

Analysing Supply Chain Strategies Using Knowledge-Based Techniques

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Abstract. We are experiencing a digital revolution that is rapidly changing the way business is conducted. In this new economy, information is shared speedily and many participants are collaborating. Effective and seamless collaboration between distributed supply chain members is therefore crucial. To understand how this may be done, we describe a knowledge based framework for abstracting, enriching, analysing and improving supply chain models. We employ business process modelling as a useful methodology for capturing and analysing supply chain strategies. In addition, we use a meta-interpreter and workflow engine for simulating business processes to help understand business scenarios. Its declarative approach makes business rationale more transparent. Our work is demonstrated by looking at a case study of Dell's supply chain management that depicts its PC supply chain operation logics and strategies.

Keywords: supply chain management, business process modelling, simulation, workflow engine, Dell, FBPML, declarative approach, logical formal method.

1 Introduction

We have entered a Digital Economy era. The emergence of the Web and the general transformational impact of information and communication technologies upon business activity have lead us to an epoch where e-business, e-commerce, and electronic goods and services are perceived as standard practices. In fact, as “defined by the changing characteristics of information, computing and communications, the digital economy is now the preeminent driver of economic growth and social change” [1]. In this new business reality, competition is consumer-driven and there is a need for closer collaboration between companies. The Internet is recognised to “provide considerable opportunities for firms to streamline their business operations” [2], and to collaborate or even virtually integrate, especially among supply chain (SC) members. We are experiencing integrated value chains and emerging business models, including autonomous virtual enterprises. In the meantime, this digital revolution “makes commerce less local, more interstate and more global” [1].

In such a highly distributed environment, where there is a need for integration, it is important to assure coordination among the different business actors, especially among SC members. We believe that a third-party broker could successfully

undertake this task, given that he is strategy-aware, flexible and reliable to changes. In this case, an important question is what sort of knowledge is needed for such a broker.

In this paper we regard integrated supply chain management as an integral part of the digital economy, and we focus on knowledge capture for a SC broker. We, thus, suggest a framework for abstracting, enriching and analysing supply chain strategies with the use of knowledge-based techniques. Business process modelling is recognized as a useful vehicle for analysing SC strategies, and a cyclic modelling framework is introduced. A workflow engine is presented to carry out the simulation of business processes, and thus will be used within the suggested framework for reasoning about and comparing SC strategies. Finally, recognising Dell as the coordinator and manager of its supply chain, we introduce its case study to show how our framework can be applied in real-world business scenarios.

2 Background Information

Supply Chain Management (SCM) is defined as “the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders” [3]. A supply chain, i.e. all parties involved in fulfilling a customer request, has to manage the flow of information, products and funds throughout its tiers so that it has the right products in the right quantities at the right time and at the minimal cost. The digital economy has enforced and facilitated the surge of SCM, hence “SCM consciousness is accelerating up the corporate agenda” [4]. In fact, experts state that “enterprises are currently competing through their supply chains” [5], thus reflecting the significance of SC coordination, alignment and integration.

Dell is a successful SCM example, as it uses the knowledge of coordination to improve SC performance by operating as a SC organiser. Dell “coordinates information sharing, incentive alignment and collective learning to focus on direct selling and build to order” [6]. Its *direct model* involves selling PCs directly to customers through its website Dell.com, hence bypassing the cost-adding distributors and retailers while getting access to valuable marketing information. Moreover, Dell differentiates its strategic approach towards different market segments (i.e. large organizations, small and medium businesses, and personal consumers), with a main focus on large customers. Dell was one of the first computer companies to highlight *component assembly* as a respectful core activity. The *build to order* strategy means that a computer is built only after an order has been placed, a practice requiring close collaboration between Dell and its suppliers. According to Michael Dell, “*Dell’s partners are treated as if they’re inside the company*” [7], thus virtual integration is accomplished and real-time information is shared through ValueChain.Dell.com. Furthermore, the high selection and evaluation criteria that Dell sets for its suppliers guarantees long-lasting relationships between them [8]. Hence, we believe that Dell has a threefold role: it is a computer manufacturer, a point of contact for customers and an overall SC manager. The last two points upgrade Dell to a SC broker in the digital economy.

Business process modelling is a popular tool for enhancing business performance, as it “allows the capturing, externalisation, formalization and structuring of

knowledge about enterprise processes” [9], thus enhancing knowledge management. *Workflow Management Systems* involve process modelling, process reengineering, and workflow implementation and automation [10]. According to Mentzas et al. [11] there are three basic categories of workflow techniques: communication and activity based, and hybrid techniques. In our work, we follow the activity-based approach.

