, or modification of, computer programs or data.
Non-repudiation	degree to which actions or events can be proven to have taken place, so that the events or actions cannot be repudiated later.
Accountability	degree to which the actions of an entity can be traced uniquely to the entity.
Authenticity	degree to which the identity of a subject or resource can be proved to be the one claimed.
Maintainability	degree of effectiveness and efficiency in which a system can be modified by the intended maintainers.
Modularity	degree to which a system is composed of discrete components such that a change to one component has minimal impact on other components.
Reusability	degree to which an asset can be used in more than one system, or in building other assets.
Analysability	degree of effectiveness and efficiency in which it is possible to assess the impact on a system of an intended change to one or more of its parts, or to diagnose a product for deficiencies or causes of failures, or to identify parts to be modified.
Modifiability	degree to which a system can be effectively and efficiently modified without introducing defects or degrading existing product quality.
Testability	degree of effectiveness and efficiency in which test criteria can be established for a system or component and tests can be performed to determine whether those criteria have been met.
Portability	degree of effectiveness and efficiency in which a system or component can be transferred from one hardware, software or other operational or usage environment to another.
Adaptability	degree to which a product or system can effectively and efficiently be adapted for different or evolving hardware, software or other operational or usage environments.
Installability	degree of effectiveness and efficiency in which a system can be successfully installed and/or uninstalled in a specified environment.
Replaceability	degree to which a system can replace another specified software product for the same purpose in the same environment.

Following the above-listed system-oriented Non-Functional Requirements, another complementary set of NFRs is needed to specify the system behaviour in a certain context. Such NFRs describe the quality to which the anticipated system can be used by specific users to meet their demands to achieve specific goals with effectiveness, efficiency, freedom from risk, and satisfaction in specific contexts of use [18]. This complementary list is depicted in Figure 2, and fully described in Table II, as well. Like system-related NFRs, this list is organised as characteristics and sub-characteristics, where the former provides a generic description that does not need to smart, while as the latter needs to be refined to be smart NFRs.

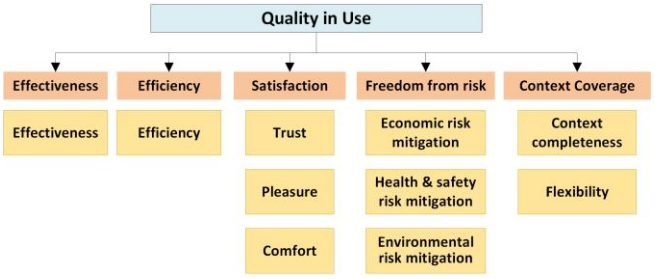

Figure 2. Quality in Use-related Non-Functional Requirements

As depicted in Figure 2, this list is limited to the qualities that can be affected by the context of use. Context of use includes users, tasks, equipment (hardware, software, and material), and the physical and social environments in which a system is used [18]. Some of the system-related NFRs can be affected by the context of use, but generally they are not affected by the context of use.

TABLE II. QUALITY-IN-USE RELATED NON FUNCTIONAL REQUIREMENTS

Characteristic/ Sub-characteristic	**Definition**
Effectiveness	accuracy and completeness in which users achieve specified goals.
Efficiency	resources expended in relation to the accuracy and completeness in which users achieve goals.
Satisfaction	degree to which user needs are satisfied when a system is used in a specified context of use.
Trust	degree to which a user or other stakeholder has confidence that a system will behave as intended.
Pleasure	degree to which a user obtains pleasure from fulfilling their personal needs.
Comfort	degree to which the user is satisfied with physical comfort.
Freedom of risk	degree to which a system mitigates the potential risk to

	economic status, human life, health, or the environment.
Economic risk mitigation	degree to which a system mitigates the potential risk to financial status, efficient operation, commercial property, reputation or other resources in the intended contexts of use.
Health and safety risk mitigation	degree to which a system mitigates the potential risk to people in the intended contexts of use.
Environmental risk mitigation	degree to which a system mitigates the potential risk to property or the environment in the intended contexts of use.
Context coverage	degree to which a system can be used with effectiveness, efficiency, freedom from risk and satisfaction in both specified contexts of use and in contexts beyond those initially explicitly identified.
Context completeness	degree to which a system can be used with effectiveness, efficiency, freedom from risk and satisfaction in all the specified contexts of use.
Flexibility	degree to which a system can be used with effectiveness, efficiency, freedom from risk and satisfaction in contexts beyond those initially specified in the requirements.

Finally, the definitions of the above-mentioned NFRs (i.e., *System*-oriented and *Quality-in-Use*-oriented) are generic enough to accommodate NFRs specifications for a wide range of software systems. For effective TEL system architecture, these NFRs need to be refined to be smart. This means that various thresholds need to be added to these generic definitions based on the NFRs elicitation workshop, explained in Section III. For instance, *Recoverability* will have more specific numbers to describe the conditions in which the system can recover the data affected and re-establish the desired state of the system. This means recoverability requirement specification will look like: "*In the event of interruption or failure, the system must recover the data affected and re-establish the desired state of the system according to the following parameters: (i) Recovery Time Objective (RTO): 30 minutes and (ii) Recovery Point Objective (RPO): three hours*. For clarification, RTO refers to time duration in which users/organisations want to be able to recover the replicated data, while RPO refers to the maximum amount of data that can be lost before causing serious damage to the organisational services. Similarly, *Capacity* NFR needs to be customised with a precise list of parameters, so the refined specification will look like: *the system must be capable of effectively and efficiently performing its functions as expected in the case of having 2500 concurrent users and hosting the contents/activities of 80000 online courses*. In this case, 2500 concurrent users and 80000 courses represent the maximum parameters required by a certain institution. To respond to the early-identified NFRs, a high-level architecture for TEL software system will be proposed in the next section.

IV. THE PROPOSED E-LEARNING SYSTEM ARCHITECTURE

As introduced earlier, NFRs are known as architecturally significant requirements. Ideal software architecture describes the concerned software system through a set of artefacts and relationships between these artefacts. Such artefacts include models, processes, principles, and guidelines that guide the selection, creation, and implementation of software solutions aligned with business requirements. Furthermore, this includes decisions taken during building the high-level architecture of the software system, where these decisions have significant impact on the system quality, performance, availability, etc. [19]. This explains why software architecture is influenced by NFRs, and consequently, justifies investigating NFRs and architecture together. Literature evidence, especially [2], [5]-[7], reveals that the key Non-Functional Requirements that influence software architecture decisions are: performance, compatibility including: co-existence and interoperability, maintainability especially reusability and modularity, adaptation, and flexibility. Moreover, lessons learned from current TEL practices in academic institutions, such as the heavy move towards cloud-based e-learning solutions, puts further emphasis on interoperability and co-existence requirements, because different cloud-based e-learning systems usually share the same hardware environments.

Such requirements can be better met by flexible architecture, such as Service-Oriented Architecture (SOA) that is designed to support flexibility, interoperability, reusability, etc [6]. Therefore, we opt for a service-oriented enabled architecture for e-learning system, where the overall e-learning service is composed of more than one software system, such as LMS (e.g., Atutor, Moodle, etc.), plagiarism checker (e.g., Turnitin), video streaming (e.g., Kaltura), student record system, etc. Some of these systems might be developed in-house, hosted on premises, or provided as a SaaS. Figure 3 depicts the architecture of SOA-enabled e-Learning System. As explained in Figure 3, the proposed architecture is composed of the following three layers: (i) presentation-service layer, that has the necessary set of interfaces to communicate with underneath layers, (ii) business layer, that includes all sub-systems or components (e.g., LMS and video streaming), and (iii) data layer that hosts every possible source of data.

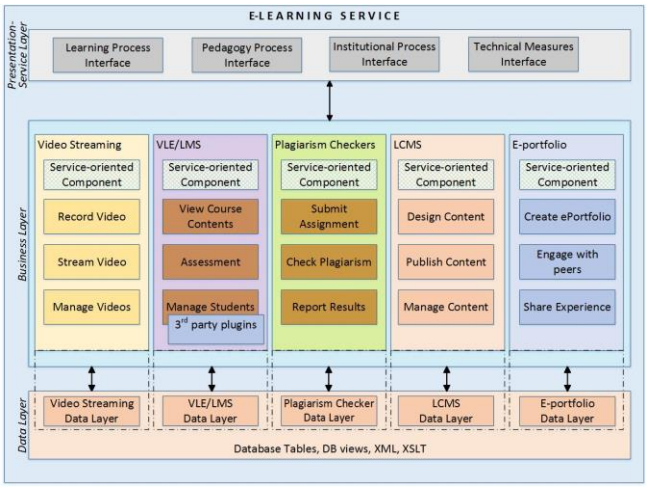

Figure 3. Service-enabled e-Learning System Architecture

The first layer, presentation-service layer, includes the following four components. *The first component*, learning process interface, manages and monitors all learning and teaching processes carried out by students. Such processes mainly include LMS capabilities, such as finding learning

contents and managing e-learning activities. To better facilitate this component's job, there is a need to improve the architecture/design of the current LMSs via adding what we call here "*Service-oriented component*". This component allows flexible access to the internal capabilities of the LMS (e.g., looking for certain contents of a particular course or analysing various activities done by a group of users for learning analytics purposes). This component needs significant changes to be introduced to the LMS stretching from architectural design of the intended LMS through specific algorithms that can identify and discover web services that meet users' demands.

The second component, pedagogy process interface, handles learning content through all of its stages (i.e., design, development, publishing, etc.) This can be done through interaction with Learning Content Management System (LCMS) component in the business layer. This component retains complex processes since designing learning contents includes various pedagogical approaches that considerably vary. For instance, designing behavioural-based content, which is instructor-centred contents that contain: a) learning objectives, b) learning contents, and c) assessment exercise is different from designing a social constructive-based content which is driven by students' interactions. Both types of contents are based on underpinning pedagogical models that can be represented via a set of processes that explain the workflow needed to design, develop, and publish learning contents. Similarly, service-oriented component, for LCMS, is needed here to make this process achievable via web services.

The third component, institutional process interface, handles all institutional processes that are related to e-learning, such as assigning roles to e-learning actors (e.g., module leader, instructor, and examiners). This also includes students' enrolments, other administration tasks, tracking other related processes (e.g., financial processes). The automatic execution of these processes is challenging because most institutions have their own business rules that could be complicated due to the wide range of programmes offered by universities and the adopted service models. This component will communicate, via web services, with Human Resources (HR) systems and students' record systems that can provide the necessary information to achieve this task.

The fourth component, integration interface, handles all technical aspects needed for successful e-learning services. One of the most important aspects here is the security because e-learning service, as introduced earlier, is a hybrid service that may combine on-premises software, public cloud, and private cloud. Also, considering the evolving requirements for academic institutions is highly important. This requires continuous monitoring for the current e-learning services, such as doing performance testing and penetration testing. This allows benchmarking for the current level of service, so the institution can investigate the impact of adding additional components to the e-learning service.

As described earlier, each of the above-mentioned interface component, in the presentation layer, liaises with one or more service-oriented component in the concerned sub-system in the business layer. For instance, institutional interface might liaise with one or more than one service component to setup the proper plagiarism check processes that might be dynamic as they differ from undergraduate to postgraduate or lifelong learning programme. This applies to models/tools that use specific learning approaches (e.g., Game-based Learning model [20]). In addition, certain arrangements need to be done at the data level to make sure data are accessible by permitted stakeholders whenever is needed. Despite the fact that Non-Functional Requirements are more persistent, with little changes are expected, there is a need to manage the changes that could happen over TEL software development life cycle. Therefore, it is recommended to use suitable requirement management tool or model to keep the e-learning service reliable and efficient. This includes reviewing the current set of requirements either based on agreed timeframe or whenever we have new requirements from stakeholders. Finally, it is worth mentioning that the early-identified business layer might have extra sub-systems based on the Functional Requirements coming from different departments in the academic institution.

V. CONCLUSION AND FUTURE WORK

In this paper, we handled the challenging problem of managing Non-Functional Requirements, more specifically eliciting and specifying NFRs, in the context of TEL. Lessons learned from TEL practices revealed that NFRs are ignored due to many reasons, which could seriously impact the overall e-learning system/service. Therefore, we opt for a comprehensive approach based on ISO 25010 to elicit and specify Non-Functional Requirements. Furthermore, this paper presented flexible service-oriented architecture for e-learning software systems that can better meet the required capabilities (i.e., Functional and Non-Functional Requirements). This work revealed the need to adopt open and flexible architecture for TEL systems. This means that these systems should be designed in a way that is accessible via web service mechanism to allow further agility. Moreover, it highlighted the need to develop service identification and service discovery algorithms that consider e-learning particularities.

REFERENCES

[1] R. Hammad, M. Odeh and Z. Khan, "Towards a generic requirements model for hybrid and cloud-based e-learning systems," The IEEE 5th International Conference on Cloud Computing Technology and Science (CloudCom), 2013, pp. 106-111, Bristol, UK.

[2] J. Eckhardt, A. Vogelsang and D. M. Fernández, "Are non-functional requirements really non-functional? an investigation of non-functional requirements in practice," The 38th IEEE/ACM International Conference on Software Engineering (ICSE), 2016, pp. 832-842.

[3] S. Kumar, A. K. Gankotiya and K. Dutta, "A comparative study of Moodle with other e-learning systems," The 3rd International Conference in Electronics Computer Technology (ICECT), 2011, 414-418.

[4] S. Graf and B. List, "An evaluation of open source E-learning platforms stressing adaptation issues," The 5th IEEE

 ISBN: 978-1-61208-614-9

International Conference on Advanced Learning Technologies (ICALT), 2005, 163-165.

[5] D. Ameller et al., "Non-functional requirements in architectural decision making," IEEE Software, vol. 30, (2), pp. 61-67, 2013, doi:10.1109/MS.2012.176.

[6] L. Chen, M. A. Babar and B. Nuseibeh, "Characterizing architecturally significant requirements," IEEE Software, vol. 30, (2), pp. 38-45, 2013, doi: 10.1109/MS.2012.174.

