A Goal–Oriented Approach for Business Process Improvement Using Process Warehouse Data

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Abstract. In a process-oriented enterprise management, process optimization focuses on studying and evaluating existing processes, such as utilization of resources and identification of problems in the process flow and functionality, for facilitating potential improvements. Conventional data warehouses do not provide information necessary for studying processes, such as executed process activities, utilized resources, or control-flow. Thereby, decisions on process improvements either cannot be taken, or they are taken without complete information. Additionally, process improvements methods commonly suffer from a number of limitations with respect to their complexity, efficiency and degree of automation. In this study, we consider process-oriented data warehouses and thereby we identify the information required from such awarehouse, to facilitate a semi-automatic method for improving processes, starting from established business goals toward concrete decisions. A case study from the Swedish health care sector is used to ground and illustrate the presented method.

Keywords: Business Process Management, Business process optimization, Process warehouse, Goal analysis, Decision making.

1 Introduction

Enterprises are continuously looking for ways to improve their business processes. This activity is no longer a luxury – in order to stay competitive, or to achieve a level of quality, effective methods for process improvements need to be employed.

In enterprise practices, any process improvement analysis requires profound information about the running processes. Conventional data warehouses cannot provide an adequate basis for an in-depth analysis of business processes, because data from transactional systems (OLTP) [1] is extracted, transformed and loaded in data warehouse [3] i.e. the data about ongoing activities is not captured. As a consequence, credible decisions on potential process improvements by using data-oriented warehouses as information sources cannot be taken at all [2].

The second problem concerns the amount of information that needs to be considered when analyzing the data from the execution logs. Process warehouse is a large database and the magnitude of data needed for a decision is very small as compared to

the total size of a process warehouse. Therefore, identification of information that should be consulted for decision making is a pre requisite of the decision making process and it is a complex task. Thereby, there is a significant need for structuring a process warehouse in a way that will enable a fast extraction of the process data relevant for improvement decisions.

The third problem in the process improvement effort concerns a lack of automation in the analysis methods. In this task, business experts, envisaged for making improvement decisions, heavily depend on IT personnel to get the information about running systems. The major obstacle in this context is that the business process data is widely un-automated for analyses.

Following the outlined, in the effort to evaluate quality of existing business processes, it is of a great importance to consolidate methods for enabling an efficient insight to process-related data. To achieve that, in this study, we present a goal-based Decision Relationship Model for process analysis and improvement. Starting from business goals, we explore a Decision Relationship Model based on using data from a well-structured process warehouse. In addition to the proposed model, we define a semi-automated procedure including a set of guidelines for managing the analysis of processes with the use of the proposed Decision Relationship Model.

The rest of the paper is organized as follows. Section 2 of the paper discusses the related work. Section 3 contains the Process Design Framework based on four perspectives. A case study from Swedish health care sector is presented in section 4. Our Decision Relationship Model is presented in section 5. A method of using the Decision Relationship Model for process improvement is given in 6. The case study from Swedish healthcare sector is used to exemplify the use of the method for process improvement in section 7.

2 Related Work

Process analysis is a “feedback” phase in the process lifecycle, in which evaluation of executed processes, diagnosis of bottlenecks and optimization of processes takes place [5, 6]. Business Process Management Systems (BPMS) enable process analysis by logging process data and later on querying it with built-in and third part reporting tools [2]. The acquired reports are used for analyzing executions of operations, identifying bottlenecks and detecting deficiencies. However, the use of reports with current BPMSs presents performance, data quality and semantic limitations [2, 7, 8]. Processes Warehousing [4, 9] and Process Mining [10] have been presented as the techniques to overcome these limitations.

Process mining is used to reveal hidden patterns in process logs for analysis and optimization of process models [11]. In addition to that, it has been used for business alignment (i.e. for comparison of expected and real behavior of an information system or its users [12]) and re-discovering process models from event logs [13]. In general, data miners are the technical experts who are engaged in discovering potential relationships between data elements [14].

