Market-based Workflow Management for Supply Chains of Services

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Abstract

This paper proposes the application of market-based workflow management for enabling a new form of relationship between customer and suppliers of services. This form is more flexible than the usual long-term fixed relationship with single partners. It allows customers to coordinate their processes with the services operated by the suppliers while still benefiting from a market competition enhanced with more customers and suppliers. A software system is being prototyped to demonstrate the concepts. It consists of a set of workflow systems and an automated trader system. The workflow systems reside in different organizations and the trader system acts as an intermediary among the customers and suppliers of services, maintaining information about their offers and requests. The traded services are treated as workflows. An illustration is given in the domain of logistics, where a company outsources part of a transportation process to external suppliers of the required services.

1. Introduction

Companies are challenged daily to find new ways of reducing costs and augmenting sales. Optimizing supply chains is one of the ways in which large savings have been observed. As the economy changes, as competition becomes more global, it’s no longer company vs. company, but supply chain vs. supply chain [1]. This has brought a continuous evolution of the commercial relationships between the actors of the supply chain, ranging from original buyer-seller transactions with simple (anonymous) purchases to a wide range of relationships, e.g. vertical integration, co-competition [2], partnership [3], strategic alliances, sub-contracting or outsourcing.

The market volume of service outsourcing is increasing every year, probably inspired from the success of industrial subcontracting: letting others do what they do better and/or cheaper [4]. Still, gaining maximum benefits from an outsourcing operation is not easily achieved. One problem is that coordination of processes by the customer’s organization is more difficult, because part of the work is executed outside the company’s boundaries. Indeed, the outsourced service can be considered as a sub-part of a process initiated in the customer’s organization. This process is composed of a set of tasks, one of which is the outsourced service. The outsourced task will produce a result that will be used by the customer’s organization in order to complete the process. Thus, the whole process spans the customer and the supplier of the service and could be considered as an inter-organizational workflow that should be defined and managed in order to ensure that it produces the desired level of quality in time and budget.

A second problem is that the outsourcer might miss opportunities to lower the price he will pay for the service. The reason is partly a consequence of above coordination issue. The market competition between suppliers of services is not very efficient because outsourcers prefer to work with a single supplier. In other words, it requires less effort to integrate processes with a known supplier, than to have to adapt every time to new ones. Thus, the turnover of service providers can be very low, reducing market competition. Some could argue that augmenting trading volume with one supplier helps to negotiate lower price. Incidentally, some studies do not confirm a reduction of price with one-to-one relationships with suppliers [5].
Workflow Management Systems, which provide the tools and functionality to design, implement, and automatically coordinate the execution of business processes, have received great attention in recent years [6]. Modern WFMS allow resources to execute the work steps from anywhere due to web-enabled access for widening end-user access. There are also works for enabling inter-operability between different WFMS, allowing inter-organizational processes to be executed over heterogeneous systems [7], [8], [9] and "wide area" workflow management [10]. But none of today’s approaches includes support to enable competition between suppliers of services while still allowing management of the inter-organizational workflow between customers and changing suppliers.

A promising approach for reducing both risks described above is market-based workflow management [11]. The principle of market-based workflow management is to establish a market in which tasks (or services) contained in a workflow are treated as traded goods. Thus, workflows act as consumers by buying services from their suppliers.

Running an electronic marketplace and, second, better coordinated inter-organizational processes would cost less as a result of decreased risks of delays and better overall quality. Production costs of services should be lowered, since a more active market competition between suppliers would drive down the price. Another targeted outcome would be that the number of potential suppliers of services would increase, because facilitated access to such an electronic market would represent a new channel of sale. This new channel would leverage existing skills and capacity by directly plugging suppliers into it with coordination support that would normally take longer to deploy.

The contributions of this paper are:

- to present how market-based workflow management would be supported by a software system composed of an electronic marketplace with accompanying workflow management systems, and
- to demonstrate the use of a such system with a case-scenario in the domain of logistics.

