BUSINESS PROCESS ENTERPRISE MODEL
Operations Research for Managing Business Process Communication and Performance

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Keywords: Enterprise modelling, Business process, Simulation, Communication flows, Organization theory.

Abstract: This paper presents a computational model of a generic enterprise (BPEM, which stands for Business Process Enterprise Model), based upon the core concept of business process. BPEM may be seen as a bridge between two worlds of "Enterprise Models", the world of mathematical models, formal and fully operational for optimization purposes and the world of conceptual models (boxes & arrows type) for management science, for reasoning and communicating about what a company is. Our model was built as the minimal and most elegant model that is detailed enough to investigate difficult management science issues such as the influence of hierarchical organization on performance, the optimal usage of various communication channels or the benefits of lean-management-style control of processes. BPEM is organized around four concepts: business processes, capabilities that encapsulate resource management, hierarchical and transverse management organization, as well as information flows that are required to run business processes.

1 INTRODUCTION

Operations Research has a long tradition of successes to improve the performance of enterprises. The traditional approach is to define a business problem with a mathematical model and to use optimization techniques to provide an optimal or an improved solution that translates into better business performance. The goal of this paper is different, since we aim to use mathematical modelling and optimization techniques to provide insights about the intrinsic performance of business processes.

The contribution of this paper is to propose a computational model of a generic enterprise, which describes its business processes, its organization and its information flows. Because of its generic nature, such a model cannot be used to "solve" business problems, but it is a tool for better understanding, through analysis or simulation, a number of hard questions from management science. For instance, we may assess the benefit of *lean management* applied to business processes, evaluate the impact of organizational architecture or study the impact of the amount of time spent during meetings, which is often criticized in today's large organizations.

The search for a realistic enterprise model is nothing new. It is at the heart of management science. Without a model, entreprises are left with trials and errors, with empiric studies of what works and what does not, as far as organizations and reorganizations are concerned. The difficulty is that simple models that are adequate for paper studies leave too many aspects of corporate life aside, while intricate computational models tend to be too complex to understand, hence the results obtained though simulation leave most practical managers skeptical. Our aim, with the model that we propose in this paper, is to find a balance bewteen the two.

This paper is organized as follows. Section 2 discusses the motivations behind introducing a computational model for enterprise performance. We relate our approach with a number of pre-existing enterprise models, and with classical theories of the enterprise. We define the objective assigned to this model, which is to evaluate short-term performance – the long-term issues of learning and structure evolution are left aside – with respect to organization – that is, the way decisions and communications are handled –, business processes and capability management. Section 3 provides a description of BPEM (*Business Process Enterprise*

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BUSINESS PROCESS ENTERPRISE MODEL - Operations Research for Managing Business Process Communication and Performance.
DOI: 10.5220/0003718200110020
In *Proceedings of the 1st International Conference on Operations Research and Enterprise Systems* (ICORES-2012), pages 11-20
ISBN: 978-989-8425-97-3

Model). This model may be seen as the combination of business process, value creation, organization and communication models. This model is the fruit of many years of simulation, trying to reach the afore-mentioned compromise between simplicity and the ability to look at complex aspects of enterprise efficiency. Section 4 demonstrates this claim with various examples of applying BPEM to different sides of management science. We first use this model for a study of the use of different communication channels. We have also used this approach to characterize some of the benefits of *lean management* (Womack, Jones and Root, 2004). Last we explain how this model may be used to evaluate the impact of organization on performance. Section 5 concludes with some perspectives about new applications and future work.

2 MOTIVATIONS

2.1 Enterprise Theories

Our goal is to build a computational model – suitable for simulation and optimization –, but any model reflects a theory of the enterprise. Our work is, therefore, rooted in the tradition of describing and understanding the inner working of a company. The first pillar of our approach is none other than F. Taylor's scientific organization of companies from (Shafritz and Ott, 2001), based upon business processes, break-down of activities and specialization. Although one of our goal is to challenge the benefits of "breakdown & specialize", business processes are still a powerful tool to describe a company.

A second key concept of "Enterprise Theory" is "transaction costs", as defined by Ronald Coase and further developed by O. Williamson. One of the main benefits of a company is to reduce transaction costs. Thus, it is necessary to take transactions and communication into account in our model. Our work is equally influenced by the SCP model of E. Mason, which separates structure, conduct and performance.

