# Verifying Existence and Composition of Workflow Activity Patterns in Real Workflow Processes

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***Abstract.*** *In this paper we present a collection of high level workflow activity patterns based on the semantic of specific business functions (e.g., notification, task execution request, approval). In particular we discuss three pattern samples (approval, unidirectional and decision patterns). Moreover we gather the results of an analysis of their adoption on a wide set of real workflow processes (models). The analyses showed that the patterns are not only enough but also necessary to model all the 190 workflow processes which were subject of the investigation. We also show and discuss specific sequences or combination of patterns which were more often in the workflow processes analyzed. In larger research we apply these patterns as well as the analyses results in the development of a suite for process modeling and normalization.*

## 1. Introduction

During the last years, companies have been exploring numerous techniques for business process management (BPM) in order to align their information systems in a process-oriented way and to stay competitive in their market. Accompanying this trend the significance of BPM has increased and new quality standards have emerged. According to the quality standard *ISO 9001:2000*, for example, an organization should be mainly represented by its core business processes rather than by its organizational chart. If BPM is associated with Information Technology (IT), it will become possible to offer additional benefits to the organization, such as: (a) precise and unambiguous description of the existing business processes; (b) improvements regarding the definition of new processes; (c) effectiveness regarding the work coordination between different agents; (d) real time gathering of precise information about process executions; and (e) standardization of business processes.

For (computerized) business processes there exists a variety of fragments which can be understood as self-contained activity blocks with a well-defined semantics [Thom 2006a], [Thom 2006b]. In particular, a certain *process fragment* (or *recurrent business function*) may occur several times within one (or different) process definition(s). As an example, consider the evaluation process for price adjustment as depicted in Figure 1. This process includes activities with the following partial order: (a) a decision activity (to fix whether the input is a shopping order or not) (b) activity 'send e-mail to manager informing about price adjustment'; (c) activity 'evaluate request of price adjustment'; (d) activity 'notify managers about conclusion of evaluation; (e) activity 'notify managers about automatic approval'; and (f) activity 'prepare request to be sent'. Altogether this process comprises fragments having generic semantics that can be described as patterns such as decision (activity *a*), notification (activities *b*, *d* and *e*), and task execution request (activities *c* and *f*).

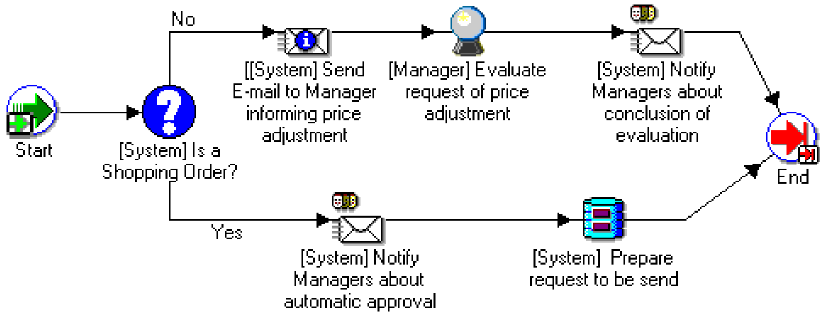


**Figure 1: Evaluation process for price adjustment**

Recently, research on workflow patterns has emerged in order to increase the reuse of recurring workflow structures. More precisely, different workflow patterns have been proposed for control flow modeling [Aalst 2003], resource management [Russell 2004], data modeling [Russell 2005], service interaction [Barros 2005], workflow exception handling [Russell 2006]. All these pattern sets have in common that they are relevant for implementing a workflow modeling tool, or for defining or evaluating a particular process description language. However, these structural patterns provide only a partial answer to the question what business functions a modeler has to consider repeatedly in various process models.

Usually, such process *fragments* [Flores 1998], [Medina-Mora 1992], [Malone 2004], [Muehlen 2002] are re-designed for each workflow application. Of course, this lack of reusing model fragments and process knowledge has resulted in high costs and error rates regarding the modeling and maintenance of process-oriented applications. While there is some research reported on how metadata can be organized to manage large-scale modeling projects (see [Thomas and Scheer 2006]), to our best knowledge there exists no (empirical) work evidencing the existence of recurrent patterns in real workflow applications. Furthermore, there is no work on which patterns are needed and how good they may support the modeling of at least specific kinds of business processes. Beyond that, contemporary workflow modeling tools do not provide functionalities that enable users to define, query, and reuse such patterns in a proper way.