A language that supports business process modelling and workflow system development is the *Fundamental Business Process Modelling Language* (FBPML) [12]. It is a merger and adaptation of two standard languages: PSL and IDEF3, that results with both formal process execution semantics and rich visual modelling methods. These characteristics make it suitable for our work. Hence, FBPML is used in the modelling and simulation procedures. Interested readers are referred to [12] and [13] for further specification and notation of FBPML.

3 Capturing Supply Chain Processes and Strategies

3.1 A Cyclic Modelling Framework

Existing documents on SCM are often written in natural or structural languages and often intended to facilitate business studies focusing on certain aspects of the SC. They, therefore, cover only partial information needed to enable fully automated SC analysis and automation. To address this issue, we used a systematic, cyclic modelling framework that allows us to incrementally capture and enrich SC processes and strategies. A schematic abstraction of our framework is provided in Fig. 1.

In this *cyclic modelling framework*, the modeller is to first identify processes and data from the described organizational environment that is relevant to business operations and SC strategies. He then creates a suitable initial model and evaluates it to identify information gaps. If the existing model is satisfactory then it constitutes the final BPM; otherwise the modeller needs to find ways to fill these gaps. Once new

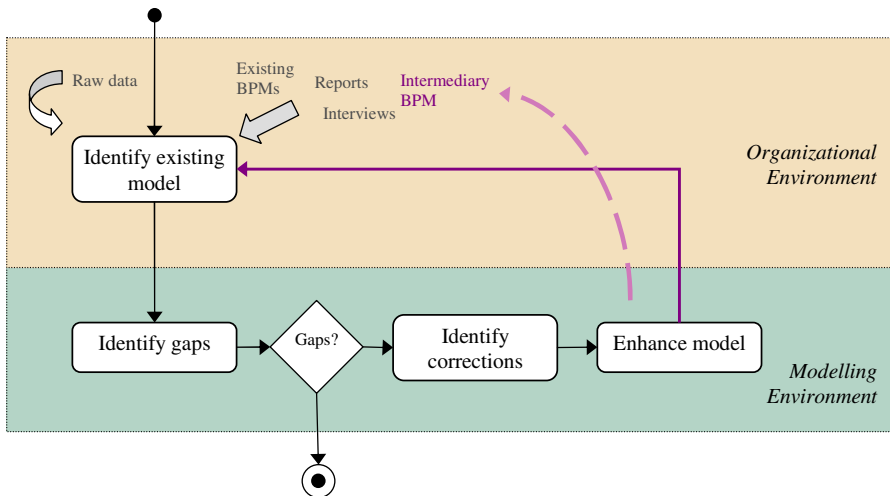


Fig. 1. Cyclic modelling framework

filler information is identified, he adds it to the existing BPM and creates an improved version of the model, which is provided as input for the next cycle of the modelling procedure. When no gap is identified, the modelling framework is ended. To identify information gaps, we suggest the following evaluation criteria and corresponding questions: i) soundness: does the BPM follow correctly the modelling specification, and are the semantics reliable?, ii) completeness: does it cover all important SC processes, strategies and business scenarios? iii) realism: does it correspond to real business and SC strategies? iv) level of detail: is it abstract enough to provide an overview of SC strategies and detailed enough to derive interesting information?

3.2 Development of Dell’s BPM

While most of the literature that covers Dell’s SC strategies is theoretical, we suggest business process modelling as a useful methodology for capturing and making those strategies concrete. We have applied the cyclic modelling framework explained above to the case study of Dell in order to develop a BPM that provides insight into the company’s successful SC strategies, allowing us to perform interesting analysis. The initial input data was the MIT Process Handbook [14, 15] and its specific entry for Dell, as well as other literature that covers Dell’s business and SC strategies and operations. By applying the cyclic modelling framework, we have encountered three distinctive larger loops. Each loop is identified with the lack of specific type of information and subsequently is provided and enriched with new information.