The importance of communication is a cornerstone of our approach, as will be illustrated in Section 4. We follow in the footsteps of March and Simon who wrote "*The capacity of an organization to maintain a complex, highly interdependent pattern of activity is limited in part by its capacity to handle the communication required for coordination*" in (March and Simon, 1993). Their book is focused on decision making, *and the flow of information within organizations that instructs, informs, and support decision making processes.*

Performance is defined as valued creation, as defined by M. Porter in (Porter, 1980). Value analysis is a common technique that is jointly used with business process decomposition (for instance with *lean management*). Starting with a value chain that defines the position of a company within its industrial ecosystem, value creation may be attributed to business processes, through the definition of work units (services, products, etc.).

Our work is strongly influenced by Mintzberg (Mintzberg, 2009), who is famous for proposing different model of enterprises and organizations. Mintzberg has characterized different types of organization (from hierarchical to matrix- or networked-organization). Our overall model (cf. Figure 2) is quite close in its structure with Mintberg's organizational model in (Gabarro, 2005).

2.2 Enterprise Models

Modelling the enterprise is necessary for the design of information systems, as well as the formalization of frameworks for total quality management (TQM). Therefore, there already exist a number of semi-formal models that describe what an enterprise is and (partially) how it operates. Since our goal is to propose a computational model which may also be used for explanation and communication, we tried to inherit as many traits as possible from existing "enterprise models". Here is a list of models which are fully compatible with BPEM:

- A traditional view of a company is the function/ business process matrix (Galbraith 1998). In this model, the company is seen as a set of functional units, which operate business processes. Each unit is responsible for a given activity, the combination of which makes processes that deliver value to customer.
- CEISAR is a research center dedicated to Enterprise Architecture, which has developed over the years a complete and elegant "enterprise model" (CEISAR, 2008). The cornerstone of this model is the business process, a sequence of actions that produce value (to the end customer). Business Processes are operated by actors, who rely on resources (managed with their own processes). The CEISAR model describes the organization of roles, actors and various resources including information.
- BAPO is a model developed at Philips (Van der Linden *et all*, 2004) for an ITEA project

related to software management. BAPO stands for Business, Architecture, Processes and Organization. The BAPO model provides with ways to characterize the maturity of a company across those four dimensions (in a way similar to CMMI (Chrissis, Konrad and Schum, 2003)).The process characterization (predictability, repeatability, quantification) is somehow similar to the model of Section 3.3. The organizational model, although focused on software organization, carries the key traits that we use in BPEM.

- IDEA (Ludwig and Farcet, 2010) is a system engineering methodology which includes an “Enterprise Architecture model” based on processes, capabilities, and roles. An enterprise is a collection of capabilities and roles that execute processes that rely on services. The introduction of capabilities in BPEM (3.2) is directly inspired from IDEA. IDEA is itself inspired from the NATO Architecture Framework (NAF).
- Similarly, the British Ministry of Defense produced an Architecture Framework called MODAF which includes an enterprise model that is also based on capabilities, roles and activities (MODAF, 2008).
- The French “club of business process owners” produced in their collective book a rich “enterprise model” that goes further than the previously mentioned ones (Club de Pilotes de Processus, 2008). In an approach that is similar to CEISAR’s, the core of the model is built around business processes and information systems, but this core is itself placed in a continuous improvement loop. This loop models the reaction of the enterprise according to its current performance and its strategy, using the transformation levers such as learning, innovation and re-engineering.

These models are conceptual models, which easily lead, for instance, to UML models. They define precisely the concepts which are necessary to describe and understand how an enterprise works. One of the most thorough efforts to produce an “Enterprise Architecture Model” that includes an “Enterprise Model” is the PRAXEME method which is related in (Bonnet, Detavernier and Vauquier, 2009). A computational model relies on a conceptual model, but goes further, to fully specify “how things work”.