The Process Warehousing technique is significant because it works as a data source for process mining [15, 16] and provides a foundation for process-oriented decision support systems [17]. Additionally, it supports various analytical tools (like OLAP)

for *what-if* analysis and it is also recognized as a tool for analysis of process execution, identifying bottlenecks and other decision supporting analysis [5, 9]. In general, process warehouse users (PW users) are the technical experts who answer the questions or provide historical data for answering questions of business experts. A number of efforts have been made to design and develop process warehouses [18, 19, 20] which are user driven, goal driven or data driven [21]. Also, some studies (such as [22]) have been conducted to evaluate the design quality of different process warehouses.

Application of process warehouse has been discussed in several areas such as healthcare [23], engineering [24] and businesses. However, these studies discuss the use of process warehouse on a high level and therefore concrete guidelines on using process warehouse and methods for identification of information for analysis are missing.

A few studies have been conducted on the use of goals for data warehousing and process warehouse [25, 26]. These studies have at least one of the following limitations, a) the study scope is restricted to data-orientated information systems, b) the decision-relevant information are elicited purely manually, c) the focus is on the identification of requirements for data warehouse, d) DW design requirements are based on a set of queries, whereas all the queries cannot be identified at the design time.

Our approach focuses on the utilization of process warehouses for analysis and optimization of business processes. The approach differs from the outlined related studies as we: a) rely on a process-oriented (i.e. not data-oriented) warehouse when analyzing collected execution data; b) structure process-execution data from several perspectives to be able to decrease the amount of data relevant for different analysis and c) outline a goal-oriented approach for process improvement, that is in a semi-automatic method for obtaining the relevant information from a process warehouse.

3 Process Design Framework

A business process has been defined in various ways [27, 28]; however the core of all definitions is that, a process has a set of activities that are executed in an ordered way. In order to design a process, Curtis has proposed four design perspectives of a process model [29]: *functional*, *informational*, *organizational*, and *behavioral*. The main purpose of Curtis process design framework is to enable the obtainment of a complete, i.e. explorative process model.

a) Functional perspective: The perspective considers how a process is decomposed, i.e. what *activities* are to be executed. Activities can be either *atomic*, or *composite*, which are recursively refined to atomic ones. Functionality of an activity is defined by its name, which uniquely identifies the goal of the activity.

b) Informational perspective: The perspective regards the *resources* manipulated in a process. A resource can be either *traditional*, such as a product, or service, or *informational*, such as data and artifacts. A resource is consumed or produced by an atomic process activity.

c) Organizational perspective: This perspective describes the distribution of the responsibility for executing process activities. The main focus here is on the *notion of the actor*. An actor can be an organization unit, a human or a software system.

Actors are commonly modeled as roles, that is, as the set of the functions that an actor is responsible for performing. Using the organizational perspective, it is possible to dedicate and control responsibilities of parties engaged in a process.

d) Behavioral perspective: This perspective concerns the flows of data and activities within a process. The *data flow* describes the flow of information resource from one activity to another. The second flow aspect describes the *control flow*, i.e. when an activity is to be executed in relation to others. For specification of coordination rules among activities, process specifications rely on three basic control flow constructs: sequence, parallel execution and conditional branching. The basic and the advanced control flows, such as synchronization, looping and advance branching, make possible to specify decisions made according to certain *business rules*.

In this study, we use the described process design framework for defining the organization of the data of a process warehouse and to identify the information required for decision making. Additionally, we extend the framework with a temporal aspect that we found as also relevant when analyzing executed processes:

e) Time perspective: It describes the occurrence of events, status of resources, notion of actors and control flow from *temporal* perspective. The perspective is meaningful together with at least one of the four perspectives. Temporal perspective for organizational perspective could be about the availability timing of actors and time utilized by actors etc.

4 Case Study

In this section we introduce a real world case from the Swedish health care sector. Figure 1 shows a process model of an eye-care referral case that is used in this paper as an example study for illustrating the applicability of the proposed approach. The healthcare process is modeled using the Business Process Modeling Notation (BPMN) [30].

Fig. 1. The base eye-care referral process

The referral process given below belongs to a primary eye-care centre at the commune level. On facing an eye health problem, the patient calls hospital, and a time-slot is offered to him/her. This is followed by a payment and registration, and patient visits a doctor during the allocated time-slot. A primary diagnoses investigates the nature of the disease and a treatment is given in case more investigation is not required. However, if the diagnose needs an expert's treatment, a copy of the referral is forwarded to a specialist.