[7] C. Miksovic and O. Zimmermann, "Architecturally significant requirements, reference architecture, and metamodel for knowledge management in information technology services," The 9th IEEE/IFIP Conference on Software Architecture (WICSA), 2011, pp. 270-279, doi: 10.1109/WICSA.2011.43.

[8] D. Pandey and V. Pandey, "Importance of requirement management: a requirement engineering concern," International Journal of Research and Development A Management Review, vol. 1, (1), pp. 66-70, 2012. ISSN (Print): 2319–5479.

[9] H. Men, J. Liu and J. Han, "Applied research on Atutor," The International Conference on E-Learning, E-Business, Enterprise Information Systems, and E-Government (IEEEE'09), 2009, pp.107-110. ISBN: 978-0-7695-3907-2.

[10] T. Acosta and S. Luján-Mora, "Comparison from the levels of accessibility on LMS platforms that supports the online learning system," The 8th Annual International Conference on Education and New Learning Technologies, 2016, pp. 2704-2711, doi: 10.21125/edulearn.2016.1579.

[11] I. Vlasin and C. Chirila, "Online contest based on integration of activities, adaptability and students cooperation using Ilias LMS," The International Scientific Conference eLearning and Software for Education, 2016, pp. 67-74.

[12] K. Logan and T. Neumann, "Comparison of Blackboard 9.1 and Moodle 2.0," Learning Technologies Unit. University of London, London, UK, 2010.

[13] R. D. Rucker and L. R. Frass, "Migrating Learning Management Systems in Higher Education: Faculty Members' Perceptions of System Usage and Training When Transitioning from Blackboard Vista to Desire2Learn," Journal of Educational Technology Systems, vol. 46, (2), pp. 259-277, 2017, doi: 10.1177/0047239517711954.

[14] D. Dagger et al., "Service-oriented e-learning platforms: from monolithic systems to flexible services," IEEE Internet Computing, vol. 11, (3), pp. 28-35, 2007, 10.1109/MIC.2007.70.

[15] A. G. Booth and B. P. Clark, "A service-oriented virtual learning environment," On the Horizon, vol. 17, (3), pp. 232-244, 2009, doi:10.1108/10748120910993268.

[16] M. R. Barbacci et al., "Quality attribute workshops (QAWs)," International society for Bioelectricity, Shreveport L.A., 2003.

[17] R. Hammad, M. Odeh and Z. Khan, "Towards a model-based approach to evaluate the effectiveness of e-learning," The 9th European Conference on IS Management and Evaluation – ECIME, UK, Bristol, 2015, pp. 111-119, ISBN: 978-1-910810-55-2.

[18] ISO/IEC 25010 "Systems and software engineering–Systems and software quality requirements and evaluation (SQuaRE)–System and software quality models," The International Standard Organisation (ISO), 2011.

[19] N. Medvidovic and R. N. Taylor, "Software Architecture: Foundations, Theory, and Practice," John Wiley & Sons, 1st edition, 2010, ISBN: 9780470167748.

[20] R. Hammad "Game-Enhanced and Process-Based e-Learning Framework," In: Tian F., Gatzidis C., El Rhalibi A., Tang W., Charles F. (eds) E-Learning and Games, July 2017, Lecture Notes in Computer Science, vol 10345, Springer, Cham. pp. 279-284, doi:10.1007/978-3-319-65849-0_30.

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Information Systems: From Innovations to Innovation Generators

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***Abstract*—The objective of this study is thus to investigate how IS can enable organizational capabilities that may lead to organizational innovativeness. (i.e., an organization's potency to generate innovations). To do so, we review the innovation and IS literatures and use structuration theory to propose a research model, its related hypotheses and methodological aspects tied to its validation. Finally, the proposed model's anticipated contributions are discussed.**

Keywords-innovation; organizational innovativeness; structuration theory; product lifecylce management systems; radio frequency identification devices.

I. INTRODUCTION

In today's complex technological era, organizational innovativeness – defined as an organization's potency to develop and introduce innovations in various forms (e.g., product, service, process, system, business structure, business model) [1][2] – is increasingly viewed as a multidisciplinary activity [3][4] based on a few key organizational capabilities: functional and integrative capabilities [5]. As such, and because evidence from the IS literature suggests that functional and integrative capabilities could potentially benefit from the support of IS [6][7][8] [9], it seems primordial that the IS literature acknowledges the double nature of IS by studying them not only as innovation per se but also as innovation generators.

Based on this premise, the present study aims to answer the following research question: "What is the role of IS in the creation of organizational innovations?" Accordingly, the objective of this study is to investigate the impact of IS on functional and integrative organizational capabilities and, indirectly, on organizational innovativeness.

The rest of the paper is organized as follows. First, in Section 2, the literature on innovations is reviewed to identify the potential antecedents of organizational innovativeness while structuration theory is examined to resolve the apparent conflict between the "push" and "pull" perspectives within the innovation literature. Third, in Section 3, anchored on this resolution and thus the now established duality of innovations, a set of hypotheses linking key organizational capabilities to organizational innovativeness is proposed. Fourth, in Section 4, we investigate the IS literature and more specifically studies that discuss Product Life-cycle Management (PLM) systems and Closed-loop PLM systems to propose a second set of hypotheses that establish the enabling role of IS in the creation of certain organizational capabilities which may lead to organizational innovativeness. Fifth, in Section 5, the key methodological aspects tied to the empirical validation of this study's hypotheses are discussed. Finally, this research's anticipated theoretical contributions and practical implications are discussed in Section 6.

II. THEORETICAL DEVELOPMENT

A. Novelty: the Key Characteristic of Innovations

Novelty – defined as the extent to which a product, service, process, system, organizational structure, or business model departs from what already exist – is the key criterion that an organizational component must have to meet to be considered an innovation. Aware of the importance of novelty in the making of innovations, researchers generally identify innovations as either radical or incremental [10]. Radical innovations are those that produce fundamental changes in the activities of an organization or an industry and represent clear departures from existing practices [11]. On the other hand, incremental innovations merely call for marginal departure from existing practices [11].

Another important aspect of innovations is that they are externally determined. That is, the concept of innovation can only make sense when an innovation is compared to a specific external referent. For example, cell phones can only be considered innovations when they are compared to regular house phones and not when they are compared to more evolved smart phones. Thus, to innovate an organization has to create a product, service, process, system, organizational structure, or business model that departs from what already exists in its specific frame of reference. As such, an organization in the manufacturing industry, relying on supply chain logistics and transportation systems might be considered innovative whereas a firm relying on these same systems in the transportation industry will only be considered attuned to what already exists. Therefore, organizational innovativeness not only depends on what an organization does but also on what is done by other external stakeholders within the same environment.

This dual nature of organizational innovativeness is epitomized in the innovation literature by the presence of two

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overarching rival perspectives which see innovation generation as either a "push" or a "pull" phenomenon [12]. More precisely, there seems to be a polarization on innovation antecedents where the characteristics of the organization (i.e., "push" perspective) and the characteristics of its environment (i.e., "pull" perspective) are viewed as rival predictors of a firm innovativeness. Partisans of the "push" perspective have shown, for example, that a firm's structure, culture, management practices and strategies significantly influence organizational innovativeness while, on the other hand, adepts of the "pull" perspective have identified that an organization's industry, region, government policies, and technological environment significantly impact its innovativeness [12].

However, doubtful of the apparent conflict between "push" and "pull" adherents, some authors have argued, based on evidence from practice, that the process of innovation generation might be better conceptualized as an evolutionary, non-linear, iterative process between the firm and its environment [3][4]. In other words, this third and new perspective suggests reconciling previous research findings by defining organizational innovativeness as a duality where an organization is at the same time influencing and influenced by its environment rather than as a dualism where both types of innovation antecedents are considered orthogonal. Nevertheless, in spite of these authors' insightful observations, little theoretical let alone empirical work has been undertaken in the innovation research field to account for this duality. As such, the best rationale on the duality of innovations doesn't come from innovation studies but rather from the field of sociology and more precisely from Giddens' [13] answer to the debate between "functionalist/determinist" and "voluntarist" sociologists.

B. Duality of Innovations: an Explanation Anchored on Giddens' Structuration Theory

Giddens [13], analogous to authors of innovation research doubtful of the "push" and "pull" orthodoxy, acknowledged that the debate between Functionalist/determinist" – defined as sociologists entrenched in the orthodox consensus who saw agents' actions as a result of environmental forces and demands [14] – and "voluntarist" – defined as sociologists who argue that agents reflectively act without restraint and have the power to tailor their surrounding environment to their needs [15] – could in fact be resolved by acknowledging the duality of agents' behaviors. More precisely, noticing common grounds between these protagonists and the mutual influence between an agent and its environment (i.e., the duality of structure), Giddens [13] redefined the agency concept and then developed the structuration theory to provide a sound explanation to this duality. Indeed, recognizing that previous conceptualizations, which defined agency in terms of intention, failed to account for the duality of structure, Giddens [13] proposed to redefine agency in terms of transformative capacity. Thus, according to Giddens [13], agents are characterized by their ability to take action, to deploy a range of causal powers, including that of influencing those deployed by others [13]. Furthermore, similar to Bachrach and Baratz [16], Giddens [13] also recognized that agents' actions and thus their transformative capacity are to some extent limited, due to the rules and resources agents use when taking action. In other words, the rules and resources drawn upon by agents when taking action are simultaneously constraining and enabling agents' actions, creating the duality of structure. Thus, the concept of agency, which defines agents in terms of transformative capacity and entails the enabling and constraining role of rules and resources, is at the essence of the duality identified in the sociology and innovation literatures. As such, by instantiating the concept of agency to the particular context of society construction, Giddens [13] was able to demonstrate that social structures are not fixed but rather exhibit structural properties since social structures emerge from agents' constant reproduction of already existing rules and resources.

By instantiating the concept of agency in the context of innovation generation, one can realize that its basic assumptions still hold: agents, by taking action, still draw on rules and resources that simultaneously constrain and enable. However, instead of simply reproducing them, agents, because of the novelty criteria, also need to significantly depart from them (i.e., they enact a novel behavior). Therefore, similar to Schumpeter [17] who depicted innovation activities as a process of recombining and/or reconfiguring existing pieces of knowledge in some novel way [17][18], this view of innovations establishes that organizational innovativeness rests on the transformative capacity of organizations. In other words, an organization's innovativeness rests on its ability to draw from existing rules and resources while significantly departing from them by creating new knowledge.

III. CONCEPTUAL FRAMEWORK

Based on the theoretical background presented above, the premise of this article is that IS usage improves an organization's capacity to innovate. This section exposes the nine hypotheses tied to our research model shown in Figure 1. The first four hypotheses of our model explain how organizational capabilities (functional and integrative) lead to organizational innovativeness while the last five hypotheses explain how two types of IS (PLM and Closed-Loop PLM systems) may provide a platform to support and improve these key organizational capabilities.

A. The Positive Impact of Functional and Integrative Capabilities on Organizational Innovativeness

Having established, through structuration theory, that organizational innovativeness rests on an organization's ability to draw from existing rules and resources and to create knowledge, it is now essential to go back to the innovation literature and more precisely to the work of Verona [5] to define these key capabilities. Verona [5], who also anchored his research efforts on the premise that an organization's capacity for action resides in its capabilities [19], identified a set of capabilities that, similar to the ones suggested in structuration theory, are linked to the duality of organizational innovativeness. More precisely, the author identified two types of capabilities, functional and integrative [20], that enable the creation of knowledge. Functional capabilities refer

to capabilities that allow an organization to develop new knowledge while integrative capabilities are defined as capabilities that allow an organization to integrate knowledge from different sources [20]. Recognizing that sources of knowledge can be located within and outside organizational boundaries, Verona [5] sub-divided integrative capabilities into internal integrative capabilities and external integrative capabilities (i.e., those that integrate knowledge from sources within the organization's boundaries and those that integrate knowledge from sources outside the organization's boundaries). As such, Verona [5] and Giddens [13], although guided by different research objectives, both posited capabilities as a core property of agents and defined capabilities tied to organizational innovativeness as an ability to draw from existing sources of knowledge to create new knowledge. Accordingly, organizations aiming to maximize their innovativeness must develop functional capabilities as well as internal and external integrative capabilities. Based on this premise, the following three hypotheses are formulated:

Hypothesis #1: An organization's functional capabilities positively influence its innovativeness.

Hypothesis #2: An organization's internal integrative capabilities positively influence its innovativeness.

Hypothesis #3: An organization's external integrative capabilities positively influence its innovativeness.

Furthermore, because the duality of organizational innovativeness implies that sources of knowledge both enable and constrain the creation of innovations, an additive interaction between functional and integrative organizational capabilities is also expected. Based on this premise, the following hypothesis is formulated:

Hypothesis #4: The interaction between the three organizational capabilities will have a positive influence on organizational innovativeness.

B. The Positivie Impact of IS Usage on Functional and Integrative Capabilities

Recognizing the importance of organizational innovativeness to develop and maintain a competitive advantage, organizations have adopted various practices and IS to support their initiatives [9]. Amongst these, PLM practices and PLM systems seem the more promising since there is an increased awareness that they may represent the foundation upon which the key organizational capabilities that lead to organizational innovativeness may be developed [9]. For instance, Pratt & Whitney used the PLM system developed by Siemens (i.e., the Tecnomatix solution) to limit the development of its engines to within 3 years, which was considered competitive at the time [21]. Furthermore, by using this system, Pratt & Whitney was able to design innovative engines that minimize downtimes by making maintenance operations as simple as possible [21].