2.3 A Computational Model of Enterprise Efficiency

A computational model allows the simulation of a company’s internal working. To specify a computational model, it is necessary to understand which aspects of the functioning are deemed to be interesting. BPEM has evolved from a number of computational studies, aimed at characterizing issues from management science. BPEM may be defined as the “simplest common model” that supports these kinds of studies. Namely, here are some of the issues that we want to address through computer simulation:

- value creation (especially with respect to SLA – service level agreements), in the spirit of (Reinertsen, 2009),
- reactivity to events and load distributions,
- *lean management* (pull vs. push, focus on lead time reduction, WIP – *work in progress* – management),
- management of communication flows,
- shape of the management organization (shape of the hierarchical pyramid, process-function matrix).

On the other hand, we tried to make BPEM “just right”, using “Occam’s razor principle”, in order to deliver computational experience that as close to self-explanatory as possible. This requires to avoid “generic efficiency parameter” (we shall see later that there remains a few) and to keep away from parts that are really difficult to model (in an operational way). This is why BPEM is only concerned with “short-term efficiency” and why we leave aside issues such as:

- learning (as well as the capitalization of knowledge, although BPEM shares many concepts with (Nonaka, Toyama and Hirata, 2008)),
- long-term evolution & self-organization,
- resource management optimization (we shall assume later on that resources are used optimally).

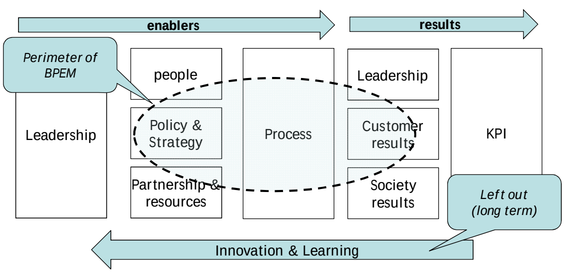

Figure 1: BPEM perimeter from an EFQM perspective.

To illustrate what is left aside, we use the EFQM framework in the previous figure (EFQM is the *European Foundation for Quality Management*). The background of Figure 1 is the EFQM model of enterprise functions. We see that BPEM (dashed ellipse) is only concerned with the core of the company's activities. This approach is similar to "enterprise simulation" models that are produced for "serious games" software (Datar, 2000). Indeed, as we shall see in section 5, a possible outcome of BPEM is a scenario-exploration tool which helps understanding the impact of organizational architecture.

3 THE "BPEM" MODEL

3.1 Enterprise Model

The BPEM model is defined as the combination of four components:

- The core of the enterprise is a set of business processes that are triggered by external events which represent customer requests. Business processes entail a sequence of activities supported by the enterprise's capabilities.
- Each process run consumes a quantity of resources and takes a certain amount of time, both of which are explicitly modelled (cf. 3.3). The value that is created by a successful process termination is a function of time. There exists an explicit SLA (service level agreement) with an associated time window. A delivery after the maximum allowed time brings no value.
- The teams that combine human resources (skills and time) and material resources are glued together by a management organization that performs the necessary decision-making. This organization is the juxtaposition of two common forms: a hierarchical pyramid that links the CEO to all team leaders, as well as a transverse "process" organization which is dedicated to "horizontal" communication (Galbraith, 1998).
- BPEM associates two kinds of information flows to business processes, horizontal (synchronization & transfer) and vertical (reporting and management). Information flows are measured with time (the time it takes to process/understand a given piece of information) and are generated according to the business processes. Communication flows are supported by a central component called the "communication matrix" which represents the sum of all communication channels (face-to-face, phone, email, meetings, etc.).

This model is summarized by the figure below. Notice that we have represented the information system explicitly, but that it does not play any specific role in the operational semantic that we shall develop, where it is seen both as a resource and part of the communication matrix. Making it visible on this figure is useful for communication purposes (cf. the link with Enterprise Architecture models such as those of Section 2.2).

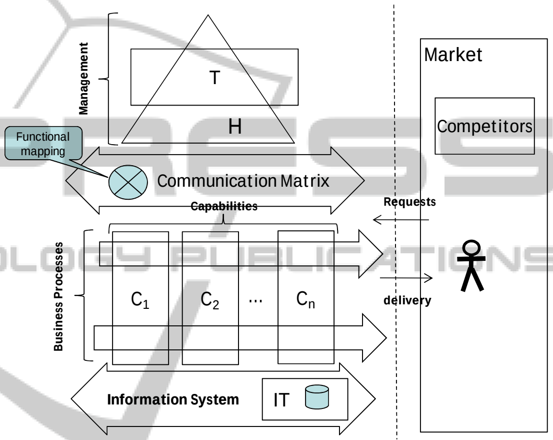

Figure 2: Overview of the BPEM model.