We first examined the initial process model, BPM#0, for Dell as provided by the MIT Process Handbook and found that the lack of process sequence in the model was an important limitation. To rectify this problem, we introduced sequences based on business logics and created a new version of the initial BPM, BPM#1. This new version was used as input for the second iteration of the cycle. Subsequently, BPM#1

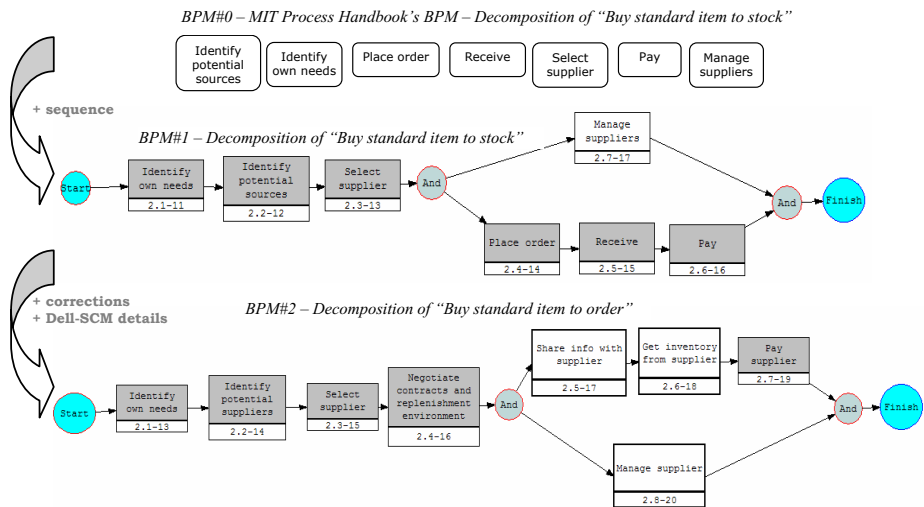


Fig. 2. Example processes of Dell’s procedure “Buy standard item to order” throughout the modelling framework

was evaluated against the criteria in Sec. 3.1, and several further information gaps have been identified: i) some of Dell's SC strategies were not covered, e.g. virtual integration with different customer segments, ii) at several points it was too high-level to provide interesting SCM information and enable automation, iii) a mistake was identified, i.e. instead of buy-to-order, Dell was presented as buy-to-stock that is contradictory to Dell's well-known SC strategies, and iv) the assembly procedure of computers was not presented, which is a core operation of Dell. After suitable corrections were made, a new version of the BPM was created, BPM#2. Again, BPM#2 was used as input of the third loop repetition and was found to be satisfying for capturing Dell's SC strategies. In Fig. 2, we provide these three versions of the model of the same business process – one for each BPM version. Interested readers can refer to [16] for further information on the complete BPM.

4 Workflow Engine

4.1 Workflow Engine Design and Architecture

We will now present the Declarative Workflow Engine, DeWE, that has been designed for business process simulation, and which will later be used for SCM analysis. Since time and cost are important SC performance measures, DeWE will be given an appropriate *business context*, and calculate the total time and cost for a SC, given that we know the time and cost of each process involved. Moreover, when comparing different strategies through BPM simulation, one is interested in the business operations in the average case, so that e.g. when comparing the computer assembling procedure of two companies, such as Dell and IBM, it is possible to compare the average time and cost. To start the workflow engine, we use the notion of event that can be used to represent external customer order or internal events. We define the minimum values for processing time and cost to be 1 and 0, respectively.

Our workflow system has been implemented by adopting a declarative approach and it consists of three main components: a specification of the process model, a specification of the current world state, and the workflow engine algorithm. Note that DeWE treats each process in the BPM as a class definition, where instances of these processes are created and changed at run time due to events or (internal) computational changes.

4.2 Workflow Engine Reasoning Engine and Logical Representation

DeWE's reasoning engine was implemented in Prolog, and a simplified set of rules is provided below. Once the BPM simulation is started, DeWE is instantiated with BPM and its world state is initialised. A step execution involves scheduled actions', junctions' and processes' execution. A reached junction is executed, if its executions semantics are satisfied, according to FBPML specification [12, 13]. For instance, an and-joint junction is executed, only if all preceding processes have completed their executions. A process instance is executed, if its preconditions and trigger conditions hold. A trigger represents a request to invoke a particular process that can be caused by an internal or external event, while a precondition is a requirement that makes sure that process actions can be carried out successfully.

