Enterprise modeling:process and REA value chain perspective

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ABSTRACT: The paper focuses on enterprise business value chain modeling as an alternative to business process modeling. Well known REA methodology proposed by McCarthy and Geerts is used as the basic modeling framework. The research presented in the paper results in a generic semantic enterprise model using REA ontology. This rather static model is then converted into UML activity, sequence and state diagrams thus achieving dynamic view of the REA model. The dynamic REA view connects the process model and the value chain perspectives. It is shown that by using REA model transition called dynamization not only process models at task level can be achieved but also a consistency check of the REA model can be accomplished. By means of step by step value chain modeling of the enterprise a consistent process model can be reached preserving all advantages of the typical business process modeling methods. [1]

1. Introduction

Enterprises have been operating in global competition environment. They are forced to improve quality and flexibility of business operations in general. To achieve this goal, they need to understand the fundaments of their processes with the appropriate theoretical background leading to process optimization and corresponding support by information technologies. Enterprise process optimization is typically based on business process modeling. There are also other modeling perspectives used like information technology (IT) view and business value chain perspective. While the business process perspective concentrates on business processes and workflows aiming to describe company operations, the value chain perspective illustrates the value flows among the participants inside and outside the company. One of important advantages of the value flow modeling is that it captures the cross concern activities and represents the actual aim of the business processes – the value exchanges between the company and the environment. On the other side, the value chain perspective does not capture process sequences and states. It is often assumed that business process and values chain modeling are difficult to interconnect.

In this paper we focus on value chain modeling perspective and possibilities of its interconnection to business process modeling perspective. First, the foundations of value

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chain methodology are presented and the leading value chain methodology REA (Resources – Events – Agents) is described. Next, the notion of REA operational and REA policy levels and their relation to controlling and controlled company units is presented. This static representation of a company is then supplemented by dynamic views of value chain models presented in form of UML diagrams. This leads to possibility to formulate business process models based on the REA methodology. The last section presents final discussion and outlines further research orientation.

2. Value chain models and the REA methodology

New modeling and system design techniques are required for information technologies that can support the enterprise in achieving and sustaining the necessary flexibility. Current techniques use business process models, representing the operations inside the company from the control, data flow, resource handling and co-ordination of cross-operational processes points of view (Axenath, Kindler and Rubin, 2007; Davenport, 1992; Ericson and Penker, 2006; Koubarakis and Plexousakis, 1999; Řepa, 2007; van der Alst, 2004; Zdun and Dustdar, 2007 etc). Formal notation of business process modeling can be found in Busines Process Modelling Notation, 2006. During last few years efforts have been made to generalize modeling attitudes by means of enterprise ontologies (see e.g. Dietz, 2006).

Distinctly from business process modeling methods, value chain perspectives typically concentrate on values flows inside the enterprise and on value exchange with the environment, that is, they are primarily based on underlying economic activities. The formal attitude to value chain modeling is defined by corresponding ontologies defining concepts and rules to be shared by other modelers (Cummins, 2008; ISO/IEC 15944, 2007).

Currently, the most popular value chain enterprise ontologies are e^3-value (Gordijn and Akkermans, 2003), and the REA (Resources, Events, Agents) ontology (McCarthy, 1982; Geerts and McCarthy, 2000, 2002).

The e^3-value ontology stipulates that the actors exchange value objects by means of value activities. The value activity should yield profit for the actor. Deeper insight in e^3-value modeling in e.g. (Gordijn and Akkermans 2003; Huemer, 2008), shows that this method only covers exchange and trade processes but omits production and conversion processes. The state-of-the-art e^3-value model only focuses on operational level (what has happened) but not on management policy (what could or should happen).

Our object of interest is the REA ontology, because it links together business process modeling with the underlying economic phenomena. The REA model represents a conceptual framework and ontology for Enterprise Information Architectures (McCarthy, 1982; Geerts and McCarthy, 2007). The REA ontology illustrates the value flows inside and among enterprises. The value flows modeled by means of REA can be decomposed into several levels (Figure 2.1).