PLM can be defined as a strategic approach that aims to provide more product-related information to the organization during the whole product lifecycle. Building on and extending the ideas of product data management (PDM) [22], this approach emerged from the necessity to move beyond simple engineering concerns of products and to provide a shared platform for creation, organization, and dissemination of product related knowledge [23][24]. PLM systems consisting of information processing systems or a set of information technology (IT) systems were conceived in order to support these considerations by forming an organization's product information backbone [25]. These systems, rooted in computer-aided design (CAD) and PDM systems, establish a set of tools and technologies that provide a shared platform for collaboration among product stakeholders and streamline the flow of information along all the stages of the product lifecycle [22][26]. However, although these systems were originally intended to support every phase of a product lifecycle (i.e., beginning of life (BOL), middle of life (MOL) and end of life (EOL)), most PLM systems currently fail to support products once they are sold, that is during their MOL and EOL phases [27]. More precisely, PLM systems, because of business and technological constraints, cease to collect product information once the product leaves the control of the organizations or its boundaries [23][24][27]. As such, by (1) integrating people, processes, business systems and information throughout the whole product lifecycle, (2) fostering horizontal connection between an organization's silos, (3) enhancing information sharing, (3) facilitating change management, and (4) enticing use of past knowledge [23][24], current PLM systems only support functional and internal integrative organizational capabilities and leave external integrative capabilities unsupported. Based on this premise, the following two hypotheses are formulated:

Hypothesis #5: The use of PLM systems positively influences an organization's functional capabilities.

Hypothesis #6: The use of PLM systems positively influences an organization's internal integrative capabilities.

Even though traditional PLM systems fail to address external integrative capabilities, recent advances in product identification technologies (PIED), such as radio frequency identification (RFID) and Auto-ID now enable organizations to collect product information beyond their organizational boundaries [23][24][27]. These new systems that comprise previous functionality of PLM systems while also including the new functionalities provided by PEID are referred to as Closed-loop PLM systems [28]. These new systems, by automatically capturing data outside the boundary of the firm, alleviate both the business and technological constraints of traditional PLM systems and give organizations the potential to also support external integrative capabilities. Based on this premise, the following hypotheses are formulated:

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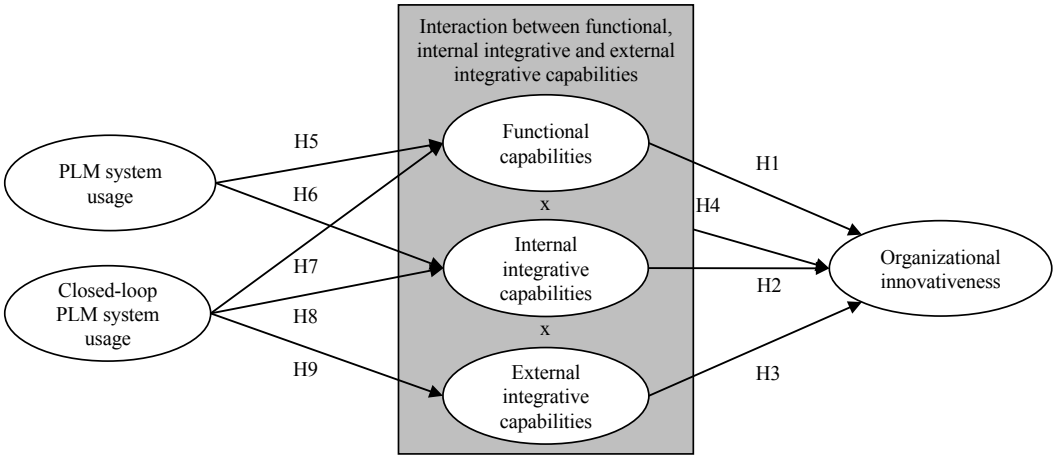

Figure 1. Research Model.

Hypothesis #7: The use of Closed-loop PLM systems positively influences an organization's functional capabilities.

Hypothesis #8: The use of Closed-loop PLM systems positively influences an organization's internal integrative capabilities.

Hypothesis #9: The use of Closed-loop PLM systems positively influences an organization's external integrative capabilities.

IV. METHODOLOGY

As our research is still in progress, this section explains the methodological framework we have devised, but not yet used, to test our research model. More precisely, we present our intended research setting, data collection procedures, survey instrument and data analyses procedures.

A. Research Setting

The up-to-date list of all Canadian manufacturing firms maintained by Statistics Canada (a Canadian government agency) will constitute this study's sample frame. More precisely, the sample frame will be limited to Canadian manufacturing firms active in the transportation equipment manufacturing industry (NAICS 336) (e.g., motor vehicle, aerospace, shipbuilding and other transportation equipment manufacturing). Three reasons justify the selection of this specific frame: First, manufacturing firms are often the middle men in the supply chain to which they pertain enabling them to influence and be influenced by both upstream and downstream partners and thus to the full range of the duality of innovativeness. Second, organizational innovativeness is already recognized as a key driver of success in this specific industry and thus is a salient topic to potential respondents. Third, manufacturing firms, especially in this particular industry, are amongst the very few organizations that have adopted to varying degrees PLM and Closed-Loop PLM systems, making this a rare setting where their influence on organizational capabilities is likely to be observed [29][30].

B. Data Collection

Data will be collected by the means of a field survey. More precisely, business managers will be asked via e-mail to fill the first-half of an online survey (available through a first hyperlink) and to ask their engineering counterparts to fill the second-half of the online survey (available through a second hyperlink). Business managers will answer questions regarding their organization's innovativeness (i.e., criterion variable). Considering the fact that innovation may be of various forms and taking into account this study's research setting, business managers will be asked to evaluate the innovativeness of their organization in regards to two forms of innovation: product and process innovations. On the other hand, engineering managers will answer questions regarding the organization's functional and integrative capabilities as well as the use of PLM and Closed-Loop PLM systems within their organizations (i.e., predictor variables). Seeking responses from respondents from two different organizational sub-units should alleviate some potential sources of common method bias. In addition, to maximize this study's response rate, a Tailored Design Method (TDM) will be used. Specifically, this procedure comprises four essential elements: (1) a respondent-friendly questionnaire; (2) a five-contact strategy (in the form of five different e-mails to be sent to business managers); (3) a personalized correspondence; and (4) incentives in the form of a privileged access to the research findings (e.g., a tailored benchmark report) and a chance to win an electronic gift card of a 500$ value on Amazon (i.e. one gift card for each type of respondent).

C. Survey Instrument

The electronic survey will comprise measures adapted from the literature. The measures tied to the organizational capabilities will be adapted from [5][31][32]. Measures tied to

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PLM and Closed-PLM systems use will be adapted from [17][18][27][33][34][35]. Finally, measures of organizational innovativeness will be adapted from [1][2][36]. A pre-test of the questionnaire will also be conducted with several business and engineering managers in order to test the reliability and validity of the questionnaire as well as to identify potential upgrades prior to the full-scale inquiry.

D. Data Analyses

Structural equation modeling (SEM) based on LISREL covariance software package will be used to test this study's research model. LISREL is chosen over PLS and traditional regression methods as it better supports the study of interactions amongst research variables [37], a key particularity of this study. Furthermore, because most of this study's measures were previously used and tested, this research is more confirmatory rather than exploratory in regards to its measures. As such, it is more appropriate to use LISREL, which is more stringent then PLS [37]. Also, since using the SEM approach allows for the evaluation of both the quality of the measurement and the construct interrelationships, this approach will be used to first test the measurement model and then to test the structural model. To test the measurement model, a confirmatory factor model (i.e., the measurement model) will be used to measure the fit between the theorized model and observed variables. Then, to test the structural model, results of the measurement model will be used to create a path-analytic model to investigate the relationships hypothesized in this study [38].

V. CONCLUSION

Recognizing the potential of IS as innovation generators, the present study aimed to answer the following research question: "What is the role of IS in the creation of organizational innovations?" Based on the theoretical and conceptual background put forth in this study, we assess that IS play an enabling role in the creation of organizational innovations. Specifically, IS provide a platform to support and improve the key organizational capabilities (functional and integrative) that lead to organizational innovativeness. If validated, our understanding of the role of IS in the creation of organizational innovations is likely to yield important theoretical contributions and practical implications.

A. Theoretical Contibutions

From a theoretical perspective, by identifying novelty as a key criterion of innovations and by instantiating the concept of agency in the context of innovations, this research significantly improves our understanding of the creation of organizational innovations. Also, the sound conceptual framework developed in this study allows for the reconciliation of conflicting views on innovation generation and sets the groundwork for further research on this important topic. Furthermore, by highlighting the duality of organizational innovativeness, this study theoretically justifies the necessity of functional and integrative capabilities as well as the additive interaction stemming from their mutual influence. In doing so, this research also establishes the importance of IS in the innovation generation process, by revealing their positive impact on functional and integrative organizational capabilities. Accordingly, the present research also explains how IS can support the creation of organizational innovations.

B. Practical Implications

From a practical standpoint, the present research anticipated results should allow managers to improve the innovation capabilities of their organizations by identifying the key role of functional and integrative capabilities as well as their additive mutual influence. Furthermore, by being amongst the first study to highlight the role of IS in the generation of innovations, this study should enable organizations to not only improve their innovativeness but also to reap greater benefits from their current IS. Furthermore, by highlighting the key characteristics of PLM and Closed-Loop PLM systems, this research should also provide sound arguments for why firms that aim to innovate should use Closed-loop PLM systems that incorporate PEID and not limit their use to PLM systems.

C. Limits and Future Research Avenues

The theoretical and methodological contents presented above suggest a few limits and related future research avenues. First, our study sample only comprises Canadian organizations involved in specific industries. To address this limit, future research could aim to replicate our research efforts with a different sample frame. For example, it could be interesting to replicate our research efforts with organizations from service industries and/or from different countries. Second, although we use the concept of duality at the heart of structuration theory to show that organizational innovativeness rests on an organization's ability to draw from existing rules and resources and to create knowledge, our research model does incorporate all the tenets of structuration theory. In the future, we hope to extend our research model in order to take into account more tenets of the theory.

REFERENCES

[1] A. Azedegan and K. J. Dooley, "Supplier Innovativeness, Organizational Learning Styles and Manufacturer Performance: an Empirical Assessment," Journal of Operation Management, vol. 28, no. 6, pp. 488-505, 2010.

[2] T. M. Hult, R. F. Hurley and G. A. Knight, "Innovativeness: its Antecedents and Impact on Business Performance," Industrial Marketing Management, vol. 33, no. 5, pp. 429–438, 2004.

[3] D. Leonard-Barton, "Develper-User Interaction and User Satisfactionin Internal Technology Tranfer," Academy of Management Journal, vol. 36, no. 5, pp. 1125-1139, 1993.

[4] R. Subroto, K. Sivakumar and I. F. Wilkinson, "Innovation Generation in Supply Chain Relationships : a Conceptual Model and Research Propositions," Journal of the Academy of Marketing Science, vol. 32, no. 1, pp. 61-79, 2004.

[5] G. Verona, "A Resources-Based View of Product Development," Academy of Management Review, vol. 24, no. 1, pp. 132-141, 1999.

[6] E. K. Clemons and M. C. Row, "Sustaining IT Advantage: the Role of Structural Differences," MIS Quarterly, vol. 15, no. 3, pp. 275-292, 1991.

[7] E. K. Clemons and M. C. Row, "Information Technology and Industrial Cooperation: the Changing Economics of

 ISBN: 978-1-61208-614-9

Coordination and Ownership," Journal of Management Information Systems vol. 9, no. 2, pp. 9-28, 1992.

[8] K. D. Joshi, L. Chi, A. Datta, and H. Shu, "Changing the Competitive Landscape: Continuous Innovation through IT-Enabled Knowledge Capabilities," Information System Research, vol. 21, no. 3, pp. 472-495, 2010.

[9] Y.-M. Tai, "Effects of Product Lifecycle Management Systems on New Product Development Performance," Journal of Engineering and Technology Management, vol. 46, no. 1, pp. 67-83, 2017.

[10] J. E. Ettlie, W. P. Bridges, and R. D. O' Keefe "Organization Strategies and Structural Differences for Radical versus Incremental Innovation," Management Science, vol. 30, no. 6, pp. 682-695, 1984.

[11] S. Gopalakrishnan, and F. Damanpour, "A Review of Innovation Research in Economics, Sociology and Technology Management," Omega, International Journal of Management Science, vol., 25, no. 1, pp. 15-28, 1997.

[12] N. Becheikh, R. Landry and N. Aamara, "Lessons from Innovation Empirical Studies in the Manufacturing Sector: a Systematic Review of the Literature from 1993-2000," Technovation, vol. 26, no. 5-6 , pp. 644-664, 2006

[13] A. Giddens, "Elements of the Theory of Structuration", The Constitution of Society, University of California Press, 1984.

[14] L. Winner, "Engines of Changes," Autonomous Technology: Technics out of Control as a Theme in Political Thought, MIT Press, Boston, MA, 1977.

[15] J. R. Galbraith, "Designing Complex Organization," Addison-Wesley, Reading, MA, 1973.

[16] P. Bachrach and M.S. Baratz, "The Two Faces of Power," American Political Science Review, vol. 56, no. 4, pp. 947-952, 1962.

[17] J. Schumpeter, "The Theory of Economic Development," Cambridge, Mass: Harvard University Press, 1934.

[18] S. Paruchuri, "Intraorganizational Networks, Interorganizational Networks, and the Impact of Central Inventors : a Longitudinal Study of Pharmaceutical Firms," Organization Science, vol. 21, no. 1, pp. 63-80, 2010.

[19] M. Iansiti and K. B. Clark, "Integration and Dynamic Capability: Evidence from Product Development in Automobiles and Mainframe Computers," Industrial and Corporate Change, vol. 3, no. 3, pp. 557-605, 1994.

[20] B. Lawson and D. Samson, "Developing Innovation Capability in Organizations: a Dynamic Capabilities Approach," International Journal of Innovation Management, vol. 5, no. 3, pp. 377-400, 2001.

[21] S. G. Lee, Y.-S. Ma, G. L. Thimm, and J. Verstraeten "Product Lifecycle Management in Aviation Maintenance, Repair and Overhaul," Computers in Industry, vol. 59, no. 2-3, pp. 296–303, 2008.