Activities of the referral process give the functional perspective of the process i.e. *offer a time-slot, get payment* etc. The relationship between activities of the referral process gives the behavioral perspective i.e. *get payment* follows *offer a timeslot* and *provide examination* (activity) can either be followed by *set a diagnose* (activity) or *give referral copy* (activity). *Payment amount* and *referral copy* gives the informational perspective (data) related to the eye care process. The *doctors* and the *phone attendant* give the organizational perspective of the referral process. Finally, time perspective is related to all the perspective when the process is executed i.e. the *call-time, offered time-slot, doctor's availability slots* etc.

5 A Decision Relationship Model for Process Improvement

The purpose of this section is to present and describe a Decision Relationship Model (DRM). For that, each component of the DRM is explained with examples, and a semi-structured definition for representing the components.

Various types of users may be involved in process analysis and improvement. These are, *business experts* who define desired goals regarding process analysis, *decision makers* who take concrete improvement decisions and *technical experts* who interact with process warehouse.

The overall aim of our Decision Relationship Model (DRM) is to reduce the gap between business experts, decision makers and technical experts by providing a structured way of using process warehouse for identifying data related to decision making. For using our approach the business expert should define a process goal and decompose it to one or more leaf goals. By using the given process-related leaf-goals, PW experts can identify the information that is necessary for decision maker to take decision.

The Decision Relationship Model (DRM) (presented in Figure 2) consists of the following elements: Business Process, Leaf Goal, Decision-Associated-Information (DAI), Decision and Action. Below, we describe the elements of our model,

a) Business Process: Process is defined as a set of activities. Primarily, a process includes the activities which are performed in a specific order, the actors who perform the activities, the resources involved in the process and the data or messages transferred between actors or activities.

b) Leaf Goal: Leaf Goal is 'a desired state on any of the four process elements' of a business process: resources, actors, activities and flow (see Section 3). An example of a leaf goal is, "avoid more than 8 hours workload of doctors". A semi structured formulation of goals is defined as follows

(Condition on process element)

Fig. 2. Decision Relationship Model for Process Improvement

Condition is a desired state and it could be anything related to a process element. A leaf goal defines the targeted element (resource, actor, activity or flow) of a process for process improvement. For example if goal is *optimal use of doctor's availability*, the doctor (actor) is the targeted area (of the process), in which improvement is desired. Leaf goal is defined by business experts and it is fulfilled by the actions which are identified through decision making.

c) Decision Associated Information: The 'information that must be consulted to take a decision' is called Decision Associated Information (DAI). It is the information that can be used for evaluation of the available alternative decisions which leads to selection of an alternative (decision). Based on the five perspectives of the Process Design Framework (given in Section 3), the data in the process warehouse can be organized into four primary categories and a secondary category. The primary categories are: functional, informational, organizational and behavioral information whereas the time (the secondary information) is a part of each primary-category of information, because it doesn't give any meaningful information independently.

The data in process warehouse that is related as: actors are called organizational information, activities are called functional information, resources are called resource-related information and ordering is called control information. This classification is used for identifying which information should be consulted for which kinds of decisions. For example, in order to take a decision on ordering of activities, behavioral information should be consulted. It is important to identify DAI, because a PW typically involves a large amount of data and thereby the technical expert may not identify the necessary information that must be consulted for decision making.

In what follows, we define the keywords that are used for identifying which data element in the process warehouse is related to which category of information.

- *Organizational Information*, The information that is related to actors, workload of actors, activities associated with actors, completed activities by the actor, failed activities, pending activities and temporal information on actor.
- *Functional Information*, The information that is related to activities, start-time, end-time (expected and real), output, deadlock, frequency, cycle-time, activities failed due to resource unavailability and activities failed due to actors non availability and temporal information on activities.
- *Resource-related Information*, The information that is related to resource, activities related to resource, consumed, produced, transferred, utilized/usage,

required, available, deficient, condition of resource, affect of absence of resource, minimum level and temporal information on resources.

- *Control Information*, The information that is related to outcome of sequence, frequency, deadlock, alternative paths and temporal information on ordering.

d) Decision: Decision is 'a directive of a course of action' on resource, actor, activity or flow. A decision can be formulated as

(Directive on element) e.g. (add more actors).