Concerning this problematic in an earlier work, on [Thom 2007a] we presented a first approach towards the implementation of workflow activity patterns based on an Event-driven Process Chains (EPCs) tool [Keller 1992]. Recently we proposed a suite for both process modeling and normalization based on the reuse of semantic process patterns (see [Thom 2007b]). In this paper we gather samples of workflow activity patterns. However, the main contribution of this paper is the description of a case study where we analyzed 190 real workflow processes (models and not instances) from different organizations as well as application domains. Taking the results of the case study we show that the workflow activity patterns do not only exist in real workflow applications, but are also necessary and sufficient to model all the workflow processes which were subject of our investigation. We believe that the use of these patterns together with other existent patterns (e.g., control flow patterns [Aalst 2003]) might not only reduce design effort (e.g., it is a small set of patterns that seems to require little effort to learn) but also optimize and improve the quality of it (e.g., the user can reuse design solutions stored in a knowledge database). This database is part of a larger research where we propose a suite for workflow design based on patterns reuse (cf. [Thom 2007a], [Thom 2007b]).

Against this background, the outline of this paper is organized as follows: Section 2 gives an overview of the workflow activity patterns. In particular, we discuss the approval, notification and unidirectional as three examples. Section 3 gathers the results of an extensive case study where we investigated the existence of the patterns in 190 workflow processes (models). In this section we also show how complete is the set of patterns for the design of the 190 workflow processes. In Section 4 we present some patterns combinations by dividing the set of workflow processes on System-Intensive and Human-Intensive –oriented process. This classification is useful to obtain more precise results concerning the kind of processes the patterns are more suitable to be found. Moreover, this information will be used in the development of a knowledge database of patterns. Finally, Section 5 concludes the paper and gives an outlook on future research.

## 2. Workflow Activity Patterns

A **W**ORKFLOW **A**CTVITY **P**ATTERN refers to the description of a recurrent business function frequently found in business processes (e.g., notification, decision, approval). We derived a set of 7 patterns from an extensive study based on the literature (see [Thom 2006a] and [Thom 2006b]). Examples of patterns are approval, question-answering, unidirectional and bi-directional performative, information, notification and decision patterns.

A block activity is suitable to represent each pattern according to [WfMC 2005]. The block activity concept is particularly suited because it allows to encapsulate the well-defined semantics and to represent their atomic characteristics. This means that all activities defined inside a block activity pattern must be completed before the superordinated workflow can continue its execution.

We describe three example patterns with the Business Process Modeling Notation (BPMN). The complete set of patterns can be found in [Thom 2006a]. For each pattern we describe “context”, “problem”, “forces” and “Solution”. The solution includes one “design choice”. Currently we are working to improve the patterns documentations (e.g., examples of the patterns use, how they can be implemented and additional design choices).

**Pattern1:** Approval

**Context:** A document must be evaluated by one or more organizational role.

**Problem:** How to model a human decision-making in the workflow process?

**Forces:**

- In case of multi-approvals (concurrent), the number of times that the decision-making activity is repeated may vary depending on the level of centralization of authority (less or more) as well as the direct supervision of work existent in the organizational unit(s) where the process is executed.
- The decision-making activity is generally performed by a human.
- The decision-making activity must have more than one kind of response (e.g. approval and reproval).

**Solution**: To include in the workflow, a human activity that characterizes a point of decision-making on the sub-product in question (e.g. a document requiring approval). This decision-making activity will be repeated according to the level of centralization existent in the organizational units where it is executed. Figure 3 shows a single approval.