In Section 2, an overview of the requirements for a system supporting market-based workflow management is given. In Section 3, ACE-flow1, a software system specifically developed for supporting the requirements is presented. Section 4 illustrates the use of ACE-flow with examples and a case-scenario demonstrating how the solution would support the electronic trading of services in supply chains. Section 5 summarizes and presents future research.

2. Requirements

To introduce the requirements let’s consider the example of a company outsourcing any formal verification of technical documents to external experts (e.g., software code inspection [13]). The reviewing by the external expert has to be preceded by several tasks executed in the outsourcing company as shown in Figure 2, e.g., the preparation of the artifacts to be reviewed and the creation of the checklist containing the aspects that experts will have to check in particular. After these documents and/or information have been sent to the expert, the process continues with the verification of the artifact and completion of forms describing the findings. When completed, the forms are sent back to the outsourcer, who will have to

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consolidate the findings and eventually communicate the results through the publishing of a written report. Two types of requirements should be covered: inter-organizational process management and management of a market of services.

2.1. Inter-organizational process management

In above example, the whole process is composed of a set of tasks, each of them executed by some resources. Successful execution of the workflow should guarantee that:

(1) the workflow ends in time, i.e., there is no delay in the delivery of the final report,
(2) the result of the purchased service has reached desired quality standards, e.g., all important defects have been detected by the reviewers and,
(3) the allocated budget is respected.

First, to organize the whole process requires definition of all tasks, their dependencies, the information flow and the resources needed to execute the tasks. In the above case, external suppliers of the outsourced service execute one of the tasks. During execution of the process, all resources (internal and external to the company) should be automatically informed when they can start to execute their task, as well as to receive all needed information for their work in order to avoid any delay. The monitoring of the workflow should allow precise coordination of the resources at execution time, e.g., by informing a resource that its execution will start at another date than previously scheduled. It requires that information be structured in a way that it can be shared between both parties and according to the timing of the process. In the above example, it would consist of information related to the attributes of the services, e.g., dates of execution and natures of the artifacts, as well as the information that will be exchanged during service execution (e.g., percentage of completion of the work at 50% duration).

Second, the suppliers must have a means to facilitate their supply of information to the outsourcer. A pre-requisite for the supply of this information is that suppliers monitor their work executed when operating the service. Indeed, their service can also be considered as a workflow, composed of tasks, e.g., reading the artifact for verification and filling the form for entering results. The sending of information about the status of their workflow as well as its result at the end should be as automated as possible in order to decrease chances of delaying the customer's process. However, the autonomy of each of the business partners should be preserved as much as possible, since both are separate entities wanting to continue independently executing their own tasks.

Third, the suppliers can keep private any information they want, e.g., about how exactly they realize the activity, since they might want to protect their know-how.

![Figure 2: Outsourced verification](image)

2.2. Management of an electronic market of services

The above requirements relate to workflow management and inter-organizational processes. Enabling an efficient market of services in this context
requires allowing customers to access an electronic market directly from within their processes and to find available services. The services should be described in a way that facilitate searching and later bidding process. Second, in order that the market function as efficiently as possible, diverse kinds of organization and various systems might be used for monitoring and managing processes and services, which should be able to inter-operate. A third major requirement is that the whole cycle of the commercial transaction between both parties should be automated as much as possible, from the searching of adequate services, placing orders, to executing and delivering.

Figure 3 illustrates the simplified case. The outsourcer first searches for a service related to "technical verification". A catalog managed by the electronic marketplace is browsed and when a suitable type of corresponding service is found, the outsourcer can place an order. Services can be of any kind: transport of materials, production of components, market survey, printing of a brochure, scaffolding in construction project, testing in software development, etc. They might be described in different catalogs that would be specialized by domain (e.g. construction, software, marketing, logistics), because each of the domains has its own semantics to describe their services. As introduced in the preceding section, the information that will be placed in the order reflects the need of the tasks in the context of the whole process. For instance, values of the execution dates are the planned dates of the corresponding task in the workflow. The order has to be placed early enough so that the company can adapt its process if no suppliers are found available for the desired dates. When the order has been entered, the marketplace will send a request for offer to all suppliers that have registered for the selected type of service. When the offers have been back, the manager selects the best by matching offers and demand based on the values of service’s attributes. The execution of the service by its supplier will be then directly activated from the customer's company. Status about progress and final results (e.g., the completed verification forms) will be received directly by the customer in the WFMS executing its process.