[22] F. Ameri, and D. Dutta, "Product Lifecycle Management: Closing the Knowledge Loops," Computer-Aided Design and Applications, vol. 2, no. 5, pp. 577-590, 2005.

[23] H.-B, Jun, J.-H. Shin, D. Kiritsis and P. Xirouchakis, "System Architecture for Closed-Loop PLM," International Journal of Computer Integrated Manaufacturing, vol. 20, no. 7, pp. 684-698, 2007.

[24] H.-B, Jun, D. Kiritsis and P. Xirouchakis, "Research Issues on Closed-Loop PLM," Computer in industry, vol. 58, no. 8-9, pp. 855-868, 2007

[25] A. Sääksvuori and A. Immonen, "Product Lifecycle Management," 2nd edition. Springer, London, 2002.

[26] J. Stark "Product Lifecycle Management: Volume 1 - 21st Century Paradigm for Product Realisation," 3rd edition, Springer, London, 2015.

[27] S. Talbot, E. Lefebvre and L.-A. Lefebvre, "Closed-Loop Supply Chain Activities and Derived Benefits in Manufacturing SMEs," Journal of Manufacturing Technology Management, vol. 18, no. 6, pp. 627-658, 2007.

[28] P. Hadaya and P. Marchildon, "Understanding Product Lifecycle Management and Supporting Systems," Industrial Management and Data Systems, vol. 112, no. 4, pp. 559-583, 2012.

[29] M. Abramovici and O. C. Sieg, "Status and development trends of product lifecycle management systems," The conference on Integrated Products and Product Development (IPPD-2002) Feb., 2002.

[30] L. Zhekun, R. Gadh and B. S.Prabhu, "Applications of RFID Technology and Smart Parts in Manufacturing," The confrence on Design Engineering Technical Confernces (DETC-2004) ASME, Sept. 2004,

[31] A. Malhotra, S. Gosain and O. El Sawy, "Absortive Capacity Configurations in Supply Chains : Gearing for Partner-Enabled Market Knowledge Creation," MIS Quarterly, vol. 29, no. 1, pp. 145-187, 2004.

[32] S. A. Zahra and G. Georges, "Absorptive Capacity, a Review, Reconceptualization, and Extension," Academy of Management Review, vol. 27, no. 2, pp. 185-203, 2002.

[33] T. Chiang and A. J. C. Trappey, "Development of Value Chain Collaborative Model for Product Lifecycle Management and its LCD Industry Adoption," International Journal of Production Economics, vol. 109, no. 1-2, pp. 90-104, 2007.

[34] D. Kiritsis, "Closed-Loop PLM for Intelligent Products in the Era of the Internet of Things," Computer-Aided Design, vol. 43, no. 5, pp. 479-501, 2011.

[35] S. Lee, "Business Use of Internet-Based Information Systems: the Case of Korea," European Journal of Information Systems vol. 12, no. 3, pp. 168-181, 2003.

[36] J. P. Jansen, F. A. J. Van Den Bosch, and H. W. Volberda, "Exploratory Innovation, Exploitative Innovation, and Performance: Effects of Organizational Antecedents and Environmental Moderators," Management Science, vol. 52, no.11, pp. 1661-1674, 2006

[37] D. Gefen, D. W. Straub and M. C. Boudreau, "Structural Equation Modeling and Regression: Guidelines for Research and Practice," Communications of the Association for Information Systems, vol. 4, no. 1, pp. 1-77, 2000.

[38] G. S. Kearns and A. L. Lederer, "A Resource-Based View of Strategic IT Alignment: How Knowledge Sharing Creates Competitive Advantage," Decision Sciences, vol. 34, no. 1, pp. 1-29, 2003.

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Two-level Architecture for Rule-based Business Process Management

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***Abstract*— One of the main challenges in Business Process Management (BPM) systems is the need to adapt business rules in real time. A serious obstacle is the lack of adaptable formal models for managing dynamic business rules. This is, due to the inadequacy of the models ability to describe the rule components, meta-rules, relationships and logical dependencies. To overcome this drawback, this paper presents a two-level rule-based approach to control BPM systems. The model accounts for logical representation of rules components and their relationships in Process-based Systems, as well as a method for incremental indexing of the business rules. The incremental indexing mechanism is described as an approach to control process execution and adaptation of business rules in real time based on rules propagation. Therefore this model provides a basis for an efficient and adaptable solution for managing business rules changes.**

Keywords-Business Process Management; Rule-based Systems; Meta-Rules; Rule Dependencies; Object-orientation.

I. INTRODUCTION

There are several definitions for business rules proposed in the literature. The most commonly used definitions of business rules are described [4]. In general, a business rule is defined as a rule that constrains, controls or structures some aspect of information, applications and processes in business. Business rules have been considered from many different perspectives. For example, business rules can be used by credit card companies to approve credit card applications. E-commerce businesses use business rules to understand customers shopping habits. Banks may use business rules to analyse data to establish suspicious or fraudulent online activities. Other applications that use business rules exist in areas such as insurance, airline, telecom, and manufacturing industries, etc.

In Business Process Management (BPM) systems, the behaviour of executing business process workflows is controlled by various business rules. Transforming and configuring dynamic and scattered business rules through process flow routines is very demanding. Typically, the organizations will have many business rules to enforce in their business processes. However, the business rules tend to change frequently. The most challenging task is to propagate these changes when there are multiple rule dependencies. In BPM systems, a change to business rules means reconfiguration of every process and other related rules. Inefficiency and inconsistency of the business rules are often unavoidable. The manageability and maintainability of the business rules is therefore becoming time consuming and a costly exercise. To address these problems, an adaptive Business Rules Framework for Workflow Management [1] has been developed. It is based on modelling of both business rule components and meta-rules, as well as business processes, flows and events in a unified manner, accounting for the structural patterns of description for various objects. This unified approach allows for the defining of the explicit and implicit relationships between business rules and indexing them incrementally, which eliminates the need for keeping a log of the changes.

This article has six sections to follow. Section II gives an overview of related work. Section III introduces the two-level approach for building the architecture of rule-based systems for BPM. Section IV describes the basic concepts used to construct the two-level architecture. Section V describes the current status of implementation of the whole framework. Section VI presents formal definitions and illustrates the use of dependency trees to define business rules relationships. Section VII concludes the article with a brief description of the next stage of implementation of the framework.

II. RELATED WORK

In recent years, substantial efforts have been made towards developing solutions to tackle the ever-growing problem of business rules adaptation. This section presents some methodologies and approaches adopted by existing rule-based systems. The existing commercial Business Rule Management Systems (BRMSs) integrate rule technology (rule engine) specifically for rule management. The IBM BRMS [2],[3] has the greatest business rules capabilities on the market. IBM BPM includes a customized version of IBM's Operational Decision Manager (ODM) tool for its business rules, which incorporates tools such as Eclipse to give inexperience programmers the ability to create and modify rules. The well-known IBM BRMS, WebSphere ILOG JRules [4], which provides a flexible tool for rule modelling, is now part of IBM ODM. While IBM BRMS provides integrated environment with rich and flexible tools for business rule modelling, there are some notable limitations in relation to the ability to manage changes to business rules. There is no straightforward way to change rules that affect more than one process. Multiple changes to business processes will need to be applied even for the simplest business rule changes. This seriously limits the business agility that business rules are designed to provide.

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There is no separation of the various parts of the business rules components, i.e., Event, Condition and Action. This means a change made on the "condition" part of the rule will require invoking the whole rule. Separating rule components provides flexibility and increases performance, as only the part that needs changing is exposed on the business rule application. Henceforth, various parts of the rule need to be stored in appropriate structures to facilitate their management, similar to the existing structures for data in database systems. Rules are executed one by one in a procedural manner As a consequence, this creates additional work when the rules sequences change or when a separate rule in a particular sequence is changed. This complicates the ability to perform logical deduction hence its inability to manage changes to multiple business rule hierarchies [5].

C Language Integrated Production System (CLIPS) is specifically designed to facilitate the development of software to model human knowledge or expertise [6]. The CLIPS expert shell provides a platform where expert knowledge may be categorized as rules. To supplement its rules management capability, CLIPS works as an inference engine that enables it to perform the inference procedure whereby rules are interpreted to generate various actions as appropriate [7]. This mechanism employs the embedded pre-existing rules-based knowledge as "facts" to drive the firing mechanism of the inference engine and thereby produce a recommended conclusion to a problem. Even though CLIPS provide an interactive, text oriented environment for modelling rules, there is no dedicated knowledge base and, thus, facts are volatile and ~~are~~ purged from its memory as soon as its execution is terminated. To overcome this fundamental limitation, an external rule-base system must be added for a seamless integration with CLIPS. This adds to the complexity and cost for managing rules. The problem becomes worse when rules are scattered and changing.

Java Expert System Shell (JESS) [8][9] is another rule engine, originated from CLIPS and written entirely using Java. There is an extension called VISUAL JESS, which improves the comfort of using the tool. Pitfalls of JESS for dynamic systems are well documented [10].

Oracle BRMS is a leading Business Rules product, probably one of the finest products in the market. Oracle offers a Rule Author, a web-based graphical authoring environment that enables creation of business rules. In addition, Oracle provides an embedded business rules engine to its BPM system. The Oracle BPM application can add/remove and change the state of business objects in the working memory, and allows the rule engine to reason and update processes by triggering events or invoking specific processes based on the outcome of the rules. Like IBM BRMS, it faces similar limitations - it remains impossible to specify the dependencies between the rules based on the relationships between BPM objects. This causes multiple changes to be necessary to adjust already configured processes and update existing business rules even in the case of a simple rule change.

OpenRules [11], another powerful BRMS for rule-based application development, provides both complex Business Rule editor as well as a tool for building user interfaces. It allows the use of external tools such as MS Excel, Google Docs, and Eclipse IDE to create a complex, decision support system. OpenRules has similar limitations like the Oracle and IBM products. In this case it becomes even more complicated to deal with multiple changing rules as the rule management remains a tedious manual task.

JBoss Drools BRMS [12] is a sophisticated open source BRMS and has a lot of functionalities, which allow users to write and validate business rules that can then be added to Java Applications. While Drools distinguishes the structural elements of the rules syntactically it does not treat them in a special way semantically. At the same time, the users are free to define, classify, and modify the rules according to their specific requirements. Business rule components (i.e., Event, Condition, Action, etc.) are not defined as objects. This brings additional complexity in terms of change management. Furthermore, this work does not address the aspects of rules relationships and dependencies.

There are only a few proposals in the literature, which consider the business rules functionality and change [13]-[15]. Their focus is on rule execution and they do not provide support for modelling business rules. As a rule, they do not address how changes of business rules are managed. There is no clear, well-structured definition of the rule components and relationships; a common drawback of all industrial rule-based frameworks. We believe that a more flexible and efficient approach to manage business rule changes is required.

The next section outlines the two-level architecture of rule-based BPM systems, which addresses the above issues. Presenting a flexible approach for defining rules as objects, attributes/properties and relationships enabling logic and object programming power during rule implementation.

III. TWO-LEVEL ARCHITECTURE FOR BPM SYSTEMS

The formal model presented here is based on the understanding of the actual BPM system as an event-driven and constantly evolving process, with two functioning levels. The first level is the Process level, which governs the execution of business processes, while the second level, the Rule level, is a meta-level that controls the actual business rules. Features that are considered on the first level are: business processes, information and material flows, events, conditions and actions, which comprise the business domain. The users may intervene only via events that can trigger activities prescribed by the business rules. This way we can model manual, automated and fully-automatic processes as part of the business workflows. The second level considers the relationships between rules and dependencies between them, classifications of the rules, and meta-rules. The business rules are made up of events, conditions and actions, or the famous "When <event> If <condition> Then <action>" structure, whereas process execution level is made up of processes, steps, flows (material and information flows), roles, etc. For instance, if some events are observed during execution of a working process, then the corresponding business rules, which depend on these events, are triggered and lead to actions, which in turn perform the

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transition to a new step, which may execute other processes or amend the parameters of the current process. The model uses business rules to glue together processes in a business process workflow. The rule control level provides a level of abstract "independence" between the two levels, suggesting that the rules can be changed without affecting the workflows that have been completed. The rule level controls the execution of business workflows adding the business logic to them. The business rules appear at all stages of the workflow from initiation, to execution, to termination. Based on the distinct roles they play in the workflow development, they can be organised in a taxonomic hierarchy: the Execution rules are divided into Flow and Process rules; the Flow rules are divided into Sequence, Fork and Join rules; and, Process rules are classified into Time-based and Non-Time-based rules.

IV. BASIC CONCEPTS OF THE TWO-LEVEL RULE-BASED ARCHITECTURE

This section presents basic concepts to support creation of objects, properties, and, relations for the model and meta-model. The concepts have been developed in a purely logical manner.

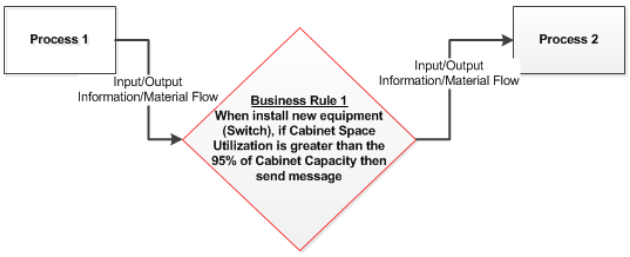

Figure 1. Example of a Business Rule.