Direction is the course of action and element is the element of process model on which the directive is applied. Decision is result of a decision-making activity performed by management and it is done in consultation with Decision-Associated-information (DAI) that is provided by data warehouse expert. The possible directives to achieve a goal could be on an element or on a set of elements.

e) Action: An Action is a 'realization or implementation of a decision' taken by the management. As a result of realization the goal is achieved. In the process improvement life cycle this is related to the implementation of the solution.

In the remaining part of this paper, we present a method for using the Decision Relationship Model and exemplify the use of the Decision Relationship Model to discuss the applicability of the Model.

6 Using DRM for Process Improvement

In this section we describe how the presented Decision Relationship Model (DRM) can be used for improving business processes in an organization. For that, we present a four-step method for guiding the use of the model. For each step we define input, output, involved actors (users) and high-level guidelines (wherever possible) for the users.

Figure 3 shows the possible use cases and the actors of the Decision Relationship Model. For process improvement, business users' model business goals. The goals serve as an input for technical users (PW experts) for identification of Decision Associated Information (DAI). Decision maker uses DAI for decision making to produce directives (called decisions) for improvement of processes that are realized by business and technical users.

Fig. 3. Use cases of Decision Relationship Model for Process Improvement

Step 1: Define Goal Models

In the first step, a goal model is developed by business experts in such a way that it is broken down to one or more leaf goals (see Figure 4). As stated earlier, a leaf goal is a desired state on any of the four process element of business process: resource, actor, activity and flow. A goal can be broken down into several sub-goals and each sub-goal can further be broken down into sub-goals of its own. The process continues until the leaf goals are reached. Figure 4 shows the meta-model for the goal model in which self-loop on sub-goal can be used to build a hierarchy of goals. The goals at the same level can have AND, OR or XOR operator between them. The goal model is used to: a) identify the targeted elements of the process model for process improvement, and b) identify a desired state of the element.

Fig. 4. Metamodel for Modeling Goals

There are some goal modeling languages (like i*, KAOS) however they are not used in order to a) keep the solution generic i.e. independent of any goal modeling language, b) keep the focus on DRM, without going deep into any specific language.

Step 2: Identifying Decision Associated Information

Inputs to this step are leaf-goals (*condition on process element*), whereas the output is decision associated information (DAI). Typically, this step is performed by technical experts (PW experts).

A process warehouse is a non-volatile database with a large amount of data; however, not all the information required for decision making. Therefore, PW experts are supposed to provide only the information that is related to a decision-making. By using the guidelines (presented in this section) together with the keywords, presented in decision associated information, PW experts can provide the information sufficient for the decision making.

Guideline 1. If goal is a *condition* of actor, the decision-associated-information is organizational, functional information.

Justification. If the leaf goal regards the actor, then the organizational information should be consulted for the decision(s) that fulfills the goal. However, the actors are related to the activities for which they are responsible, and therefore some decisions may need for consultation of the functional information. For example, if goal is to optimally utilize doctors' working hour, it may only require information on doctor, their working hours, and the activities on which they are involved. However, the decision maker may go deeper to analyze which activities are performed by doctors in order to reschedule doctors' involvement in valuable activities only.

Based on the guidelines it is suggested that PW expert should primarily provide actors' information and secondarily functional information about the process on which the goal is defined, to decision makers.

Guideline 2. If goal is a *condition of resource*, the decision-associated-information is resource, functional information

Justification. If the goal is on resource the resource-related information should be consulted for the decision(s) that fulfills the goal. However, the resources are produced, consumed or transferred as a result of activities therefore some decisions may need functional information. For example, if goal is to consume a resource it may only require information on the total resources, consumed resources and available resources. However, the decision maker may go deeper to analyze the affect of presence and absence of each resource on activities and time slots of activities in which the resources are consumed.

Based on the guidelines it is suggested that, PW expert should primarily provide resource related information and secondarily functional information about the process on which the goal is defined, to decision makers.

Guideline 3. If goal is a *condition of activities*, the decision-associated-information is organizational, functional, resource related, control information.

Justification. If the goal is on activities functional information should be consulted for the decision(s) that fulfills the goal. However, actives play a central role in the process and changes in activities may affect the resource involved in the activities, the actors who perform the activities and the ordering of the activities. Therefore organizational, functional, resource-related and control information should be consulted for decision making. For example, if goal is to perform activities at some specific order and at specific time the decision maker should consult the information on the activities. However, before deciding a specific time for an activity the availability of related resources and related participants should also be consulted.