The scenario described above can have different variations of bidding mechanism, depending on the domains and on the customs of the business actors. In some cases, all offers could be presented to the customer for self-selection. At the other extreme, the customer may let the manager of the marketplace operate the selection.

Finally, a last requirement is to ensure quality in the outsourcing operation. The manager of the market should take into account the degree of successes in past executions operated by the bidding suppliers. It requires monitoring and logging all executions.

Figure 3: Marketplace of workflows

3. Solution

In the framework of the ACE-flow project, an applied research initiative sponsored by the Swiss National Fund for Scientific Research (SNF), a software system is being prototyped to demonstrate the concepts of market-based workflow management applied in the context of services' outsourcing. The system is built by integrating and adapting existing components of electronic marketplace platforms and Workflow Management Systems.

As illustrated in Figure 4, the ACE-Flow system consists of a set of workflow systems (WS) and a trader system. The workflow systems typically reside in different organizations and represent the software components through which these organizations actually provide and request the execution of workflows. The trader system acts as an intermediary among the workflow systems and maintains information about the workflow systems, the workflows offered and requested, and the actual workflow executions.
3.1. Trader system

The trader system provides a wide range of services to WS participating in the marketplace:

Register/deregister. WS may enter or leave the marketplace by registering/deregistering with the trader system. By registering with the trader system, WS actually enter into a contract with the trader system defining several aspects of the behavior expected from the trader system as well as from the WS.

Exporting workflow types. A WS can export a locally defined workflow type to the trader system. Exporting a workflow type means that specific information about the workflow type (e.g., the data needed and produced by the workflow instances) is transferred from the exporting WS to the trader system, i.e. the trader system maintains an electronic catalog of exported workflow types. After a workflow type has been exported to the trader system, it becomes visible to all WS in the marketplace.

Querying and browsing the electronic catalog. The trader system allows the WS contained in the ACE-Flow System to browse and query the information it maintains about workflow types and workflow systems.

Importing workflow types. From the electronic catalog, a WS can import a workflow type in order to define a new workflow type that includes the imported workflow type as a building block.

Add/remove provision of workflow types. A WS can declare that it offers (to other WS) the execution of workflows of a certain workflow type that previously has been exported to the trader system. In case a WS offers the execution of workflows of a certain workflow type t, the WS is said to provide t. A WS provides a workflow type for certain conditions (cost, time, quality, etc.), where those conditions that remain stable over longer periods of time are recorded in the electronic catalog of the trader system.

Workflow execution. The trader system accepts requests from WS to execute workflows, where the requests may also include requirements concerning the workflow execution (e.g. time and cost constraints). Once the trader system has received a workflow execution request, a bidding process is started. It involves the WS offering the execution of the workflow in question during which the trader system determines the provider that will carry out the workflow in a way that best suits the requirements of the requestor.

In the following we will discuss the electronic catalog as well as the process of workflow execution in more detail.

3.2. Electronic Catalog

The electronic catalog maintained by the trader system contains information about the workflow types exported and about the WS providing the workflow types. A workflow type comprises the following:

- an identifier,
- a description of what instances of the workflow type actually do,
- a set of formal input parameter definitions modeling the data consumed by the workflow,
- a set of formal output parameter definitions modeling the data produced by the workflow,
- a state transition diagram defining the possible execution states of the workflow and transitions among them, and
- a set of facets.

The state transition diagram is a mean to define important milestones of the workflow so that during workflow execution, the requestor of the execution is kept updated about the reached milestones.