Fig. 1 depicts a typical business rule. From such rule, the following concepts can be identified:

A. *Business Objects*

The business objects are the building blocks for implementing business rules and business processes. The following types of objects can be distinguished:

- **Processes:** Building blocks of the business workflows. *Examples:* Process1 (Manage Cabinet Space Availability) and Process2 (Order Cabinet).
- **Flows:** Capturing data/material and information in and out the processes. *Examples:* Cabinet Capacity, Cabinet Utilization, New Equipment, etc.
- **Events:** Asynchronously registered situations that trigger the rules. *Example:* Filling up the cabinet up to the max capacity
- **Conditions:** Synchronously occurring situations. *Example:* Sufficient space in the cabinet to mount a new server

B. *Object Properties*

Formally described, the business rules and workflows can be constructed in terms of object characteristics. The object properties provide information about the characteristics of the objects. For example, the object "Process" may have properties such as: process id, name, status, creation date, etc. From the viewpoint of the conceptualization of our ontology, object properties can be classified into one of the following types:

- **Identification properties** - examples are process id, name, type, etc.
- **Qualitative description properties** - these are categorical or nominal properties, which can be described qualitatively only - for example status, deviation, trend, etc.
- **Quantitative description properties** - these properties can be described using a fixed value that can be estimated quantitatively - for example, the number of closed processes, etc.

In [16], object properties are described as a common approach to specify characteristics or attributes of a real-world object instance, which in turn helps to understand how to interact with the object. By introducing property characterization for each object, our model can fulfil the requirements for flexibility and maintainability of the formulation of business rules to control processes.

C. *Business Rules*

The structure of business rules is based on the famous Event-Condition-Action paradigm [17]. Various business rule classifications exist in the literature [18]. In connection to BPM systems, the following rule classification were identified:

- **Initiation Rules**

  Initiation Rules depicts rules that specifically initiate a process. Depending on the conditions of the rule, a process can be launched and thus continue execution. Some Initiation rules are driven by events only, these are known as Start Event. The business workflows can be started only by Initiation Rules after a suitable triggering event. The triggering events can be manually or automatically invoked.

- **Event or Process Rules**

  Event or Process Rules group rules that are defined during the execution of a process. An example for such a rule is the filling up of a container which generates a warning about reaching the capacity limit.

- **Flow Rules**

  Flow Rule formally depicts rules that control the flow of processes. Intermediate processes depend on Flow Rules (if this is a specific name then capitalize) to progress from one process to another.

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- **Termination Rules**

  The business process terminates based on a Termination Rule, which is triggered by suitable termination event AFTER the process is finished, or on process execution control rule DURING the process execution in the case of emergency. In Fig. 1, Execution Rule was used to check cabinet space availability. The decision to install new network switch onto a cabinet depends on such an execution rule. Some Termination Rules are driven by events only, hence known as End Event.

Objects are building blocks and they are described in this section. Object properties, apart from characterizing the objects quantitatively and qualitatively are also the main vehicle for analyzing the dependencies between the rules which apply to them. The more sophisticated the properties, the more elaborate the dependencies that can be formulated. To allow the mapping and displaying of identified concepts into required classes and properties, a concise and intuitive notation such as EBNF [19] can be used. Although other notations are possible, EBNF is sufficient for the purpose. The term "structured" means that all direct or indirect relations between objects and their properties can be represented into AND/OR trees. The following is EBNF notation for Condition concept, based on the use of objects and their properties.

```
<Condition Object>::=   <Object> <Condition Object> |
                        <Condition Object> AND <Condition Object> |
                        <Condition Object> OR <Condition Object> |
                        <Condition Object> XOR <Condition Object> |
                        NOT <Condition Object> |
                        <Condition Property>
<Condition Property>::= <Object> <Property> |
                        <Condition Property> AND <Condition Property> |
                        <Condition Property> OR <Condition Property> |
                        <Condition Property> XOR <Condition Property> |
                        NOT <Condition Property>
```

V. FORMAL DEFINITION OF BUSINESS RULES, RULE RELATIONSHIPS AND DEPENDENCY TREES

This section briefly presents the formal definition of relationships between rules. The section also exemplifies business rules dependency trees to map rule relationships.

A. Business Rules Formal Definitions

Consider a Business Rule set R containing a collection of rule samples controlling business processes. A Rule set R has one or more related rules that has been put together to guide the movement of processes. For instance, R may be made up of Initiation Rule, Flow Rule, Event or Process Rules and Termination Rule. Let every Rule in R be expressed in terms of $\{R_i,| i= {}_1,\ldots, {}_n\}$. Each Rule definition R_i consists of a collection of Event (E), Condition (C) and Action (A). We refer to E, C and A to represent sets of Events, Conditions and Actions respectively, containing fragments of the Rule R. Now, let E be expressed in terms of $\{E_i,| i= {}_1,\ldots, {}_n\}$. And C be expressed in terms of $\{C_i,| i= {}_1,\ldots, {}_n\}$. Also A be expressed in terms of $\{A_i,| i= {}_1,\ldots, {}_n\}$. In this research, we will use notation $E_{1i}(R_1)$, $C_{1i}(R_1)$ and $A_{1i}(R_1)$ where $E_{1i} \in E_1$, $C_{1i} \in C_1$ and $A_{1i} \in A_1$ to represent Business Rule basic definition. Note that for simplicity reasons, if a part of the Business Rule has no importance in a discussion then it will be omitted. For example, $C_{1i}(R_1)$ and $A_{1i}(R_1)$ will represent a Business Rule that contains Conditions and Actions only.

B. Relations Between Business Rules

The existence of a dependency between two rules expresses that communication occurs between components (Event, Condition, and Action) of the Business Rule. For example, one Business Rule action may trigger conditions of other Business Rules or condition of one Business rule may depend on an event of another Business Rule. Therefore, Business Rules relationships can be described by analyzing Business Rule components relationships. We consider the relationship between two rules to be represented by the symbol $\xrightarrow{Relate\ to}$. For example, $R_1 \xrightarrow{Relate\ to} R_2$ means Rule 1 relates to Rule 2. If one of R_1 action activates event for R_2, we declare as $A_{1i}(R_1) \xrightarrow{Relate\ to} E_{2j}(R_2)$. Business Rules relationships can be analysed and declared in one of the following possible six ways:

i. $E_{1i}(R_1) \xrightarrow{Relate\ to} E_{2j}(R_2)$
ii. $E_{1i}(R_1) \xrightarrow{Relate\ to} C_{2j}(R_2)$
iii. $E_{1i}(R_1) \xrightarrow{Relate\ to} A_{2j}(R_2)$
iv. $C_{1i}(R_1) \xrightarrow{Relate\ to} C_{2j}(R_2)$
v. $C_{1i}(R_1) \xrightarrow{Relate\ to} A_{2j}(R_2)$
vi. $A_{1i}(R_1) \xrightarrow{Relate\ to} A_{2j}(R_2)$

These relationships are defined based on Objects and Object properties involved in Condition, Event and Action components of the Rules. Moreover, relationship can be defined in terms of qualitative and quantitative characteristics of the object parameters. We examined six ways (i-vi) of representing rule relationships based on the partial order relationship. However, it is far simpler and natural, to apply the tree structure to the model and picture the relationships between rules. Therefore, tree structure and patterns to show relationship are introduced in the next section. Rule patterns are simple enough to represent number of rule relationships. However, in practice there can be hundreds, thousands or more rule relationships. In systems with substantial number of rule relationships, three or more rule dimensions are needed to clearly depict the relationship structure. This is one of the areas that need to be explored in future studies.

C. Business Rules Dependency Tree

In our approach the rule dependencies are defined after structuring them into dependency trees, which are in the form of AND-OR graphs corresponding to the mutual co-existence of the rules. As the name suggests, the relationships will be of two kinds: AND relationships, which

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group several rules that can be fired simultaneously, and OR relationships, which group several rules that can be invoked alternatively. There are variants of AND/OR relationships: Direct AND Dependency, Direct OR Dependency, Indirect AND Dependency and Indirect OR Dependency.

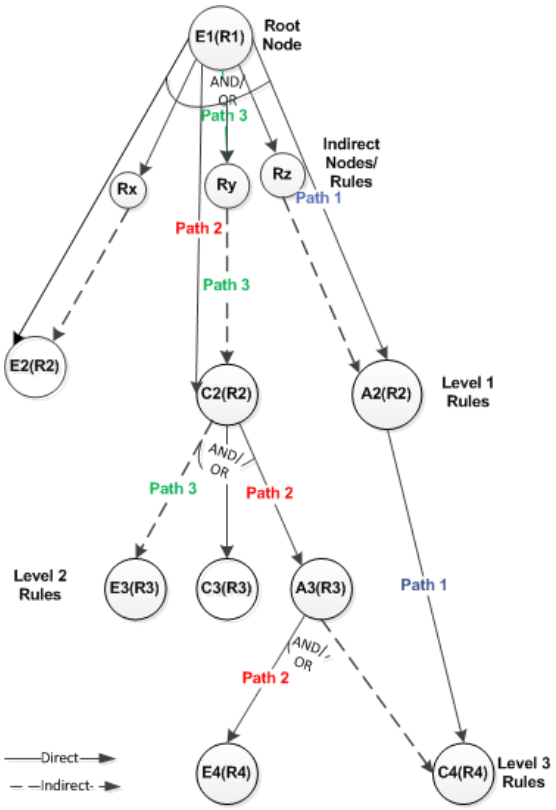

Figure 2. AND/OR Tree.

The AND/OR tree on Fig. 2 combines all relationship patterns:

- Precedence based dependencies
- Level based dependencies
- Path (Chain) based dependencies
- Node based dependencies
- Indirect node based dependencies

The dependency trees make it easier to understand the relationship between rules. The dependencies will be used in construction of the algorithm for real-time inference within BPM system. Structuring of the rules into dependency trees would also allow implementing of more efficient algorithms for searching the rules. Different patterns of inclusion of the rules in the trees will provide additional information to control the flow of execution as the business processes progress. In addition, we can use the trees to analyse the process behaviour in real time.

VI. PROTOTYPE IMPLEMENTATION

The implementation of the model presented here is currently underway using the open source Rule Management System DROOLS [20]. Since it is still work-in-progress, only preliminary developments are presented. DROOLS rule system comes from the area of knowledge representation. The knowledge representation arena is concerned with formally representation of knowledgebase and reasoning. In DROOLS, a rule has two-parts represented using first order logic. The structure of a rule is usually WHEN-THEN that is IF-THEN providing logic statements. This means we can infer conclusions from rule facts stored in the knowledgebase. DROOLS rule system is also perfect for rule adaptation and forward chaining. In DROOLS, the implementation of business rules is carried out using three main components: firstly, the *rule* class (drl) containing the actual rules, second, the *fact* class (pojo) containing the data affected by the rule, and third, the *tester* class (main), which calls both data and rules for execution.

To manage the rules and processes, our architecture implements Event, Condition, Action, Process and Flow (Information and Material) as separate fact classes. In addition, Initiation Rule, Event Rule, Flow Rule and Termination Rule are implemented as subclasses of the rule class which is instantiated in the main or tester class to allow runtime modification of the rules. This supports the reusability and allows adaptation of the rules and their components in the case of changes, as well as the definition of meta-rules using information associated with rule relationships. Fig. 3 illustrates the implementation of the `Condition` class using DROOLS.

```
//Condition class (Fact class)
package com.ABRIW.model;
public class Condition {

	private String Condition_Object;
	private String Condition_Property;
	private String AND;
	private String OR;

	public String getCondition_Object() {
		return ConditionObject;
	}
	public void setCondition_Object(String ConditionObject) {
		this.ConditionObject = ConditionObject;
	}
	public String getCondition_Property() {
		return ConditionProperty;
	}
	public void setCondition_Property(String ConditionProperty) {
		this.ConditionProperty = ConditionProperty;
	}
	public void setAndCondition(String ConditionObject, String AND, String ConditionObject) {
		this.ConditionObject = ConditionObject;
	}
	public void setORCondition(String ConditionObject, String OR, String ConditionObject) {
		this.ConditionObject = ConditionObject;
	}
	public void setAndCondition(String ConditionProperty, String AND, String ConditionProperty) {
		this.ConditionProperty = ConditionProperty;
	}
	public void setORCondition(String ConditionProperty, String OR, String ConditionProperty) {
		this.ConditionProperty = ConditionProperty;
	}

}
```

Figure 3. Condition class using our approach in DROOLS.

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`Condition` class defines object related configurations such as object properties and methods. Its methods include `getConditionProperty, setConditionProperty` etc. as shown in Fig. 3. In a `Rule` class, we simply create an instance of a `Condition` class. This automatically inherits the default properties and methods of the `Condition` class. The other concepts of the ontology are implemented in a similar way.

VII. CONCLUSION AND FUTURE WORK

The paper presented a two-level architecture of BPM system, which supports efficient solution for adaptation of business rules, thanks to the incremental indexing of the rules and the formalisation of structural patterns of dependencies between them. This architecture supports BPM professionals and academics with adequate means for modelling of both business process workflows and business rules. In addition, it is the basis for a seamless integration of an efficient algorithm for adaptation of the business workflows to the changing conditions.

A prototype of the above model is being implemented in DROOLS using object-oriented (OO) technology. In this approach both the business workflow processes and business rule components are implemented as objects. Two of the fundamental features of OO technology, the encapsulation and the inheritance, are used conveniently for implementing the architecture following a bottom-up strategy. This approach allows the build up of the indexing mechanism in an incremental manner. The plan, on the next stage, is to complete the implementation of two separate inference engines on top of the model: a forward chaining inference algorithm, which account the logics of business process workflows and controls their execution, and a backward chaining inference engine, which propagates the changes and adapts the rules in real-time. Work has already begun on a series of algorithms, which account for the relationships and the dependencies between the rules. Our focus here will be in exploring the structural patterns of the rule relationships and the influence on the inference on Rule level.

The architecture presented here has wide potential for applying BPM systems in many areas, such as manufacturing, chemical process control, healthcare and anywhere, where the business processes can be described in terms of operational workflows. The big advantage of this architecture is the ability to modify the business rules logics without interrupting the business workflows. Moreover, by adding some meta-rules it could become possible to test the production rules and achieve consistency.

Other issues, which may be beneficial to explore further involve the relationships between different components of the model, i.e., relationships between rules and user roles, relationships between processes and business data, relationships between processes and workflows, etc.

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REFERENCES

[1] K. Ezekiel, V. Vassilev, and K. Ouazzane, “Adaptive Business Rules Framework for Workflow Management”, to appear.