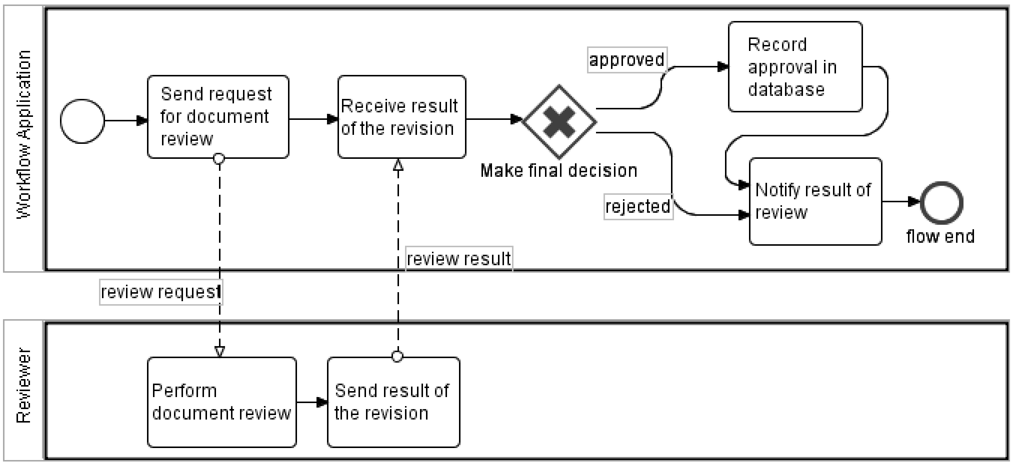


**Figure 3: Approval pattern**

In Fig. 3 an organizational role *reviewer* performs a document review either resulting in an approval or disapproval. In case of multi-approvals, it would be necessary concurrent activities. The “Make final decision”(cf. Figure 3) would be executed only when all reviewers had performed their revisions The revisions would be then performed multiple times in parallel (concurrent) or in sequence (iterative) according to the number of organizational roles specified or until disapproval occurs. Generally, the number of organizational roles is connected to the level of centralization (in high positions of the organization) with respect to decision-making.

**Pattern 1:** Unidirectional Performative

**Context:** In a workflow, there is a moment that the process must request the execution of an activity to the system or to an organizational role involved in the process.

**Problem:** While modeling the workflow, how to send a request without waiting for the result of the activity execution?

**Forces:**

- The receiver's response is not required.
- The process must keep its execution without waiting for the activity to be completed.
- The request can be done to the system or a human.

**Solution:** To include in the workflow model the sequence of activities (see Fig. 4) representing the unidirectional performative message. The sequence of activities comprises the generation of a work item in the receiver worklist. However, the workflow does not wait for a receiver response to continue execution.

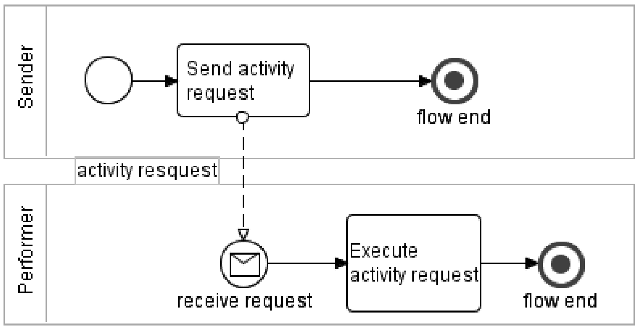


**Figure 4: Unidirectional Performative Pattern**

A sender uses unidirectional performative messages to request the execution of an activity from a receiver. As shown in Fig. 4, an activity execution request results in a work item being assigned to a receiver (i.e., a specific workflow participant responsible for the activity execution). After that, the process may continue execution without waiting for a response.

### 3. NOTIFICATION

**Context:** During the process execution, some specific events have more relevancy such that the process must inform some organizational roles about them.

**Problem:** While modeling the workflow, how can we keep the involved roles informed about some process instance events?

**Forces:**

-The notification must be sent by an electronic way.

-The process does not have to wait for a reading response to continue execution.

-The notification generally contains the status of a process activity (e.g., completed, document approved, rejected).

**Solution:** To include in the workflow the structure concerning the notifying and do not wait for response. Figure 5 shows how this structure works. There's the sending of the notification and its receiving. These activities must inform the involved roles in the process about news inherent to the respective workflow, such as, for example, the approval (or reproval) of a document, or a task that has achieved its timeout.