A facet, which describes a certain characteristic of the workflow, comprises a name, a description, and a domain definition. A workflow may have several facets such as the time needed to execute the workflow or the costs for executing the workflow. Each facet has an according domain definition specifying the possible values of the facet. As an example, consider the outsourced artifact verification
workflow shown in Figure 2. This workflow may have a cost facet described as “cost in dollars for executing the workflow”. The domain of the cost facet could be the data type Real. Furthermore, the workflow may have duration and location facets, where the duration facet describes how long the verification may take and the location facet indicates the physical location of the expert carrying out the verification of the artifact.

The electronic catalog records which WS has exported a workflow type, as well as which WS has provided a workflow type. A WS provides a workflow type for certain conditions that are expressed in terms of facet values. As an example, a given WS could provide an artifact verification workflow for $854, duration of 2 days, and the experts executing the work being located in Texas. Note that the conditions for which a workflow type is provided do not necessarily have to include a concrete value for all facets. Thus, a WS may only declare that it provides artifact verification workflows for under $900, but without giving a concrete duration or location.

3.3. Workflow Execution

In this section, we consider how workflows are executed in the ACE-Flow system. As shown in the sequence diagram illustrated in Figure 5 below, a workflow execution is carried out as follows:

1. A WS (henceforth regarded as the outsourcer's WS) that would like to outsource a workflow of workflow type $w_t$ sends an according request to the trader system. Besides a reference to the desired workflow type, the request also includes requirements (expressed in terms of facet values) concerning the workflow execution. For instance, the outsourcer of the artifact verification workflow (see Figure 2) requests that the workflow costs are below $900 and the duration is less than three days, but does not care about the exact location where the artifact will actually be verified. After the trader system has received the workflow execution request, it determines, based on the information contained in the workflow execution request and on the information available in the electronic catalog, the set of eligible provider WS could possibly carry out the workflow as required by the requester WS. Thus, in the case of outsourcing the workflow of artifact verification, the set of eligible provider WS comprises all WS that potentially offer the workflow for less than $900 in less than three days.

2. The trader system asks each of the WS contained in the set of eligible providers for one or more bids to execute the workflow.

3. Each of the WS that receives a request produces bids, where each bid defines a value for each of the facets of $w_t$. Thereafter, the bids are sent to the trader system. In the case of the artifact verification workflow, one WS in the set of eligible providers may offer the workflow for $600, a duration of two day, executed by an expert in Dallas, whereas a second WS offers the workflow for $850, a duration of one day, executed by an expert in Toronto.

4. The trader system determines the bids fulfilling the requirements of the requester WS. In case that there is more than one bid fulfilling the requirements of the requester WS, the trader system inquires the requester WS to select the optimal bid. Once the optimal bid has been determined, the trader system requests the execution of the workflow from the according WS.

5. During the actual execution of the workflow, the trader system keeps the requester WS updated about the reached milestones.

6. Upon termination of the workflow, possible results produced by the workflow are transferred to the requester workflow.

![Figure 5: Sequence in bidding and execution](image)

4. Case Example

As introduced in Section 1, companies outsourcing services usually prefer long-term, strongly linked customer-supplier relations. This usually implies that customer spends a lot of effort in selecting long-term supplier. The combination of workflow management
with an electronic market of services that has been introduced in this paper enables more flexible customer-supplier relationships, which can be established with less effort.

Example of services that could be traded on an electronic market and executed later with workflow supports can be found in the logistics’ domain (e.g., transport). Other examples are translating, printing, publishing, information searching, certifying, constructing, purchasing, mailing, placing ads, etc.

The scenario below assumes that a large logistics company needs at a specific time to outsource a specific service, e.g., transport from point A to point B. The company's clients could be its various business units (BUs) or other companies. The suppliers of the service could also be internal BUs or external companies (e.g., carriers, warehouses, etc).