3.2 Organization Model

The next figure is a close-up on the organizational model. The hierarchical part is a traditional management pyramid which is defined by its height and the average span (the number of subordinates for each manager). These dimensions have a direct impact on the propagation of information through the hierarchical channel.

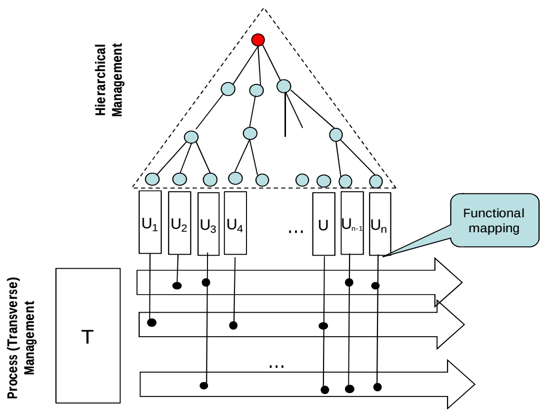

Figure 3: Organizational Model.

The process management component is simply a set of available *man.hour* of management to convey information from one part of the process to the other. It supports a transmission that is simpler (hence faster) than going through hierarchical management. This is a simple yet effective way of testing the influence of matrix-style management.

There is no assumption about the matching between processes and teams (units) which are the leaf nodes of the hierarchical organization. From a business process perspective, the enterprise is organized into capabilities, which represent the combination of resources and skills necessary to perform a given activity. Figure 4 represents the concept of capability, which may be seen as the combination of functional domain (there are *n* functional capabilities here) and resources (there are *p* resources associated with the first capability). A resource is an abstraction that covers human as well as material resources. It is described with skills/competencies, with an associated level. Hence, each resource is a *tuple* (here, there are *q* skills). The skills determine which resources may be used for which activity (cf. next section). If a resource possesses the right skills at the appropriate level, the efficiency (the time it takes to perform the activity) depends on the level difference (a high level represents a form of "mastery"). This decomposition of organizational units with skills is very similar to (Nelson and Winter, 1982).

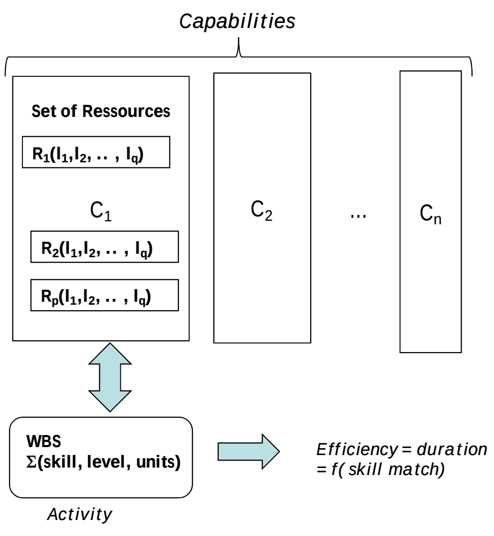

Figure 4: Capability Model.

The concept of "functional mapping" (the correspondence matrix between units and capabilities) is not part of the operational semantics since we assume that resources may be located and requested optimally (this is another instance of the "Occam's razor" principle: we found that introducing an extra layer of complexity to represent this correspondence was of no value since not enough is known in the "real world of companies" to calibrate such an extension to the BPEM model).

3.3 Business Process Modelling

Business Processes are one of the most common concepts of management literature (Burlton, 2001). We distinguish the concept of process pattern, which is a model for how the work is executed, and process instance, which is the actual sequence of activities that produce value. A process pattern is a sequence of activity pattern (this is a simplified view of what a process is, but sufficient to our purpose here). The activity pattern tells which capability is exercised, which are the necessary skills and their associated levels.