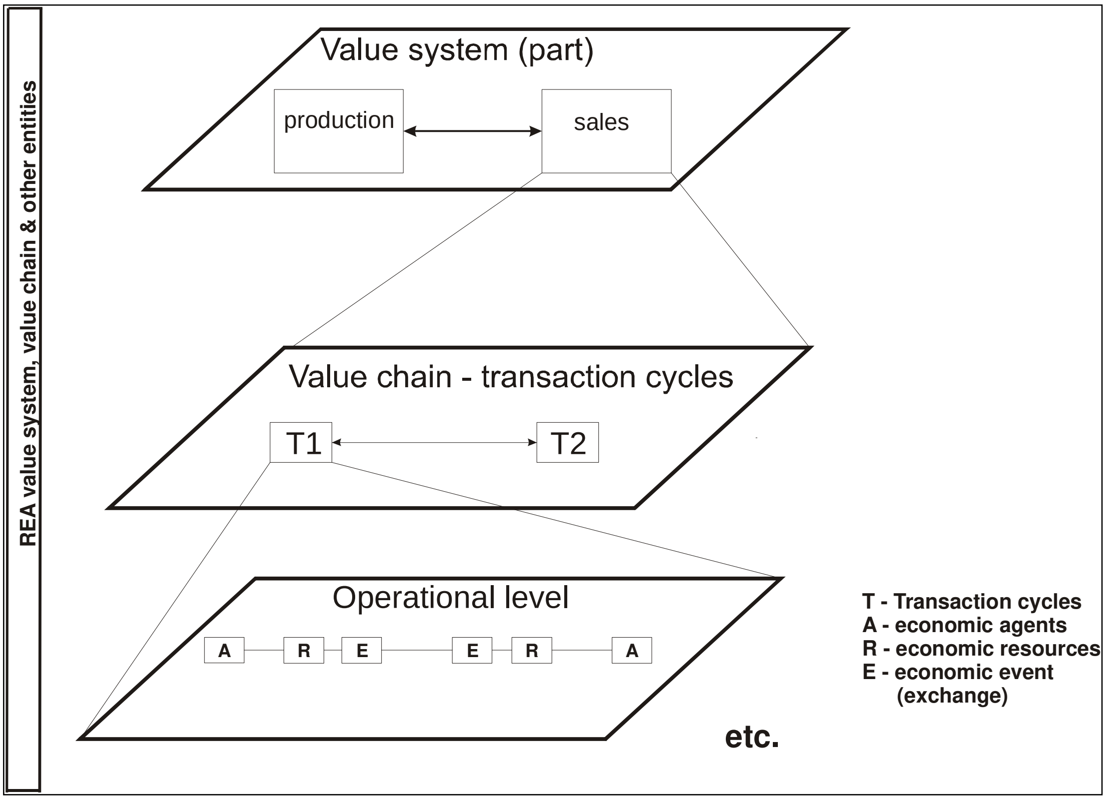

Figure 2.1: Value flow decomposition by the REA methodology
Source: own

The modeling starts at the highest level **–the value system** of the enterprise. The enterprise produces and delivers goods and services to receive cash from customers. Working capital (cash) comes from the investors, creditors, and from revenues originating in sales processes. This general value system is expanded into more specific **value chains** represented by **basic transaction cycles** decomposing value system entities. Transaction cycles can be generally presented in a form of **business patterns,** bearing enterprise value system and value chain in mind. The core of the REA models is presented as business patterns modeled at the REA **operational level.** The concept of operational level using basic notions of **economic event, economic resource and economic agent** is the base of the REA methodology. It was asserted in many other papers (Dunn , *et al., 2004;*Hruby, 2006; Chang and Ingraham, 2007; Vymetal , *et al.*, 2008 etc) that more general perspective can be obtained by using the value approach, as the basic cycles and relations are principally the same for all transaction types.

At the operational level, the economic events run in form of exchange, or conversion (production). During exchange, the providing agents provide their resources (e.g. goods) to receiving agents in order to increase their other resources (e.g. cash). In production, the providing agents provide input resources (e.g. material, tools, labor) to conversion process in order to produce the resource - product. The relation between economic events decreasing the input resources and economic events increasing the output resources is called **exchange,** eventually **conversion** duality in the REA terminology. These two basic patterns represent all REA economic events no matter what type of enterprise it concerns. However, it can be clearly seen, that the events at the operational level represent facts ("*what has happened*") rather than objectives ("*what should, could or must happen*"). In general an answer is needed to the question "*what is planed or scheduled?*" This is modeled by REA **policy level.** The policy level defined in the REA methodology can be looked upon as a set of notions originated by several semantic abstractions of the REA operational level entities. There are two core semantic abstractions defined for policy level (Geerts and McCarthy, 2006) namely typification and grouping.