Based on the guidelines it is suggested that, PW expert should primarily provide functional information and secondarily control, participant and resource-related information about the process on which the goal is defined.

Guideline 4. If goal is a *condition of flow*, the decision-associated-information is control, function perspective.

Justification. If the goal is on flow control information should be consulted for the decision(s) that fulfills the goal. However, the flow is between activities therefore some decisions may need functional information.

Based on the guidelines it is suggested that, PW expert should primarily provide information related to control and secondarily functional information about the process on which the goal is defined, to decision makers.

Step 3: Decision Elicitation

Inputs to this phase are goals and their Decision-Associated-Information whereas the output is a directive of course of action. It is a manual activity that is performed by domain experts (also called decision makers).

Domain experts have sufficient knowledge in their area and they are aware of the critical information that should be consulted for decision making. However, the decision makers may or may not have substantial knowledge to interact with process warehouse. Therefore, they rely on process warehouse experts (PW experts) for

Decision-Associated Information. On the other hand, PW users may have substantial knowledge of process warehousing but they may not be aware of the critical issue of the domain therefore they may not know the information that must be consulted.

Decision elicitation is a three phase process, including: *identification*, *evaluation* and *selection* of an alternative. In the *Identification* phase the possible alternatives of the decision are identified by the decision maker. In the *Evaluation* phase the possible alternatives are evaluated by using the DAI. Finally, in the *Selection*, the best suitable decision is selected based on the evaluation of alternatives.

Step 4: Realization of Decision

Input to this phase is a directive (decision) selected by the decision-maker which is of the form (*directive on element*). As a result of this phase the action is completed and goal is fulfilled.

In this step, the directives can be realized at two levels, business level and process level. At *business level*, the directives are realized from organizational aspects for example hiring new doctors, assigning new duties to doctors etc. Business users contribute to realization of directives for fulfillment of goals. At *process level* the directives are realized from process modeling perspective for example, changes to duties (activities) of doctor (actor), if new duties (activities) are assigned to doctors (actor). Technical users (process modeling experts) contribute to realization of directives for fulfillment of goals.

7 Application of DRM for Process Improvement: A Case Study

In this section we exemplify the use of our Decision Relationship Model with the help of a four-step method (presented in Section 6). For that, we use the eye-care referral process (presented in Section 4 of the paper) to in a step-wised manner describe the use of the Decision-Relationship-Model.

To apply the method, first business experts need to create a goal model for the Eye-Care Referral process. From leaf goals, decision associated information is collected further used for decision-making to select a directive, whose realization fulfills the top-goal. The method can be summarized as:

- By using goal modeling we identify the targeted element of the process model and its desired states.
- With the help of the guidelines presented in step 2 in the preceding section, DAI is collected.
- Alternative directives are identified (manually), and evaluated with the help of DAI for selection of a decision.
- The directives are realized by business and technical experts (i.e process modeling experts).

Below we explore the method steps in details:

Step 1: Define Goal Model

In this step the goals are modeled (by business users) and broken down to leaf goals. Figure 5 shows a segment of a goal model for the eye-care referral process. Consider that the top goal is to provide ‘*fast eye-care service*’ to patients. As described in Step 1 (in Section 6), the goal is broken down to obtain leaf goals. The sub-goals becomes ‘*waiting time should be short*’ and ‘*doctors will be skilled*’. These are further divided to leaf goals that are shown below, in figure 5.

In addition to the goal modeling, in this step, target element of process model (for optimization) and desired state of the element is identified. In semi-structured form it can be written as (condition on process element). For the goal model,

Leaf goal = ‘*doctors availability will be used optimally*’
 Target element = ‘*Doctor*’ (actor)
 Desired state = ‘*Optimal use*’
 Semi-structured goal formulation becomes (*Optimal use of doctors*)

Fig. 5. Goal Model for the eye care referral process

Step 2: Identifying Decision Associated Information

Once the target element and a desired state are defined by business experts, the next step is to identify decision-associated information. However, technical experts may not be able to easily identify the information that must be consulted in decision making. To overcome this problem, we presented the keywords for each process perspective as outlined in Section 5 and the guidelines for choosing the perspective (information) described in Section 6.