A process instance is generated by a customer's request. A request has a type (the process pattern), an expected value V, and a quantitative indication of how much work is required. It may be generic (the amount of work is a property of the business pattern) or specific (each request comes with a set of units that tell how much work is required for each skill of each activity – the unit is time, such as man.hour). BPEM uses a stochastic generator to produce such requests, with the ability to generate all types of incoming work distribution, as well as all types of workload distribution. This is a way to evaluate companies' flexibility and reactivity.

The value produced by a process is a simple linear function (see Figure 5) defined by the time window that defines the SLA of the customer's request. The maximal value V is obtained if the service is delivered before the minimum date. It is null if the maximum date has occurred and decreases linearly between these two values.

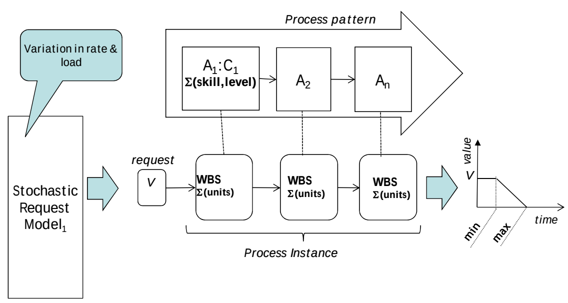

Figure 5: Business Process Communication Model.

Another major simplification of BPEM (Occam's razor) is to evaluate quality with respect to one unique dimension: time. It would be quite logical to introduce a "quality" dimension to the evaluation of business process execution. Quality could actually depend on skill match and impact the value that is being produced. We use a single-versus-dual dimension approach because we found that an additional dimension only adds complexity, arbitrary equations and factors, and does not provide any additional expressive power. On the other hand, focusing of COD (*Cost of Delay*) is justified by (Reinertsen, 2009) as the most salient metric for business processes.

3.4 Business Process Communication Model

Following the insights of March & Simon that were presented in Section 2.1, a distinctive feature of BPEM is to represent communication flows, which come in two flavors: horizontal and vertical (cf. Figure 5). BPEM does not represent inter-unit communication flows, since it may be included in the activity model, as one of the time-consuming activities. It only focuses on enterprise-wide information flows which interplay with the company's organization. The links between the communication architecture and the structure of that the company produces was pointed out a long time ago by Melvin Conway in a famous article (Conway, 1968).

The importance of information flows vary according to the enterprise's domain. Communications are more important with valued-added immaterial services, such as software development, that they are with industrial factory production. In order to use BPEM as a production/simulation model, we need to introduce communication in a quantitative form with explicit effect on performance and output.

Horizontal flows represent information that needs to be exchanged between two consecutive activities of one business process. A major feature of modern work is that a significant amount of context information must be exchanged between process participants. This is precisely one of the trends that goes against the principles of "break-down and specialization" from Frederick Taylor. BPEM associates a "synchronization and transfer flow" to each pair (A,B) of consecutive activities within a process, with the constraint that B cannot be completed until the (A→B) transfer has been completed.

Vertical flows represent the exchange of information that is necessary between the teams and their management, for reporting and decision making. These "monitoring and management" flows are associated to each activity from the business processes.

Flows are generated at the same time business processes requests are generated. A flow is mostly characterized by the amount of time it takes to process the information. This amount is a linear function of the activity completion time (the coefficient is a parameter of the model – cf. Section 4.1). We make no assumption about the communication channel that will be use to support the flow, but we also qualify the "span", which is an abstract indication of how many persons need to receive the information.

Decision making in BPEM occurs in two forms, which are related to two kinds of events (represented with short arrows in the following figure). The first kind represents a "production event", when a given activity requires significantly more resources than what was initially anticipated. The model assumes that the reaction (which requires a decision from the management) occurs with the latency of the associated vertical flow. The second type of event is a change to the value of a process instance that is currently run. The valuation change reflects an "environmental change" (from the customer/market or from the competition). The decision is a re-prioritization of the process instance, which also occurs after a delay (latency) which is derived from the associated vertical flow. In other words, BPEM generates a vertical flow associated to an activity. The simulation software (cf. Section 4.1) schedules this flow which produces a latency (the time to process the associated information) which is taken as the time it takes to react to events.