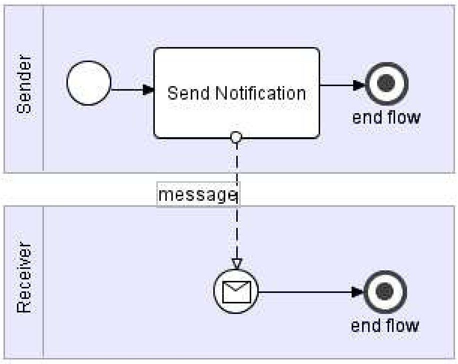


**Figure 5: Notification Pattern**

## 3. Evidencing the Existence of Workflow Activity Patterns through the analyze of Real Workflow Processes

With the goal to search for the existence of the workflow activity patterns in real applications we analyzed 190 workflow processes. These workflows have been modeled with the Oracle Builder tool and have stemmed from 12 different organizations related to different application domains. Notice that we analyzed workflow models and not instances or logs generated by the execution of them. Specially because the semantic of the activities were important to the identification of the processes. Table 1 characterizes the workflows which were subject of the analyses.

| Size of the company | Kind of decision-making | Examples of workflow processes (models) we analyzed | Number of workflow processes analyzed |
|---|---|---|---|
| 1 small | Decentralized | Management of internal activities | 17 |
| 1 large | Decentralized | TQM and management of activities | 11 |
| 6 large | Centralized | TQM; control of software access; document management | 133 |
| 4 large | We had no access to information about these companies | Help Desk, User feedback; document approval | 29 |

**Table 1: Core characteristics of the analyzed workflow processes**

We have obtained the following results from the case study, i.e. the workflow process analyses:

a) evidence with high probability that the workflow activity patterns exemplified in this paper exist in real workflow applications;

b) evidence that the set of patterns is both necessary and sufficient to model all 190 workflows analyzed; and

c) identification of sequence of patterns based on the classification of the workflow processes in *Human-Intensive* and *System-Intensive* [Le Clair 2007].

### 3.1. Method Used to Analyze the Workflow Processes

For each process pattern we calculated its support value (*S*). In the context of this paper, *S* represents the number of occurrences of each pattern (*P*) in a set of 190 workflows. For those workflows comprising more than one occurrence of the same pattern just one was considered. The following formula was considered to calculate the support:

$$S = \frac{F(P)}{T_T}$$

Where:

F(P) = frequency of a specific pattern in the total set of workflow models

$T_T$ = total number of workflow models

Initially, we identified and annotated semantic process patterns in all workflows we analyzed. Afterwards, for all workflows we counted the number of occurrences of each pattern. The obtained result then was divided by the total number of analyzed workflows (i.e. 190 in our case). Accordingly, the *(P)* for this calculation corresponds to a specific pattern while $T_T$ means the set of workflows.

### 3.2. Frequency of Workflow Activity Patterns in Real Workflow Processes

The UNIDIRECTIONAL and BI-DIRECTIONAL PERFORMATIVE PATTERNS, DECISION PATTERN, NOTIFICATION PATTERN and INFORMATIVE PATTERN are not dependent on specific application domains or organizational structure aspects. This fact mainly explains why they were identified with high-probability in practically all workflows analyzed. The same applies to the APPROVAL PATTERN. This can be explained by the high degree of centralization on decision-making existing in the organizational units for which we analyzed their workflows. This high centralization implies the use of approval activities. Besides that, several workflows belong to applications related to approval contexts. By contrast, most of the workflows analyzed do not comprise QUESTION-ANSWERING activities. Figure 6 graphically illustrates the frequency of each pattern in the set of workflow processes analyzed.