[2] S. D. Hendrick, K. E. Hendrick, Business Value of Business Rules Management Systems, IDC #231195, 2012.

[3] A. Macdonald, *The value of IBM WebSphere ILOG BRMS*, 2010, IBM. [Online]. Available from: https://www01.ibm.com /software/integration/business-rule-management/jrules-family/ retrieved: 12.2017.

[4] J. Boyer, H. Mili, Agile Business Rule Development: Process, Architecture, and JRules Examples, Springer Science and Business Media 1, 2011, ISBN: 9783642190407.

[5] P. Haley, *Confessions of a production rule vendor*, 2013. [Online]. Available from: http://haleyai.com/wordpress/ 2013/ 06/22/confessions-of-a-production-rule-vendor-part-1/ retrieved: 12.2017.

[6] J. C. Giarratano, *CLIPS User’s Guide*, 2003. [Online]. Available from:http://www.ghg.net/clips/download/documen-tation /usrguide.pdf; retrieved: 12.2017.

[7] J. Giarratano, G. Riley, Expert Systems: Principles and Programming, Course Technology, 2004, ISBN: 0534384471.

[8] E. Friedman-Hill, Jess in Action: Java Rule-Based Systems, Manning Publications, 2003, ISBN: 1930110898.

[9] A. Grissa-Touzi, A, H. Ounally, and A. Boulila, “VISUAL JESS: An expandable visual generator of oriented object expert systems”, Engineering and Technology, pp. 108–111, 2005.

[10] R. Thirumalainambi, “Pitfalls of JESS for Dynamic Systems”, Art. Intelligence and Pattern Recognition, pp. 491-494, 2007.

[11] J. Feldman, *Creating, Testing, and Executing Decision Models with OpenRules*, 2011. [Online]. Available from: http://slideplayer.com; retrieved: 12.2017.

[12] M. Salatino, M. De Maio, and E. Aliverti, Mastering JBoss Drools, Packt Publishing, 2016, ISBN**:** 1783288620.

[13] Lijun, Introducing a rule-based architecture for workflow systems in retail supply chain management. MSc Thesis, University of Borås School of Business and IT, Sweden, 2012.

[14] F. Rosenberg, C. Nagl, and S. Dustdar, “Applying Distributed Business Rules – The VIDRE Approach”, IEEE Int. Conf. on Services in Computing, Chicago, IL, USA, pp. 471–478, 2006.

[15] M. Thirumaran et al., “Business rule management framework for enterprise web services”, Int.J. Web Service Computing, Vol.1, No.2, pp. 15-29, 2010.

[16] Y. Sun, B. Liefeng, and D. Fox, “Learning to Identify New Objects”, IEEE Int. Conf. on Robotics and Automation, Hong Kong, pp. 3165 – 3172, 2014.

[17] F. Bry, M. Eckert, P.-L. Patranjan, and I. Romanenko, “Realizing Business Processes with ECA Rules: Benefits, Challenges, Limits”, Int. Workshop on Principles and Practice of Semantic Web Reasoning, Springer, pp. 48-62, 2006.

[18] P. Jayaweera, M. Petit, “Classifying Business Rules to Guide the Systematic Alignment of a Business Value Model to Business Motivation”, Proc. Int. Workshop on Business/IT Alignment and Interoperability, Collection CEUR, Amsterdam, Vol, 456, 2009.

[19] International Organization for Standardization, Information technology. Syntactic metalanguage. Extended BNF, ISO/IEC 14977:1996, pp. 1-22, 1996.

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Detecting Adverse Events in an Active Theater of War Using Data Mining Techniques

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***Abstract* – This study investigates the effectiveness of data mining techniques in detecting adverse events based on infrastructure development spending, the number of project types, and other variables in an active theater of war in Afghanistan using data sets provided by the Human Social Culture Behavior program management (2002-2010) of the U.S. Department of Defense. The study first applies feature reduction techniques to identify significant variables, then uses five cost-sensitive classification methods and reports the resulting classification accuracy rates and areas under the receiver operating characteristics charts for adverse events for each method for the entire country and its seven regions. The results show that when analysis is performed for the entire country, there is little correlation between adverse events and project types and the number of projects. However, the same type of analysis performed for each of its seven regions shows a connection between adverse events and the infrastructure budget and the number of projects allocated for the specific regions and time periods. Among the five classifiers, the C4.5 decision tree and k-nearest neighbor provided the best global performance.**

Keywords: active war theater; data mining; adverse events; prediction; classification

I. INTRODUCTION

The U.S. Department of Defense (DoD) uses the following definition for irregular warfare: "*a violent struggle among state and non-state actors for legitimacy and influence over the relevant population(s).*" Irregular warfare is a non-conventional warfare which includes non-proportional force to subdue and coerce the civilian population in the regions in which opposite forces are not large and effective. The success of irregular warfare operations depends heavily on protecting the civilian population by the military as the civilian population is the primary target of irregular warfare [1]. Recognizing the challenges of the dynamic of irregular warfare among various actors, the U.S. military has made some changes and accommodations to its force structure. Also, the DoD initiated and developed the Human Social Culture Behavior (HSCB) modeling program. The main goal of the program was to guide and help the U.S. military in understanding different cultures while operating in overseas countries and to better organize and control the human terrain during irregular warfare. The military uses HSCB models to understand the behavior and structure of organizational units at the macro level (i.e., health, politics, energy, economics, security, water and sanitation, and social and cultural aspects) and at the micro level (i.e., terrorist networks, tribes, customs, and military units). These HSCB models are important and attract a great deal of attention with regard to current and future operational military and non-military requirements. These models are also very complex as they exhibit non-linear and fuzzy behavior and are often ill-defined with respect to their socio-economic-cultural factors.

II. PREVIOUS WORK

Several studies have attempted to develop models of human behavior from patterns identified in the data in order to predict the effects of actions aimed at disrupting terrorist networks [2]. Since terrorist attacks are not random in space and time, it is possible to discover representative patterns and trends in adverse activity or behavior over time and space by analyzing the geospatial intelligence on reported incidents. The studies concluded that these patterns and trends could be used for prediction future attacks and that they might help decision-makers to allocate more resources and personnel to the places which are more likely to be attacked and also to try reduce the number of such attacks. These studies used

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fuzzy inference systems (FIS), adaptive neuro-fuzzy inference system (ANFIS) and wavelet neural networks to analyze terrorist attacks time series.

Other studies built models based on the input variables such as infrastructure development spending projects, the number of projects, and population density. The models applied multiple linear regression, data mining and soft computing techniques such as neural networks, ANFIS, and FIS as well as fuzzy C-means and subtractive clustering for predicting four categories of adverse events, i.e., the number of killed, the number of wounded, the number of hijacked, and the number of events at month *t* in an active theater of war in Afghanistan [3]. These four categories of events are collectively called "adverse events". The studies performed analysis for the entire country and its seven regions and used variable reduction techniques to eliminate redundant attributes as well as implemented sensitivity analysis for the neural network to determine the cause and effect relationship between the input and output variables. However, due to the sparse nature of the input and output data (between 87% and 98% of values for the four adverse events are 0′s, with a 0 representing lack of events), the prediction errors generated by the models for the four adverse events were significantly high. Thus due to the unbalanced nature of the data precise prediction of the number of four adverse events was an extremely challenging and difficult task.

III. DATA SETS

The data sets for the five mentioned studies and this study were provided by the HSCB program management of the U.S. DoD. The time-dependent data were collected over the years 2002 through 2010 and represent more than 30,000 records and over 100 variables. Among other variables, the data sets included the following input variables: the budgeted amount [$US] for 14 categories of infrastructure investments in the areas such as Agriculture and Health, the number of 14 project types at years *t-2*, *t-1*, and *t*, as well as the mentioned four categories of adverse events at month *t-1*, seven regions, and the male and female urban and rural population densities. The output variables included the mentioned four categories of adverse events at month *t*.

IV. DESCRIPTION OF THE STUDY AND RESULTS

This study investigates the effectiveness of data mining techniques in detecting/classifying adverse events based on the infrastructure development spending in 14 project categories, the number of project types, and other variables in an active theater of war in Afghanistan using the same data sets that were used in the five mentioned studies. First, the study recodes the four output variables (the number of killed, wounded, hijacked, and events) representing adverse events into the binary representation, i.e. two classes. For example, killed (Yes or 1) or not killed (No or 0) or an event happened (Yes or 1) or did not happen (No or 0). Then it applies feature reduction techniques to identify significant variables. Next to compensate for class imbalances, the study uses five cost-sensitive classifiers such as neural networks (NN), k-nearest neighbors (*k*-NN), C4.5 decision trees (DT), support vector machines (SVM), and random forest (RF) to detect adverse events. Finally, the study reports the resulting classification accuracy rates and areas under the receiver operating characteristics (AUROC) charts for the four adverse events for each classifier for the entire country and its seven regions. The AUROC values, which testify to the global performance of the classifiers, are measured on the [0.5, 1] scale, where 0.5 and 1 indicates a bad classifier and a good classifier, respectively. For example, the AUROC values for the entire country for the four adverse events were within the [.688, .805] range. The results show that the AUROC values for events are generally higher than the AUROC values for dead, wounded and hijacked; and that the AUROC values for hijacked are generally lower than the AUROC values for dead, wounded and events. The hijacked category was the most highly underrepresented in the data sets.

The results show that when analysis is performed for the entire country, there is little correlation between adverse events and project types and the number of projects. However, the same type of analysis performed for each of its seven regions shows a connection between adverse events and the infrastructure budget and the number of projects types allocated for the specific regions and time periods. For example, for region Eastern the following variables (project categories) were identified as significant: Energy, Governance, Emergency Assistance, and Gender, as well as urban male and female population densities, rural female population density, killed at month *t-1*, and number of events at month *t-1*. Among the five classifiers, the DT and *k*-NN generated the best rates in terms of global performance.

V. CONCLUSION

The models presented in this study could support decision makers who analyze historical economic data on how regional funds allocation can best help minimize adverse events. Though the models used Afghanistan data, they may be applicable for other countries that are looking to build infrastructure while the threat of terrorist and military activities are present.

REFERENCES

[1]. J. Clancy, and C. Crossett. "Measuring effectiveness in irregular warfare", Parameters, 37(2), 88-100, 2007.

[2]. D. Schmorrow, and D. Nicholson. Advances in Cross-cultural Decision Making. Boca Raton: CRC Press, Chapter 38, 374-384, 2011.

[3]. E. Çakıt, and W. Karwowski. "Predicting the occurrence of adverse events using an adaptive neuro-fuzzy inference system (ANFIS) approach with the help of ANFIS input selection". Artificial Intelligence Review, 48(2), 139-155, 2017.

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Revenue Optimization of Telecom Marketing Campaigns for Prepaid Customers

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***Abstract*—The design and optimization of marketing campaigns today usually still includes a high level of manual expert involvement. This applies particularly to the prepaid mobile phone sector of the highly competitive telecommunication industry. Since prepaid telecom customers are characterized by highly volatile and sparse usage data their future behavior is hard to predict, and marketers often rely mainly on experience and gut feeling when designing marketing campaigns, using only simple data analysis tools. The project developed a methodology and software prototype that helps marketers in this area to exploit the full potential of real-time big data-driven analytics for microtargeting, allowing them to make fact-based and informed decisions. Specifically, it provides an interactive solution for the semi-automated visual support of the design and optimization of single-channel marketing campaigns. The developed solutions bring a huge step towards the automation of the whole process of optimizing marketing campaigns in the telecommunication business, keeping the possibility of interactive interventions of marketers to implement strategic management decisions or use their expert knowledge. The system provides enough information for marketer to comprehend the reasons for the decision and by retracing it provides precious insights for the design of new campaigns. The solution uses machine learning closed loop and intuitive visualization based on nomograms and was prototypically implemented on Apache Spark big data stack and evaluated on sample data from two real-world prepaid telecom use cases.**

Keywords–telecom; churn prediction; predictive analytics; Naïve Bayes; Nomogram

I. INTRODUCTION

Classical data mining for marketing campaigns is usually a time consuming task. Despite the availability and use of automated analytics algorithms, the overall process of designing, adapting, executing and evaluating a marketing campaign still includes a high level of expert involvement and manual decision-making. In the age of big data, the increased volume and velocity of available data allows for added business insights and helps companies to stay competitive. At the same time, it becomes increasingly difficult to fine-tune the design and management of analytics-based marketing campaigns manually. Therefore, to fully tap the potential of real-time big data marketing analytics, a high degree of automation is needed.

The success rate of a marketing campaign depends on targeting the right customer needs and preferences. Consequently, there is an increased need for highly targeted marketing campaigns that are tailored to the needs and preferences of specific, possibly small customer groups (micro-segmentation) or even individuals (direct marketing campaigns). This requires highly agile marketing campaign management facilitating fast reaction times to customer or market events despite continuously increasing data volumes. Additionally, structural adaptations that allow for reacting to changes in the market structure as a whole must be accounted for. There is a trend in marketing towards building long-lasting relationships with customers. Since the cost for customer acquisition is much greater than the cost of customer retention [1], marketers have become increasingly interested in the latter [2]. Customer retention models aim at furthering customer loyalty and preventing active customers from changing to other providers (churning) via marketing campaigns. To achieve this, tools that support the development, management and application of customer retention models and the corresponding marketing campaigns are required and are essential Business Intelligence (BI) applications. In telecom business, the customer churn term refers to the customer turnover, i.e., loss of a service subscriber. The common reasons for churn are dissatisfaction with an existing provider, the lure of a lower price for equivalent service or better service for the same price from a different provider. Churn rate, the proportion of churned clients during a given time period, is one of the key business metrics and an indicator for customer dissatisfaction.