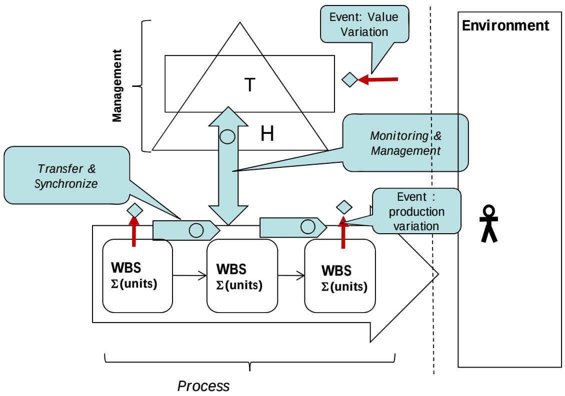

Figure 6: Business Process Communication Model.

4 APPLICATIONS

4.1 Managing Information Flows

The first application of BPEM is a simulation tool designed to study the impact of communication channels. We define four categories of communication channels:

- Synchronous one-to-one communications, such as face-to-face meetings or telephone calls.
- Meetings, which support many-to-many communications but require scheduling.
- Asynchronous communication methods, such as email, blogging, micro-blogging, Intranet document sharing, etc.
- Hierarchical scheduled communication, which uses the manager-employee relationship and the regularly scheduled face-to-face meetings.

We use a “channel communication model” which defines how communication flow units may be scheduled though each type of communication channel. More precisely, each channel is described though a number of parameters and equations that define its latency (information propagation time), the average number of recipients (when relevant), the average loss factor (from which we derive the average number of times that a message needs to be sent to be understood). Our goal is to study under which hypothesis which channels should be used preferably, for a given company context.

The focus of our interest is a matrix which tells the frequency of use of each communication channel type (including the typical amount of time spent in meetings), called the “channel policy”. The assembly with the BPEM model is described in the following figure. For a given company model (processes, organization, context = request profile), BPEM generates a load of work to be processed, which comes from activities derived from the stream of requests and communication flows associated to these activities. These tasks are fed to a scheduler, which assigns each task to the best matching resource. It is possible to play with various assignment schemes, but we usually simply select the first available resource, with the better skill match to separate ties. To schedule a communication unit, the first step is to look into the “channel policy matrix” to find which channel is used, and then use the “communication channel model” to find when the actual communication may take place. This model is not an actual scheduler (where each hour of each agent would be represented), it is a set of equations that provide an approximate formula for the latency that is observed for each communication channel.

Rather than guessing the best channel policy, it is easy to compute it as a fixed-point of a learning process, using a simple local-optimization-loop such as described in (Caseau, Silverstein and Laburthe, 2001). We incrementally modify the “channel policy” matrix in order to maximize the value generated by business processes. The result of the simulation is, therefore, the best communication channel usage, given the company description (using BPEM) and the channel characterization.

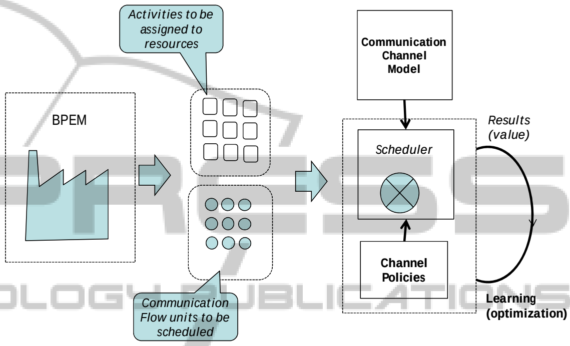

Figure 7: Simulation of Information Flows.

The BPEM company description is itself the combination of the company’s BPEM instance (its processes, its capabilities, its organization) and the “scenario” that contains the parameters that govern the stochastic load generation as well as the event generator. The BPEM instance usually does not change, while we use different scenarios to evaluate how the company reacts to changes in its environment (more about this in the next section).