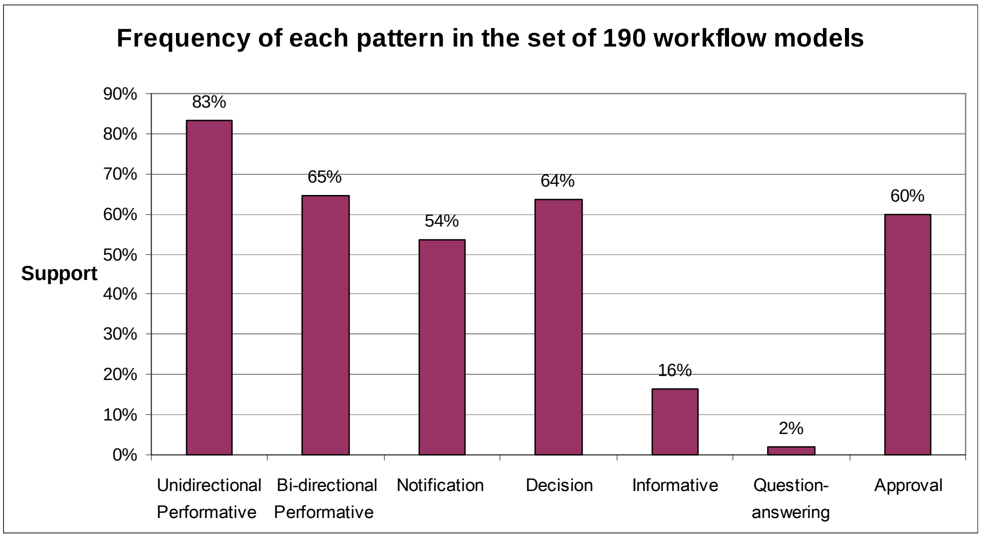


**Figure 6: Frequency of the workflow patterns in real workflow processes**

### 3.3. Discussing the Completeness of the Semantic Process Patterns for Workflow Modeling

The main goal of the study case presented in this paper was the measurement of the frequency which each one of the workflow activity patterns happens in the set of workflow processes that has been analyzed. This was done in order to verify whether these business functions (e.g., task execution request, notification) could really be considered as patterns with high probability of reuse in business as well as workflow process design at least those with similar characteristics of the processes we analyzed.

While some patterns were identified only by the analyses of the activity description (e.g., decision, approval and notification patterns), others required a more detailed analysis. For instance, the INFORMATIVE PATTERN (see [Thom 2006a]) was identified in activities where the user provides an information to the system (e.g., by the fulfillment of a field in the context of an activity). In the case of the unidirectional and bi-directional performative patterns, both the activity description and its execution result (i.e., mandatory or not to trigger the next activity in the process) were important to measure how often the patterns occur.

What really surprised us was the fact that all analyzed workflow processes can be defined as a composition of the investigated patterns (see Figure 7 for an example). That is, the set of semantic process patterns is necessary and sufficient to design all 190 real workflows that were subject of the mining effort. In each process, a specific process pattern may appear zero or more times combined with other patterns.

This fact can be considered as a very important one which points out to new questions to be investigated as part of a future work. For instance, how much could this set of patterns be helpful if it was to be integrated into a workflow design tool? One could think of an intelligent software module which relies on both a workflow activity patterns repository in order to help designers to complete their workflow design. First initiative in this approach we present in [Thom 2007a] and [Thom 2007b]. Figure 7 shows a workflow process sample where all activities match either a semantic process pattern.

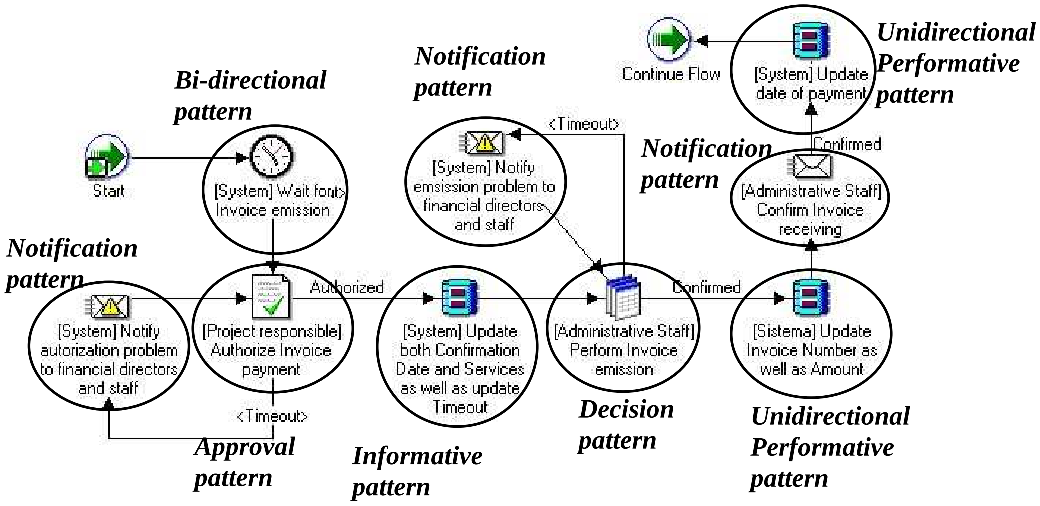


**Figure 7: A payment process built up exclusively from the combination of workflow activity patterns and control flows**

## 4. Identifying Sequences of Workflow Activity Patterns in Real Workflow Processes

Some process fragments can occur many times in the same process definition [Thom 2006a]. Each time a specific fragment occurs, there may have successive process fragments that can also occur with more frequency than other fragments.