According to Guideline 1, if a goal is condition on actor the DAI is organizational and functional information which can be acquired with the help of keywords given in functional and organizational perspective (in section 5). Therefore, for the goal (*Optimal use of doctors*) the keywords lead to:

- *Organizational Information*, The information that is related to doctors, doctor's workload, tasks performed by doctors, completed tasks by the doctors, failed tasks, pending tasks and temporal information on doctors.

- *Functional Information*, The information that is related to activities, output, deadlock, frequency, cycle-time, tasks failed due to resource unavailability and activities failed due to doctors un-availability and temporal information on tasks related to the doctors (expected and real start-time, end-time of tasks).

Step 3: Decision Elicitation

Once the target element and a desired state are defined by the business expert, the next step is a manual identification of the decision alternatives. This step takes place by domain experts having sufficient and in-depth knowledge of the domain. The identified alternatives are evaluated by using decision-associated-information and an alternative is selected.

In the eye-care referral process, the possible directives can be identified in the form of the means that could fulfill a leaf-goal. For (*optimal use of doctors*) the identified alternatives are:

- a) Reschedule doctors availability timings (office timings),
- b) Spare doctors from irrelevant activities,
- c) Involve doctors in diagnosis activities only,
- c) Allocation of time slots to patients in doctor's availability timings.

In order to evaluate the suitability of every alternative DAI should be consulted. The information required for evaluation has already been acquired by step 2. For example, the possibility of rescheduling doctors' availability timings, the temporal aspects of organizational information should be consulted i.e. arrival time of doctors, department time of doctors etc.

From the functional and the organizational information it can be elicited what are the activities in which doctors are participating, how many of them are succeeding, on average how much time each activity takes etc. For example, if doctors' are involved in checking of blood-pressure before examination and because of that doctor attends the patient for an extended period of time. In this case, the decision could be to save the time of doctors by handing over the blood-pressure checking activity to nurses. Similarly, based on the information provided by process warehouse, the alternatives can be evaluated and suitable decision(s) can be made. The decision (i.e. a directive on a process element) for the eye-care referral process can be formulated as:

(*doctor should not check blood pressure*) AND/OR
(*nurse should check blood pressure*)

Step 4: Realization of Decision

Once a directive is defined, the final step is the realization of decision. As described in step 4 in Section 6, the realization of directive can be at two levels, business level and process level.

For the directives *doctor should not check blood pressure AND/OR nurse should check blood pressure* the realization should be at two levels. At the *business level*, the nurses would be asked to check the blood pressure whereas the doctors will be stopped from doing it. At the *process level*, the process model will be re-designed in such a way that the blood pressure activity will be disassociated from the doctor

(actor) and associated with a new actor (nurse). In this way, the goal '*doctor's availability will be used optimally*' can be fulfilled.

8 Conclusion

Process models are highly important for designing and structuring the activities of an enterprise. Therefore, it is important to constantly improve those models in such a way to align them with long term enterprise goals, and thereby justify the process evolution from a strategic perspective.

In this paper, we have proposed a model-based approach for analyzing enterprise processes, using the information from a process warehouse to facilitate correct decisions for process improvements. In our approach, we have considered a process consisting of four design perspectives: organizational, functional, informational and behavioral. Furthermore, the proposed model has involved several components: goals, a process warehouse, information retrieved from the warehouse, and directives. Firstly, in a hierarchy-based goal model, the top-level goals are defined upon desired high-level improvements and decomposed to the leaf goals describing the necessary conditions on one of the four process perspectives (such as actors, activities, resources, etc). The use of leaf-goals is twofold. Firstly, they are used for eliciting a number of means that are considered as the candidates for realizing top-level goals. Secondly, the leaf goals are used as a basis for acquiring data from the process warehouse, which is also structured using the mentioned process perspectives; this enables retrieving of only the relevant information from the bulky warehouse, and in addition, in a semi-automated way. Finally, the business expert uses the obtained information to choose among the means-alternatives to make an appropriate directives about the process improvement. We have illustrated the use of our approach on a eye-care process from the Swedish health.

Regarding directions of a future work, we see the augmentation of the automation of the proposed approach, in particular guidelines, as the major issue. Another interesting topic involves the exploration of possibilities for mapping created directives into process-related parts and elements.

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