The following figure shows an example of the output of such simulation. We used this simulation tool extensively a few years ago to evaluate the importance of various communication channels.

```
=== Experiment E1 ====
   done on Mon May 29 03:47:34 2006
   scenario = S1 x 10 iterations
   context = Telephony
-------------- summary for scenario S1 @ 12463s -------------------
chanel ASYNC : (17% of info) 13% usage [9%] 114839 load -> 134096 used (85%)
chanel SYNC : (28% of info) 19% usage [13%] 110938 load -> 217216 used (51%)
chanel MEET : (44% of info) 46% usage [12%] 245355 load -> 342275 used (71%)
chanel HF2F : (8% of info) 16% usage [13%] 41170 load -> 67112 used (61%)
unit CRM : 40% usage [5%]
unit IT : 44% usage [5%]
unit Mkt : 48% usage [3%]
unit Sales : 45% usage [3%]
unit Network : 46% usage [2%]
unit Com : 45% usage [5%]
process BillUsage : 1750k$ [95%]
process SellService : 565k$ [85%]
process LaunchService : 635k$ [73%]
process PromoteService : 1068k$ [84%]
total value = 2277k$ [dev 19%]
average rate of return = 140%$
average diameter = 28 [10%]
```

Figure 8: Typical result of simulation.

What we have shown (on one practical company example) is that:

- Email is an efficient communication channel (which does not mean that alternate electronic tools cannot do an even better job). Removing email and returning to slower forms of asynchronous communication (as well as all the classical synchronous ones) produces a significant decrease in performance.
- Meetings, which are often criticized and/or abused, play a key role. There seems to exist an "optimal meeting rate", too few meetings represents missed opportunities, while too many places a burden on the time that is left open to do actual work. Obviously, but this is worth repeating, this simulation places no value on the creative and collaborative opportunities that a meeting represents. It simply evaluates meetings as one possible form of communication.

Since these preliminary findings raise a lot of questions, it became necessary to transform our simulation platform into a "white box" (see the following "perspectives" discussion).

4.2 Lean Management of Business Processes

Before giving a second example of using BPEM to investigate the benefits of lean management of business processes, it is important to state that there is much more in lean management than control strategy. The part of *lean management* (Liker, 2001) that we are able to address is only a tiny fraction of what may be described as a work philosophy (ranging from human resource principles, routines, learning, to control, visual management, etc.). This being said, one of the intriguing principles of lean management is to "reduce the lead time" (the time it takes to execute a process instance) to its minimal value. Using the BPEM model, it is easy to contrast two situations:

- A "regular situation", where most resources are optimized in such a way that their "usage ratio" is close to 90%. This is what most people consider to be a well-run company. In the world of Information Systems, it is also a desirable goal to demonstrate a high usage ratio which shows that critical assets are delivering as much value as possible.
- A "lean situation", where the SLA are much tighter (the allowed completion time is closer to the optimal lead time), which requires more resources. A "lean organization" is less intuitive, since it keeps operating critical resources at lower "usage ratio". In this experiment, the level of resource availability (e.g. staffing level if we consider people) is determined through simulation so that we achieve the same level of SLA satisfaction (say, 98%) in both cases. Obviously, finding the optimal SLA satisfaction level is business-dependant (each 1% gained brings incremental value – cf. our value model in Section 3.3 – but at a cost since more resources are required).

We have made a number of computing experiments, using both the afore-mentioned simulation platform, as well as the simulation tool described in (Caseau, 2005). Being able to use one or the other is the consequence of the fact that BPEM includes a generic BP evaluation model (hence it is a useful tool to evaluate BPM – business process management – strategies).

What we did is what was described earlier in the paper: we subjected both "companies" (i.e., BPEM instances) to different types of load: irregular, burst of different kinds, as well as a "failure" scenario when one resource is temporarily unavailable. The following table indicates the results that we have obtained in both cases (the result is the time percentage when the SLA are met). The interesting conclusion is that a BPEM model is able to demonstrate in a spectacular way the reactivity and adaptability benefits that have been claimed by proponents of lean management. Somehow, this is counter-intuitive since the "lean SLAs" are much tighter (hence, one could think that they are harder to keep)

Table 1: SLA satisfaction in lean/non-lean cases.