With the objective of evidencing which are the workflow activity patterns that succeed with more frequency one specific pattern, we analyzed 151 of the 190 workflow processes, which were subject of our case study. Again we analyzed the workflow models and not the execution logs.

Initially we made a preliminary investigation where we analyzed, for each process activity and its respective workflow activity pattern associated, what was the subsequent(s) pattern(s) that followed them. By doing that, we noticed that most of the patterns pairs had low support value and confidence. Figure 8 illustrates one of the obtained results of this first analysis. Notice that even the most frequent pair of this example (DECISION PATTERN ➔ NOTIFICATION PATTERN) has a low probability (29%).

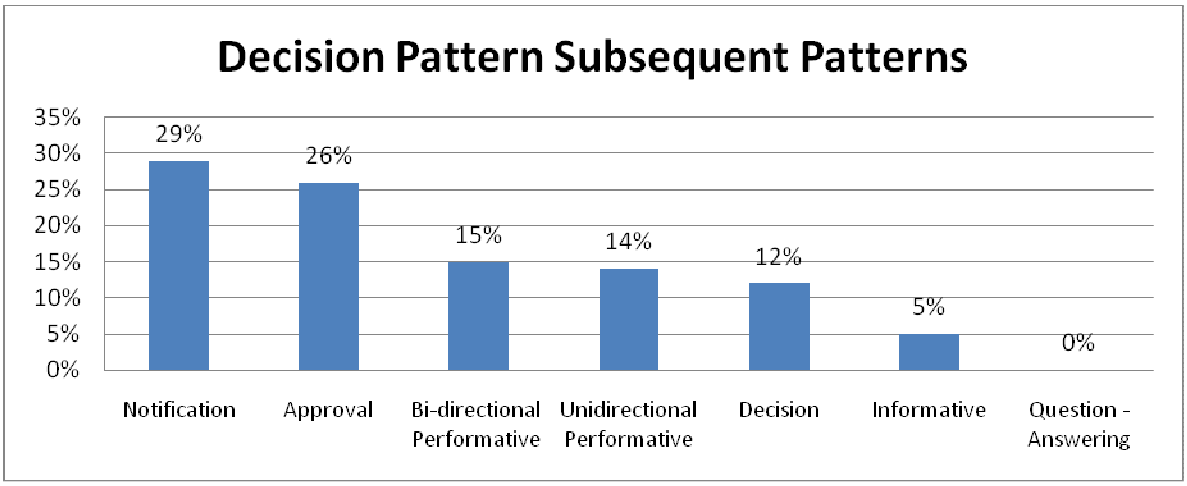


**Figure 8: Decision Pattern Subsequent Patterns on the preliminary mining**

By analyzing the workflow processes, we observed that some kinds of patterns, and their respective pairs, appear with more frequency in determined types of processes. We notices that process including decision-making activities (i.e., approvals), there exists bigger probability that the notification pattern be the follow construction after those decision activities. This fact is mainly explained because the organizational roles involved to the processes want to be informed about the result of the approval process.

In order to raise the support and confidence of the pattern pairs, we decided to classify the processes into business process categories. For that, we studied some of the main classifications found in the literature [Hammer 2001], [Harrington 1991], [Dowson 1987], [Leymann 1999]. However, most of them classify processes by application domains. Accordingly, those approaches were not feasible to our analyses because the set of processes we were investigating do not cover all the categories described on these works. We chose then the classification proposed in [Le Clair 2007] where processes are divided into *system-intensive* and *human-intensive*.

The system-intensive processes are characterized by being handled on straight-through basis, which means that there is minimal or no human touch and few exceptions. The human-intensive processes require people to get work done by relying on and interacting extensively with business applications, databases, documents and other people. This type of process requires human intuition or judgment for decision-making during individual steps.