Churn prediction modeling techniques attempt to understand the precise customer behaviors and attributes, which signal the risk of customer churn. In predictive analytics, the typical approach to data-driven churn prediction is to use a sufficiently large historical data set of customer records, containing churning and non-churning customers. The records contain customer attributes such as age, gender, tariff, average call frequency, etc., together with the information if a customer has churned at some point in time or not. The data set is used as training set for supervised learning to construct a classifier, i.e., a predictive model that classifies a customer as a potential churner or non-churner based on the knowledge of the other attribute values (the predictor variables). In an actual prediction task, the model is applied to a new data record, where the values of the customers predictor variables are observed while the possible churn event lies in the future, so that value of the class variable churn is unknown. The classification done by the model is used as a prediction of churn or non-churn of the customer segment that corresponds to the respective predictor attribute valuations (the feature vector). In case the system has predicted a customer segment of likely churners, a suitable marketing action can be launched to prevent these customers from churning. To select such an appropriate action the underlying reasons for their churning must be analyzable, i.e., a proper insight on the reasons for churning is essential in order to design effective retention methods.

Predictive analytics models traditionally used for data-driven customer churn prediction are Decision Trees [3]–[8] and Regression analysis [9] and [10], which have been com-

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plemented with Naïve Bayes classifiers and Artificial Neural Networks [11]–[13] in recent years [14] and [15]. In Naïve Bayes classifier (NBC) models, the attributes of a domain are interpreted as random variables and are represented as vertices in a probabilistic graphical model. Direct influences of the observed predictor variables on an unobservable target variable are represented as directed edges in the graph. The result is a simple tree graph structure. The strength of influence of input variables on the target variable is given by conditional probability tables, which are learned from historic data. In a prediction task, Bayes Rule [16] is used to infer from values of the observed variables the probability of possible values of the unobserved target variable. NBCs are thus map based classifications with the additional assumption of conditional independence of input variables. Examples of applications using NBCs for churn prediction are Nath and Behara [17] and and Kirui et. al. [18] or Shaaban et. al. [13]. Other predictive models that have been used for churn prediction are, e.g., rule based classifiers (Ripper, PART), Nearest Neighbor (KNN), Self Organizing Maps [19], Genetic Algorithms [20], Linear Discriminant Analysis [21], Support Vector Machines [13], Sequential Pattern Mining and Market Basket Analysis [22] or Rough Sets [23].

As a reaction to the increasing data volumes in the telecommunication sector, approaches towards churn prediction on massive data sets have been investigated. For example, Kamalraj and Malathi [24] discuss the use of data mining techniques on big data clusters in the telecommunication industry. Balle et. al. [25] describe a prototype for churn prediction using stream mining methods, which offer the additional promise of detecting new patterns of churn in real-time streams of high-speed data, and adapting quickly to a changing reality. Different scalable algorithms have been developed and implemented, e.g., Apaches open source libraries Mahout and MLlib include, besides scalable regression models, decision trees and customer segmentation models, also Naïve Bayes Classifier learning.

The research presented in this paper was funded by the Swiss Commission for Technology and Innovation CTI and is part of the project done together with two expert partners, one software developer with extended history in telecommunication business, and one large telecom service provider located in Switzerland.

The paper is organized as follows. After short introduction we describe the problem and its requirements in Section II. In Section III, we address the conceptual model. Section IV brings the insights of development of the predictive analytics and visualization core based on data analysis done in statistical environment R. Section IV shortly describes the implemented big data solution. Section V summarizes the project results and Section VI concludes its achievements.

II. Problem Description

The mission of this project is to develop a methodology and a software prototype for semi-automated predictive marketing analytics and campaign management. It will automate the life cycle of the data mining and the campaign management process as a whole, including feature selection, model learning, prediction and decision making; iterative dynamic model adaptation over time will allow for closing the analytics loop. In particular, our goal was to optimize campaign targeting in prepaid segment of a large Swiss telecom company. We aim on customer retention campaigns in general, or on churn prevention in a special case. The existing system, and its data, puts some critical constraints we have to deal with. For example, the provided historical data are aggregated and contain time series from the narrow time slots before and after the campaign offer. Within a campaign, the existing system chooses a fixed number of customers each day and offers them a particular bonus. The offer is valid for couple of days, and expires afterwards. Some particular campaigns with a bonus credit have been chosen as a proof of concept. The campaigns run for a defined period of days, their results are reported on a daily basis, and summarized at the end of the campaign.

The designed solution must possess the following properties:

(1.) Big data-driven knowledge discovery allows for detection of hidden patterns in the growing numbers of data records and customer attributes available;
(2.) A high degree of automation in analytics, prediction, decision-making and campaign execution allows for timely reaction to events, and allows to cope with big data sets;
(3.) Self-adaptability accounts for changes in the data sets and the domain structure, as well as for lessons learned of past campaigns, embedding them in a closed feedback loop for autonomous campaign optimization;
(4.) Scalability of the algorithms to a distributed big data processing environment provides the necessary computing power to analyze the increasing amount and velocity of (big) data sets in time;
(5.) A high degree of model accuracy allows for detailed or even personalized marketing decisions;
(6.) A high degree of interpretability (comprehensibility) of the domain model and derived predictions, decisions and automatic campaign executions ensure acceptance by marketers.

In the marketing field, acceptance is of pivotal importance. Campaign managers must be able to explore influence factors and variable dependencies in order to design appropriate marketing instruments (such as special offerings for young adults with high sms-frequency). They also need to understand the rationale for an automatically triggered marketing action in order to be able to justify it to potential business customers and to top management, e.g., by pinpointing relevant influence factors. Even though the high degree of automatization is desired, the choice of contents of a marketing campaign is usually not entirely reducible to structured information and often includes highly emotional contextual information (such as the choice of a protagonist in a TV spot), therefore the possibility of manual intervention of marketing campaign must be guaranteed by any decision support system in the marketing area. Particularly, it must allow the campaign manager to integrate his experience and real-world background knowledge, as well as to implement strategic managerial requirements.

The whole marketing effort serves the purpose of sustainable increase (or of interrupting decrease) of the usage of the provider's service, in extreme case, of preventing clients churn. In contrast to postpaid segment, ultimately fewer resources are used in prepaid segment on maintaining contacts with customers and marketing analytic activities in general. This lack of interest in prepaid segment is caused by its low market share in Switzerland. As a consequence, we rely here purely

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on data induced by the service usage. Further, due to its nature, the service usage by prepaid customers is usually not as homogeneous as by postpaid clients. Thus, the data available on prepaid users are much more inadequate. This adds to the complexity of modeling and causes a decrease in the model accuracy. The existing marketing solution rates the success of the campaign based on the acceptance ratio. This clearly does not bring the desired effect. Customers, which exploit the offered bonus but do not change their usage habit, are counted as profitable, whereby in real they generate a loss. Additional requirements have been set on the designed system and its models, such as simplicity and easy interpretability, possibility of intervention, capability of effective and manageable visualization, scalability, ease of use.

III. Conceptual model

Two use cases have been specified based on obtained campaign data:

(1.) the semi-automatic support of optimized campaign template instantiation for increased acceptance ratio, and
(2.) the semi-automatic support of campaign template design for increased revenue creation.

Specifications included existing situation, description, use case properties (actors, stakeholders, levels, triggers, frequency, preconditions, post-conditions), data characteristics (names, accessibility, type, volume, temporal resolution, heterogeneity, inconsistency, constraints, analysis needs) and possible use case extensions. They are the result of workshops with the telecom partner prepaid marketing team and a number of project internal workshops (HSLU-I and Consulteer AG).

The conceptual solution addresses the following issues:

(a.) *automatization of the whole marketing process (from data mining to decision making);*
Closed loop architecture with constantly trained and updated model has been specified and build for the developed prototype, containing modules for feature preselection, prediction, evaluation and adaptation. This was done in two stages. First, methods for modules have been specified and verified with small data in statistical environment and programming language R. Second, the modules have been ported to big data stack (see Section IV) and the loop has been closed. The automatization of the whole marketing process remains a challenge, the reasons are twofold: (a.) *technical* – the built prototype has to be incorporated and verified within the live system; (b.) *non-technical* – the existing marketing processes have to be rebuild towards the high level of automatization and utilizing the implemented solution.

(b.) *allow interactive intervention of marketers (e.g., to implement strategic management decisions or experience based knowledge);*
The selected approach heads towards micro-segmentation by categorization, i.e., filtering out clients with particular combination of input feature values, which evidence the potential of revenue gain if those clients are presented with the bonus. The decision making is presented to marketer in a form of recommendation to select particular small set of clients for the campaign (microtargeting). The implemented solution utilizes the intuitive visualization based on nomogram paradigm (see Section IV). It allows marketer to manually override the automatically chosen (optimal) feature combinations with preferred values and presents the gain/risk predictions for the selected choice.

(c.) *provide interpretability of the automatically determined customer segments needed to support campaign design;*
The solution based on NBC and nomogram visualization satisfies stringent conditions set on the designed system, such as scalability, easy interpretability, possibility of intervention, etc. As opposed to black box models such as neural networks (NN) or random forests, the Naïve Bayes Model provides enough necessary information for marketer to comprehend the reasons for the selection of a client for a campaign. By retracing the decision up to the input features, and identifying those mainly responsible for the classifiers choice, it provides precious insights for the design of new campaigns and allows marketing managers to justify and explain the algorithm's results to their management. This is in contrast to black-box approaches such as deep NN. These have demonstrated strong potential on finding hidden patterns in big data collections, but do not comply with the requirement of interpretability by marketing managers.

(d.) *prediction algorithm needs to be able to deal with volatile and sparse prepaid data;*
Based on data analysis done with provided campaign data and consistent with the campaign management restrictions, the methods have been chosen for data cleaning and transformation, and feature selection, as well as suitable prediction algorithm.

(e.) *usage of behavior change instead of acceptance rate as a success measure.*
Through redesigning the metric for campaign success towards more reliable and long-term change indicator (see Section IV).

The prediction model comprises six parts:

(i.) data transformation methods;
(ii.) input feature construction method (based on data exploration results);
(iii.) feature pre-selection method with dynamic binning;
(iv.) method for target variable construction (implementing a new campaign success measure for behavior change);
(v.) Naïve Bayes prediction (classification);
(vi.) automated customer selection according to class predictions.

Closed loop learning enables a predictive analytics solution to automatically adapt to changing conditions. To achieve this, feedback loops must be integrated in the model architecture. For the given use cases, four levels of feedback have been identified: (1.) Data Level Feedback, (2.) Campaign Level Feedback, (3.) Causal Loops, and (4.) Model Level Feedback. Two of the four feedback levels have been selected for implementation (Data Level and Campaign Level Feedback).

IV. Data Analytics

In telecommunications, the usage data typically consists of time series for different variables such as number of calls, number of SMS sent, date of credit charge and charged value, revenue, etc. The provided data contain for each customer and each variable (called here accumulator) aggregated data for at least three months before and one month after the offer. In

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the Figure 1, we show single accumulator data of two chosen customers. The *UserX* accepts the offer (at time denoted by dashed line A) but does not change its behavior remarkably (offer causes a small boost in his usage but it continues to sink which is observable by the slope of the blue line); the *UserY* shows the evident change of the behavior and generates notable growth in the revenue compared to the predicted values (green triangles). It is also possible that we witness the churn prevention in the case of *UserY*.

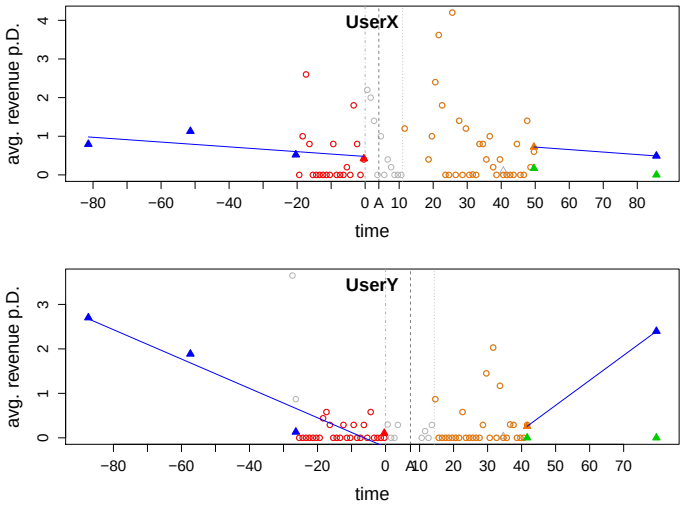

Figure 1. Customer Data Examples

The goal of the campaign is to motivate customers to increase their usage of the service. This is even the weaker condition on the selection of customers and a more general case as the churn prevention. For this purpose, it is important to classify which of the possible customers are likely to generate more usage and thus more profit for the company. Blind assignment of the offers can lead to considerable money loss. E.g., in the case, when a customer accepts the offer but does not change its usage habit (e.g., only exploits the bonus credit). Further, in the opposite case, which also has to be taken into account, the customer feels harassed by the offers he is not interested in, may even decide to churn. We utilize the classical data-driven machine learning pipeline with preprocessing phase (data cleaning and transformation), model building phase (feature extraction, model training and testing loop) and deployment phase. The trained classifier chooses the client for a campaign when it assumes that by doing so, he will increase his usage of the service and thus revenue of the company.

The current solution uses acceptance ratio as measure for the campaign success. We propose conversion shift towards more reliable and long-term behavior change indicator. We regress predictions of the accumulator values after the offer (green triangles, see Figure 1) and train the classifier with the new target variable set as the difference between predicted and real (measured) value. The predictors are variables extracted from the different accumulators, such as average number of national calls, average revenue, etc. The correlation coefficient is used to filter-out the predictors with non-significant influence on the target. In order to provide the “possibility of intervention”, “capability of visualization”, as well as the high degree of “comprehensibility and interpretability” that is needed for acceptance of an automated solution in the marketing daily business, the Naïve Bayes approach has been chosen.