For maximum automation of workflow management, clients and suppliers should have deployed Workflow Management systems (e.g., Staffware) or any other kind of support (e.g., LotusNotes, SAP Business Workflow) that allows processes to be defined and monitored during their execution. Interoperability between the various systems and for accessing the electronic market is realized through a light communication interface installed in each system's environment.

The proposed scenario deals with an airfreight shipment. Similar scenarios could be demonstrated with other logistics services, e.g., cost analysis, assembling, custom’s clearance, distribution, finishing, testing, warehousing, etc.

Consider a client asking a company’s central sales office to ship a parcel from Hong Kong to New York by air. The BU sells the full door-to-door service to the client and will have to outsource it internally to one of its operational BUs. It might also outsource some parts of it outside the company to independent suppliers, e.g., picking up the parcel and bringing it to the airport. The BU uses a WFMS to manage the services it offers as a process, including the steps presented in Figure 6.

![Figure 6: Logistic's domain scenario](image)

The sale office outsources:
- to other internal BUs:
  - the pick-up of the goods at the client’s site,
  - the control/completion of required documents (in Hong-Kong)
  - the delivery to the final destination (in New-York),
- to external suppliers:
  - the air freight shipment from Hong-Kong to New-York,
  - Hong-Kong export administrative formalities
  - USA custom’s clearance.

The following steps of the process implying interactions with ACE-flow platform are detailed in the next sections:

Step 1: requesting offers for external services
Step 2: booking internal services
Step 3: selecting external suppliers
Step 4: executing the workflow (from start to end)

4.1. Requesting offers for external services

The sale office operator browses ACE-flow catalog of the various services and selects the ones he/she needs. As shown in figure 7, he/she will select the “domain” (Shipping), the “category” (Air) and the “type” (Intercontinental) he/she is looking for and will indicate the desired values (departure & arrival towns, weight & volume, date). The global ACE-flow catalog is a meta-catalog of all various suppliers’ catalogs. Services suppliers are responsible for maintaining their catalogs, indicating the domain, category, type and range of attributes describing the services they operate.
Having selected the service, the operator completes a Request for Offer detailing their need (e.g., weight & volume). ACE-flow platform will then automatically transmit the Request to all potential suppliers and collect back their Offers, as illustrated in figure 8.

- to allow operational BUs to be challenged by external competitors: in this case, the local BU would act as an external service supplier by also answering to Requests for Offers.

### 4.3. Selecting external services

The Ace-Flow platform receives all the Offers of the potential service suppliers and rank them according to:

- how they meet the values of required facets (dates, volumes, ...),
- cost (price),
- any specified other selection criteria specified by the outsourcer,
- an evaluation of the quality of the potential suppliers, based on the tracking of their past executions logged by the platform.

As a result, the ACE-flow platform will either send back a ‘short list’ of the best Offers, or only the best Offer to the sale office operator. She/he will then only have to either select the preferred Offer or confirm acceptance of the proposed supplier.

In some cases, the outsourcer can fully delegate to ACE-flow platform the final decision upon the selection and don’t need to confirm acceptance.

### 4.4. Executing the workflow

The required data (network address, etc.) for execution are sent to both parties the supplier. In order to enable monitoring of the various outsourced services, a set of milestones are defined along the execution process. Every milestone consists of a formalized message of about progress status to be sent by the supplier to the outsourcer. As figure 9 shows, ACE-flow records delays of execution as well as other quality level indicators for ranking suppliers based on their performance (e.g. satisfaction of outsourcers). As described in section 4.2, the Offers from suppliers can be ranked also based on their past performances.

The completion of the outsourced activity results in a message transmitted through ACE-flow to the sale office, allowing automatic start of the following tasks of its internal process, e.g. invoicing the client.
Figure 9: Monitoring of execution

ACE-flow can also be used for real-time adjustment of services contracted on a long-term basis. In the case of yearly or multi-year contracts, planning of times and modalities of execution is included. But adaptations will always be required at execution time, because of unexpected events, e.g., changes in client requirements (e.g., volume, weight, timing), strikes, wars, etc. ACE-flow provides a way to fine-tune execution within long-term contracts. This would happen through an eased distribution of tasks between potential executors, optimizing resources’ allocation. It will also allow one to quickly find alternative solutions, thereby ensuring smooth and efficient execution of the services.