Having this clear separation between the processes, we divided the set of studied processes into processes that have human interaction and processes that don't have human interaction. The result of this classification is 31 processes system-intensive and 120 processes human-intensive. Figure 9 shows the results of this investigation over decision patterns in system-intensive processes. Notice that the probability of having a DECISION PATTERN → NOTIFICATION PATTERN pair has increased to 50%.

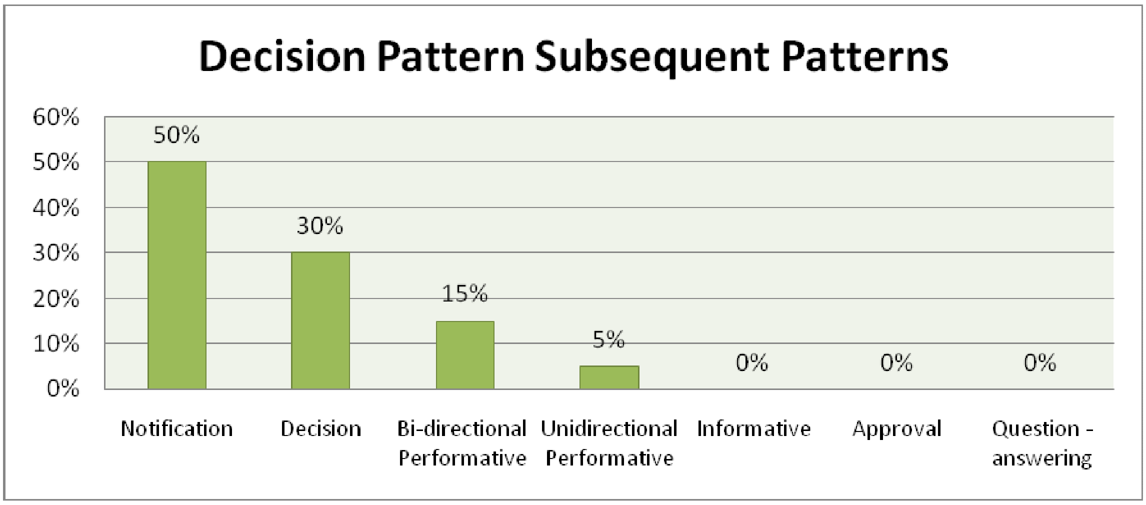


**Figure 9: Decision pattern subsequent patterns by mining only the system-intensive processes**

## 5. Conclusions

In this paper we presented samples of workflow activity patterns which can be used to design business process and workflow models respectively. In particular we reported the results of empirical studies we had performed with the main of to measure the frequency with which each workflow activity pattern occurs within a set of 190 workflow processes. This analysis was accomplished in order to verify whether specific business functions frequently found in business processes (e.g., task execution request, notification, approval) may be considered as patterns with high probability for reuse. We also showed that by dividing the processes we analyzed into *system-intensive* and *human-intensive* it was possible to identify pairs of patterns which were more frequently present in the processes.

The main advantages of this approach can be summarized as follows: (a) the completeness and necessity of the workflow activity patterns has been evidenced at least for the design of the workflow processes subject of our analyses; (b) the patterns are tool-independent and which make them easier to be adapted for any business process modeling tool; (c) it is a small set of patterns which may reduce complexity in user learning;

The result of the case study we presented in this paper will be used in the development of a suite to the analysis and properties verification in workflow specification (e.g., correctness, completeness, deadlock, processes equivalence, livelock, model checking). This suite will have a knowledge database that will store the activity workflow patterns as well as the results of our case study. We consider that this knowledge database will help on matching the patterns on process that will be extracted from legacy code and will help the user on designing the business process from scratch. By using the pattern pairs, we can help the user by suggesting which pattern is better combined with the one that he/she has already modeled.

As future work we intend to perform additional analyzes considering workflows from different application domains (e.g., health insurance and automotive). Our goal is to identify not only pairs of patterns but also sequences of workflow patterns, including more than three patterns in sequence. In this context we also intend to continue studying the workflow classifications so that we can find more specific classification and with smaller granularity to divide the set of processes. A less generic classification will be useful when we try to converge on the user needs using just a few steps Finally we consider making an experiment for comparing process modeling with and without pattern support.

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