NBC is simple and effective technique based on the Bayesian theorem. Even though, the Naïve Bayes is not the preferred classification method, its performance is often underestimated. It is fast and space effective, not sensitive to irrelevant features, and can handle streaming data well. For more information, the reader is referred to [26] and [27]. In particular, the binary NBC, where the target class can take only two possible outcomes, allows very elegant visualization with Nomograms [28]. (In case of multi-class classification problem, we create nomogram for one particular outcome class and the union of remaining outcomes represent the complement class.) The NBC nomogram provides a way to visualize the strength of influence of each input feature to a Naïve Bayes classification result, depending on its value or category. It assigns point scores to every predictor variable depending on the chosen feature value. The higher the range of the feature score is, the higher is its influence to the classification result. It thus provides marketers with the possibility to graphically explore how the choice of different feature values (i.e., attributes of a customer) influence the overall class probability (e.g., the probability of accepting a marketing offer or probability of revenue increase). The point scores of all features are easily summed up together and translated into the resulting overall probability. By fixing some attributes to particular values, we effectively filter the target population to microtargets. This allows us to optimize the target with respect to its resulting class probability and size.

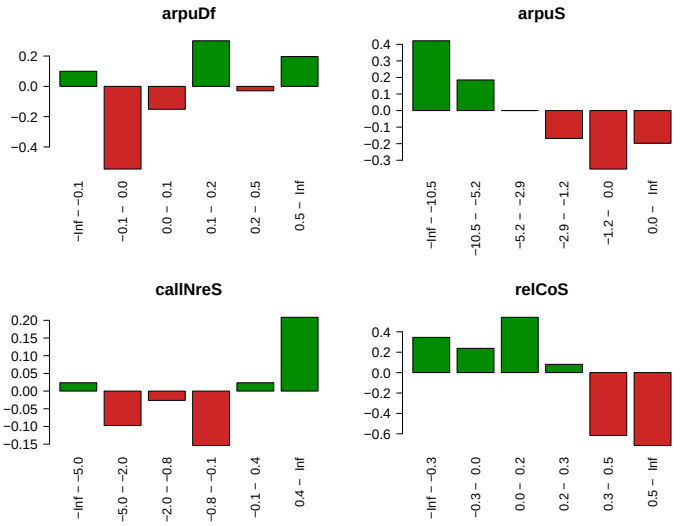

Figure 2. NBC Nomogram with 4 accumulator attributes.

As an underlying infrastructure, big data technology stack has been built based on the Apache SPARK framework for cluster computing. The main components used are: MLlib with Elasticsearch has been used to implement the Naïve Bayes prediction module, Cassandra for scalable storage and high performance data access in closed loop learning, Kafka for real-time streaming capability, and Kibana as a visualization component.

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V. RESULTS

A conceptual model of a semi-automated visual campaign design support module has been developed (based on nomograms) that directly shows predicted economic gain/loss in dependency of the selected input variables. More precisely, the model is capable of (1.) visualizing the influence of individual buckets and features on predicted economic gain/loss (2.) visualizing the impact of manual bucket/feature choices interactively, (3.) recommending optimal buckets for a given feature set, and (4.) recommending optimal features for a given campaign. The presumed adaptiveness provided by the closed loop learning module could not be evaluated, since no appropriate data has been provided.

The prediction module has been developed and evaluated on small data using software environment and programming language R (because of data availability). Yet, the used algorithms are scalable and have been also implemented with the equivalent Spark algorithms to provide a proof of concept (1.) of the implemented big data stack itself (see Section IV) and (2.) to validate the R test results for Spark.

The evaluation results of the developed approach show that (1.) the accuracy of the developed prediction module exceeds the accuracy of the two benchmark models used (telecom expert decisions and classification by a decision tree) and (2.) intuitively and understandability of Visualization and Decision Model are satisfactory and have been accepted by the telecom company. Based on the NBC nomogram visualization paradigm, a decision model and an interactive GUI prototype has been developed that allow for semi-automated campaign design support. While the prediction module provides recommendations for customer segmentation w.r.t. an existing campaign, the design of a new campaign (or the optimization of an existing one) additionally requires interpretability of these recommendations in terms of strength of causal influence of input variables and their multidimensional interaction. The NBC nomogram paradigm provides this interpretability in an intuitive way. With the GUI, the marketer is provided with the opportunity (1.) to set manual constraints for an automated optimizer (e.g., to comply with given management strategies), (2.) to choose these constraints based on intuitive multidimensional visualization of feature nomograms, and (3.) to graphically inspect the predicted (simulated) effects of his decisions in terms of expected revenue change.

Even though the performance of the utilized prediction model is not astonishing, it meets the stringent requirements specified on the designed system and still achieves satisfying results if compared with the existing solution. We measured the average gain per person for customers chosen by the trained model and compare it with the existing campaign results. The decreased performance of the prediction model is caused by the low quality of provided data and lower stability of service usage in prepaid segment in general as mentioned in Section II. In Figure 3, we show verification results of 100 rounds performed by the trained classifier. The left three boxplots show the statistic of the data from the chosen marketing campaign if present targeting approach is used. The targeted users have been split into three groups: those which accepted the marketing offer, those which did not accept it (expire) and the control group (baseline). The red boxplot shows average arpu per person and day if microtargeting with NBC model is used, the blue box on the right summarizes the advantage of the new approach compared to the actual targeting method.

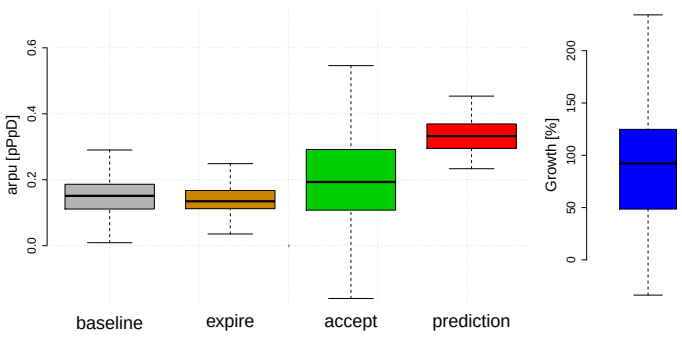

Figure 3. Testing results of 100 rounds.

A relatively new insight in telecom marketing has been gained, that the customer response rate of a digital marketing campaign usually does not appropriately reflect the business value generated by the campaign, and therefore is not an appropriate marketing success measure. More specifically, customer response measures the short-term campaign success, but disregards long term effects on return on investment induced by the campaign. Based on the data-driven marketing paradigm of customer retention beats customer poaching, a new model for measuring the marketing success of digital campaigns for volatile and sparse prepaid telecom data was developed. The metric is a function of the campaign-induced long-term behavior change of customers in the targeted segment and returns an assessment of the overall revenue increase or decline n months after the offer has been accepted. It is applicable to different intended behavior modifications, e.g., churn prevention, usage increase per channel, and can handle low quality, highly volatile and sparse input data.

VI. CONCLUSIONS

The goal of this research is twofold. To develop a methodology and a software prototype for semi-automated predictive analytics and campaign management, and as a proof of concept, to verify the designed system on a chosen use case provided by a large telecom company in Switzerland.

The implemented prototype shows that machine learning can be used to support decision makers in the telecommunication business to optimize marketing campaigns through microtargeting. Moreover, it shows that Naïve Bayes is suitable model if full control need to be granted over the decision support system. A nomogram based decision module has been developed that optimizes the size of micro segments w.r.t. predicted long-term revenue increase caused by stimulus-induced behavior change. The use of long-term revenue increase as a campaign success measure is in contrast to commonly used customer response success measures, which do not take long term effects into account and often disregard the intended effect on return on investment. Besides fully automated optimization over all input features, the decision module also allows the marketer to manually set constraints to the optimizer, e.g., to implement higher-order management strategies or to explore the customer structure in terms of effects on revenue in a simulation run. In order to permit the decision model to adapt to changing customer structures, a closed-loop

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learning approach has been used that continuously updates the underlying prediction model and corresponding nomogram values. The solution has been prototypically implemented based on an Apache big data stack and tested on two real-world use cases with prepaid customer data sets provided by the telecom project partner. The prediction accuracy of the Naïve Bayes approach has shown to exceed a decision trees approach as well as the currently used benchmark with mostly manual and experience-based campaign definition.

The detailed description of the prototype developed in this research is omitted in order to honor the non-disclose agreement with the involved industry partners.

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REFERENCES

[1] CIM, "The cost of customer acquisition versus customer retention." 2010, URL: http://www.camfoundation.com/PDF/Cost-of-customer-acquisition-vs-customer-retention.pdf [retrieved: April, 2016].

[2] K. N. Lemon, T. B. White, and R. Winer, "Dynamic customer relationship management: incorporating future considerations into the service retention decision," Journal of Marketing, vol. 66, 2002, pp. 1–14.

[3] J. R. Quinlan, C4.5: Programs for Machine Learning. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 1993.

[4] M. Mehta, R. Agrawal, and J. Rissanen, "Sliq: A fast scalable classifier for data mining," in Proceedings of the 5th International Conference on Extending Database Technology: Advances in Database Technology, ser. EDBT '96, 1996, pp. 18–32.

[5] J. C. Shafer, R. Agrawal, and M. Mehta, "Sprint: A scalable parallel classifier for data mining," in Proc. 22nd Intl. Conf. on Very Large Data Bases. Morgan Kaufmann Publishers Inc., 1996, pp. 544–555.

[6] J. Gehrke, R. Ramakrishnan, and V. Ganti, "Rainforest - a framework for fast decision tree construction of large datasets," in Proc. 24th Intl. Conf. on Very Large Data Bases. Morgan Kaufmann Publishers Inc., 1998, pp. 416–427.

[7] R. Rastogi and K. Shim, "Public: A decision tree classifier that integrates building and pruning," in Proc. 24th Intl. Conf. on Very Large Data Bases. Morgan Kaufmann Publishers Inc., 1998, pp. 404–415.

[8] J. Gehrke, V. Ganti, R. Ramakrishnan, and W.-Y. Loh, "Boat – optimistic decision tree construction," in Proc. 1999 ACM SIGMOD Intl. Conf. on Management of Data. ACM, 1999, pp. 169–180.

[9] G. Kraljević and S. Gotovac, "Modeling data mining applications for prediction of prepaid churn in telecommunication services," Automatika, vol. 51, no. 3, 2010, pp. 275–283.

[10] T. Simsek Gursoy, "Customer churn analysis in telecommunication sector," Istanbul University Journal of The School of Business Administration, vol. 39, no. 1, 2010, pp. 35–49.

[11] C.-P. Wei and I.-T. Chiu, "Turning telecommunications call details to churn prediction: A data mining approach," Expert Systems with Applications, vol. 23, no. 2, 2002, pp. 103–112.

[12] J. Hadden, A. Tiwari, R. Roy, and D. Ruta, "Churn Prediction: Does Technology Matter?" Int. J. Intell. Technol., vol. 1, no. 2, 2006, pp. 104–110.

[13] E. Shaaban, Y. Helmy, A. Khedr, and M. Nasr, "A proposed churn prediction model," J. Eng. Res. Appl., vol. 2, no. 4, 2012, pp. 694–697.

[14] J. Hadden, A. Tiwari, R. Roy, and D. Ruta, "Computer Assisted Customer Churn Management: State-of-the-art and Future Trends," Comput. Oper. Res., vol. 34, no. 10, 2007, pp. 2902–2917.

[15] N. Kamalraj and A. Malathi, "A survey on churn prediction techniques in communication sector," International Journal of Computer Applications, vol. 64, 2013, pp. 39–42.

[16] S. J. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 2nd ed. Pearson Education, 2003.

[17] S. V Nath, D. Ravi, and R. Behara, "Customer churn analysis in the wireless industry: A data mining approach," 2003, URL: http://download.oracle.com/owsf_2003/40332.pdf [retrieved: April, 2016].

[18] C. K. Kirui, L. Hong, W. K. Cheruiyot, and H. Kirui, "Predicting customer churn in mobile telephony industry using probabilistic classifiers in data mining," in Int. J. Comput. Sci. Iss. (IJCSI), vol. 10, no. 2, 2013, pp. 165–172.

[19] A. Ultsch, "Data mining and knowledge discovery with emergent self-organizing feature maps for multivariate time series," in Kohonen Maps. Elsevier, 1999, pp. 33–46.

[20] W.-H. Au, K. C. Chan, and X. Yao, "A novel evolutionary data mining algorithm with applications to churn prediction," Trans. Evol. Comp, vol. 7, no. 6, 2003, pp. 532–545.

[21] Y. Xie and X. Li, "Churn prediction with linear discriminant boosting algorithm," in Proc. 7th Intl. Conf. on Machine Learning and Cybernetics, ICMLC, vol. 1, 2008, pp. 228–233.

[22] H. Farquad, R. Vadlamani, and R. Bapi, "Churn Prediction using Comprehensible Support Vector Machine: an Analytical CRM Application," Applied Soft Computing, vol. 19, 2014, pp. 31–40.

[23] A. Amin, S. Shehzad, C. Khan, I. Ali, and S. Anwar, "Churn prediction in telecommunication industry using rough set approach," Studies in Computational Intelligence, vol. 572, 2015, pp. 83–95.

[24] N. Kamalraj and A. Malathi, "A survey on churn prediction techniques in communication sector," in Int. J. Comput. App. (IJCA), vol. 64, no. 5, 2013, pp. 39–42.

[25] B. Balle, B. Casas, A. Catarineu, R. Gavaldà, and D. Manzano-Macho, "The architecture of a churn prediction system based on stream mining," in Frontiers in Artificial Intelligence and Applications, vol. 256, 2013, pp. 157–166, URL: http://www.lsi.upc.edu/ gavalda/papers/ccia2013Churn.pdf [retrieved: November, 2017].

[26] C. M. Bishop, Ed., Pattern Recognition and Machine Learning. Springer, 2006.

[27] T. M. Mitchell, Machine Learning. WCB McGraw-Hill, 1997.

[28] M. Možina, J. Demšar, M. Kattan, and B. Zupan, "Nomograms for Visualization of Naive Bayesian Classifier," in Proc. PKDD 8th Eur. Conf. Principles and Practice of Knowledge Discovery in Databases, 2004, pp. 337–348.

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