In case of typification the specialized instance inherits both structure of data attributes and their contents. So, for example, the policy level entity Product Type defines the structure of the product by means of Bill-of-Material data structure. The Product Type instances define individual Bill-of-Material values valid for actual Product-to-be-produced (the plan "*what should happen*"). The instance of Product at operational level inherits both Bill-of-Material data structure (the structure of planned values) and individual values used in production time (facts – "*what happened*").

The grouping semantic abstraction is used when set-level characteristics are of interest and may even create an integral part together with the typification semantic abstraction. By this semantic abstraction a collection of individual entities may be specified with respect to some common properties.

A simplified scheme of operational – policy level integration is presented by Figure 2.2.

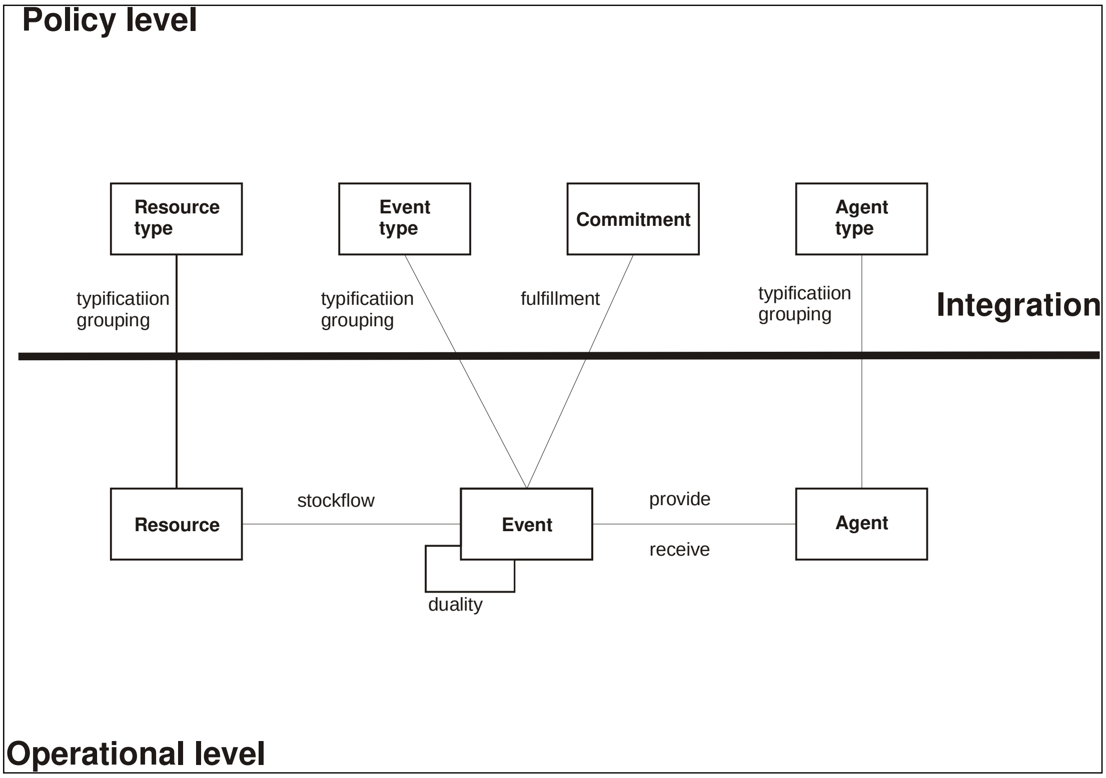

Figure 2.2: Simplified scheme of operational and policy levels
Source: own

The resource, agent and event entities are typified by policy level entities resource type, event type and agent type correspondingly. In some cases grouping can be also used. However, there is a new entity shown at policy level: the **commitment** entity. This entity is not defined by typification abstraction. There are still open research challenges regarding fulfillment relationship that are beyond scope of this paper. Commitments are typically used in cases when some event is expected, planed or induced. In fact, the commitment entity can be looked upon as a core connection of economic event at operational level to planning or scheduling entities at policy level. Thus, even in case of the simplified policy level scheme we come to the core notion of controlled and controlling value chain entities of the REA methodology. The operational and policy level entities discussed up to now pertain to the controlled part of the enterprise system. The actual attribute values of policy level instances that govern the behavior of operational level items are set by other economic events, namely the events running in the controlling subsystem of the enterprise. This situation is depicted by Figure 2.3.