Many initiatives in the logistics domain bring tools facilitating parts of the illustrated process (e.g., on-line booking, tracking facilities, automated clearance tools). Workflow systems provide ways to automatically activate external application associated to one task or step of the workflow. ACE-Flow integration of Workflow systems allows integrating other existing tool-sets, linking them to traded services. As shown in the scenario, ACE-Flow would allow a ‘one-stop’ service outsourcing process. Some requests for offers could be directly addressed to already implemented on-line booking services. The execution of the service itself could be completed through existing automated facilities (US and UK customs clearance services). And the execution follow-up could automatically connect to suppliers’ tracking systems (e.g., UPS, DHL). The client would therefore benefit from a single access point to all these services, through the ACE-flow interface.

5. Summary and Future Research

Today, outsourcing services is a major trend in competitive industries for reducing costs and focusing on core competencies. But, outsourcers face the problem of coordinating their internal processes with externally provided services. It is difficult to benefit from a market competition between suppliers of services, because companies prefer long-term fixed relationships with single partners. This arrangement enables them to have better coordination.

This paper proposes the application of market-based workflow management to enable more flexible customer-supplier relationships, which can be established with less effort.

There are at least two types of requirements that should be covered by such solution: inter-organizational process management and management of an electronic market of services. Inter-organizational process management deals with the need of defining and monitoring a set of tasks, initiated by the customer. This set of tasks is considered as the customer’s workflow. One of the tasks corresponds to the outsourced service and will be executed by the supplier, i.e. outside the customer’s organization. In turn, this task is also considered as a workflow. This workflow is the traded good/service. Management of an electronic market of services deals with supporting all phases of the commercial cycle, from information to ordering, bidding, selection and execution. Further, access to the market should be enabled for the highest possible number of actors, i.e. by allowing transactions with the various systems used by customers and suppliers for managing their own processes.

A software system, called ACE-flow, is being prototyped to demonstrate how the above requirements could be implemented with market-based workflow management. ACE-flow consists of a set of workflow systems and an automated trader system. The workflow systems reside in different organizations and represent the software components through which these organizations actually provide and request the execution of traded workflows. The trader system acts as an intermediary among the workflow systems and maintains information about the workflow systems, the workflows offered and requested, and the actual workflow executions. An electronic catalog contains the information about the offered workflows, e.g. cost, duration, description, etc.

Examples of services that can be traded with ACE-flow are publishing, mailing, printing, administrative processes, logistics, etc. A scenario example is given for a transportation service, where a logistics company needs to outsource part of the process. ACE-flow is not designed to replace existing procurement functions found in today electronic purchasing systems, but to complete them by supporting the trading of particular services, the coordination of their consumption and the integration of heterogeneous applications.
After completing the prototyping of ACE-flow, future research will include the following aspects that are not part of the current implementation.

**Adaptability:** in order to support real-world application domains, the marketplace needs to be adapted according to the requirements of these domains. For instance, the bidding protocols between the trader system and the providers of workflow executions have to be configurable in order to accommodate the specifics of each domain.

**Management of Workflow Related Information:** in the marketplace, a variety of information about provided and requested workflows has to be maintained. Furthermore, certain information is subject to frequent changes that have to be handled appropriately. For example, a provider may change information about an offered workflow. Since there will be planned or even currently executing instances of this workflow according to the original specification, mechanisms such as advanced versioning are needed to cope with changes.

**Quality of service:** the trader system has to ensure that workflows are executed according to the requirements of the requesters. This includes that the trader system has to ensure that the resources necessary to execute workflows will be available when needed. Thus, resource allocation has to be planned before workflows are actually executed.

**Note:**

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**References**