R1: IF start-up THEN (read process model AND read world state AND initialise ScheduledActions, ActionAgenda, ReadyProcesses and ReachedJunctions to [])

R2: IF found event THEN (IF its triggers are true THEN create a corresponding process instance AND execute-step is true for this event)

R3: IF execute-step THEN (execute ActionAgenda AND execute ReachedJunctions AND execute ReadyProcesses UNTIL no further action can be done; in that case update the time)

R4: IF (no event is left AND ScheduledActions and ReachedJunctions and ReadyProcesses are []) OR end of BPM is reached) THEN execute-step is false for the corresponding event

R5: IF execute ActionAgenda THEN (execute all actions in ActionAgenda, IF their preconditions and triggers are true AND no conflict between them is found)

R6: IF execute ReachedJunctions THEN (IF its process logic is true THEN extend all following branches to ReadyProcesses)

R7: IF execute ReadyProcesses THEN (expand its actions to ActionAgenda, IF their preconditions and triggers are true)

R8: IF (reached junction AND junction semantics is satisfied) THEN add Junction to ReachedJunctions

R9: IF (reached process AND process semantics is satisfied) THEN add process to ReadyProcesses

The declarative representation of the *process model* includes i) the *junction specification*, i.e. the control sequence of processes in a BPM, and ii) the *process specification*: inc. attributes of each process in a BPM, with respect to FBPML. The *world state* is declaratively specified through entity and event specification. Example predicates of junction and process specifications are provided below.

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junction(Jid, Type, PreProcesses, PostProcesses).
junction(j4, and_joint, [p16,p17],[j5]).

process(Pid, Name, Triggers, Preconditions, Actions, Time, Cost).
process(p2_2, identifyPotentialSuppliers,
[exist(event_occ(needForNewXInventory))],
[not_exist(entity_occ(supplierX)), exist(data(needsOnXinventor
y)), exist(data(relevantXsuppliers))], [create_data(potentialXs
uppliers, [sup1_good, sup2_ok])], 21, 1000).

entity_occ(EntityName, EntityId, EntityAttributeList).
event_occ(EventId, EventName, TimePoint).

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4.3 Workflow Engine Evaluation

We have used DeWE to simulate several BPMs, among which Dell's BPM. Based on those, we have evaluated it across four criteria, i) soundness, ii) completeness, iii) coverage and support, and iv) ease of use, thus answering the following questions: 1) Does it behave correctly? 2) Does it cover all needed concepts and functions? 3) Does it cover all possible BPM execution scenarios and thus support useful BPM analysis? and 4) Is it easy to use, for both experienced and inexperienced users?

The evaluation procedure can be found in [16], and it is beyond the scope of this paper to present it here. However, we mention the evaluation results, according to which our workflow engine is suitable as a tool for reasoning about SC strategies. So,

it was found to be *sound, adequately complete, relatively easy to use and covering all scenarios* prescribed by its design manifestation.

5 Analysing Supply Chain Strategies

A generic framework we deployed for analysing SC strategies consists of three steps: First, we develop a BPM that captures the company's SC strategies, and choose the most interesting processes on which analysis will be performed. Second, BPMs are analysed and improvements sought. We experiment with parallelizing sequential processes, given physical and business constraints, with the aim to confirm whether it is already at its optimal or can still be improved. And third, to examine SC strategies and compare them with alternative ones; thus by creating an alternative BPM. We found BPM can be streamlined and performance improved where there is no (hard) information or business constraints.

Using the developed BPM for Dell, we identified two interesting processes for analysis, reflecting Dell's two important SCM characteristics: virtual integration with its suppliers and direct sales model: the "buy standard items to order" and "sell directly to large business and public sector customers" processes. During our experiments, no improvement was identified, which confirms Dell's operation has reached its optimal. We have thus used Dell's model as a golden standard to compare with the BPM of a conventional PC company. The comparison of the simulation results showed that Dell's choice of buy-to-order and virtual integration with its suppliers result in higher cost and time in the case of finding a new supplier; but it leads to much shorter duration and cost overall than that of a traditional PC company (that buys to stock) on the long run, because of its two above distinctive strategies.

6 Conclusions

Recognising the significance of a SC broker in the digital economy era, we have suggested in this paper a cyclic framework for abstracting, enriching and analysing SC strategies with the use of knowledge-based business process modelling techniques. We have developed a declarative workflow engine that simulates BPM execution and calculates the related time and cost that can be used as a tool to assist SC analysis. The suggested frameworks have also been applied to the case study of Dell and PC sector. We have shown that knowledge-based techniques can help us understand SCM. With the vision of a more business-aware workflow engine, our future work is to use the suggested process-based approach within a knowledge-enriched agent context, consisting of communication, process and reasoning layers.

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