Scenario	Non-lean	Lean setting
Default	98%	98%
Irregular	84%	97%
Burst	80%	96%
Failure	78%	87%

4.3 Impact of Organizational Dimensions onto Performance

A third application of BPEM comes from the ability to evaluate the impact of organizational features on performance. A similar warning may be given to the one about lean management: the impact of organizational architecture on performance comes from more than the structural dimension of management, which is one of four in (Bolman and

Deal, 1991). However, a BPEM model of a company makes it easy to play with organizational parameters and see the effects of the following:

- Flattening the hierarchical pyramid. This is common advice amongst management consultant, and computer simulation agrees with them. For a complete discussion of the impact of the span of control see (Perrow, 1986). Simulation shows that reducing the depth shortens the communication paths and increases the reactivity. This actually implies that the hierarchical management communication channel plays an important role.
- Increasing or decreasing the number of managers. Simulation shows that managers play a key role in passing the necessary information around, which is precisely what the quote from March & Simon said. A consequence is that, when the hierarchy is flattened, the number of "transverse managers", attached to projects or processes, should be increased.
- Specialization, defining many capabilities and skills. Another interesting factor of the BPEM model is that we may decide the level of granularity with which skills are defined. The same company may be described with the use of a handful of capabilities, or with a much more detailed analysis. Depending on the communication load hypothesis (remember that the amount of communication flow units that are generated for each process is governed by a parameter), we may observe the "cost of specialization" and see that over-segmenting creates a communication burden that washes away the "benefits of specialization".

These results are not generic (they are dependent on the BPEM company configuration) but they illustrate the claim made in Section 2 that BPEM is capable of supporting management science analyses.

5 PERSPECTIVES

The software platform that was mentioned in Section 4.1 is called SIFOA (Simulation of Information Flows and Organizational Architecture). The first generation of the SIFOA simulation software was able to produce interesting results (cf. previous section) but its "black box" design made it very difficult to communicate and explain these results. Our goal is to build a "white box" version of this "management simulation toolbox". Making BPEM a self-explanatory Enterprise Model is part of this endeavor. The next step is to release the source code that implements BPEM. The scheduler which we mentioned in Section 4.1 is a key component since it supports the investigation of various queuing disciplines (Caseau, 2005), different type of flow priorization and WIP constraints, such as *kanban* (Reinertsen, 2009). Because of its stochastic request model, BPEM is a suitable tool to explore all these aspects of business process flow performance.

The communication model that we have used a few years ago is quite simple (a few equations for each communication channel) and raises many questions. A follow-up project has been the study of the influence of social networks (the underlying structure of the communication channels) on performance. For instance, we consider the efficiency of meetings as a communication channel. Meetings define an affiliation network (Wasserman and Faust, 1994), the structure of which has a direct influence on communication characteristics such as latency, bandwidth, and loss (Nardi, 2005). Our approach is to generate random graphs that represent communication needs, and study which patterns of meeting does a better job of handling these communications. Our computational model is thus composed of three parts: a random graph generator (which is tuned to generate graphs with the appropriate characteristics, since quite a few characteristics of social networks are known), a "set-coverage algorithm" which covers edges with hyper-edges, and a simulation tool that measures communication performance. Using this computational model, we were able to characterize latency (a useful finding for the simpler model of 4.1) and establish a few rules about the optimal structure of a "set of meetings" (Caseau, 2011). A next step is to use BPEM to generate communication requests that reflect more closely the needs of a company.

6 CONCLUSIONS

The contribution of this paper is an ongoing computational model of the enterprise. By construction, such a model is an open-ended proposal, but we have found that BPEM is a reliable and powerful core for many computational projects that aim at shedding light on management science issues. The conclusion of this work is threefold:

- There is a need for generic enterprise models to bridge the fields of Operations Research and Management Science. These models also play a key role for Information Systems (Winosky and Vogel, 2004). They provide a foundation to lay out what Information Systems are expected to do.

- Among those, we need computational models, with complete operational semantics. Our claim is that many of management sciences issues are complex and will benefit from the kind of analysis that one may perform through simulation. As it was said in the introduction, no such problems may be "solved" using a computer model (each company is different and too many critical factors are left aside in such a model), but our experience shows that insights may be gained about the role of the structure of organization (Nadler, Gerstein and Shaw, 1992).
- Managing information flows is a key part of management science. This is an old idea (March and Simon, 1993), but which strength has increased in the 21st century, with the increase of information overload and the advent of the "Enterprise 2.0".

Such a model may also be used for training managers, using a "serious game" software approach, both within the enterprise itself and in a management school setting.

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