The entities of REA operational level are related to corresponding entities of REA policy level by typification, grouping and fulfillment abstractions. The enterprise objectives govern the behavior of the controlled subsystem by means of objectives, decisions, indicators and rules transferred to corresponding controlled policy level entities and further reflected to operational level entities.

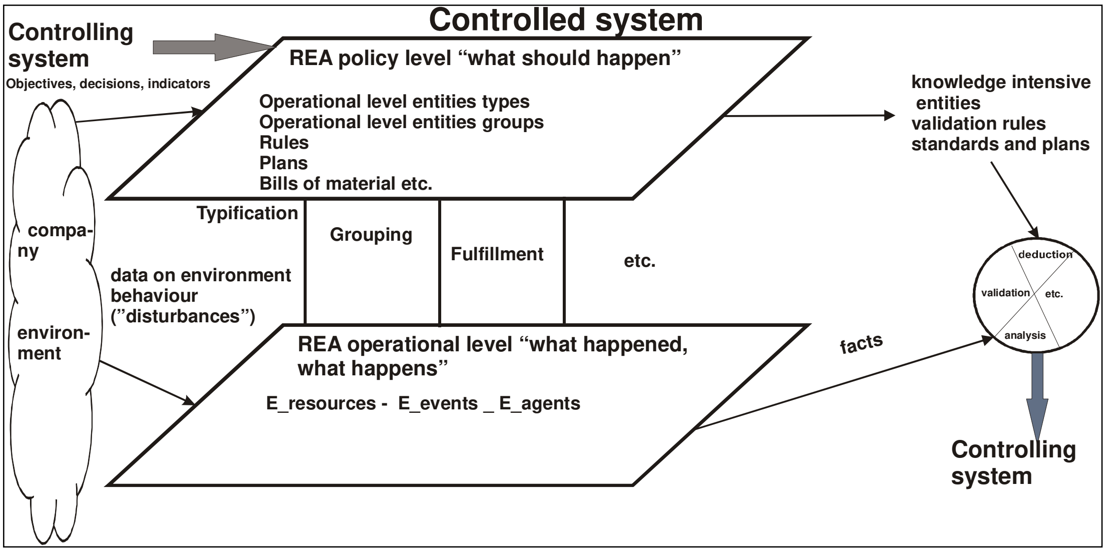

Figure 2.3: REA levels of controlled enterprise system with feedback to controlling system

Source: own

The facts describing what happens or happened are validated, analyzed and further processed to be compared with the target values. The differences from target values serve as an input to events running in the controlling subsystem. However, the controlling subsystem is also a part of enterprise. Thus, the same patterns should be found there. Indeed, the activities of controlling personnel can be also looked upon on the REA basis. The economic events at controlling subsystem operational level consume the management labor, use needed equipment and other resources. These events result in plans, schedules, production rules, etc., generally, in knowledge intensive controlling resources. The above described scheme is presented in Figure 2.4. In this figure, only one relation of controlling system to controlled system is shown to simplify the picture. The enterprise value chain can be decomposed into several transaction cycles using business patterns of controlling and controlled subsystems. The controlled subsystems are modeled by REA patterns using their own operational and policy levels. The controlling subsystem sets the rules, indicators, targets etc. of individual controlled subsystems via corresponding policy levels. The events running at controlling operational level follow typical REA patterns of agent-resource-event chains. In this way also overhead costs can be captured and modeled. Following the REA concept, each controlling subsystem needs also its' own policy level. Indeed, also controlling subsystem of an enterprise has to follow common rules, laws and other conditions set by the enterprise environment and also to follow the general enterprise strategy expressed by means of strategy objectives. The question arises, how the knowledge intensive resources originating in the controlling system can be transferred to controlled subsystem policy level. Hunka , *et al.,* (2009) proposed the notion of **reflection** abstraction realizing the connection between knowledge intensive resources produced in controlling subsystem (such as production plan) and corresponding items of controlled policy level items (such as production schedule). Following the steps described herein above and using the concept of reflection the modelers are able to define the static value flow structure of the whole enterprise.

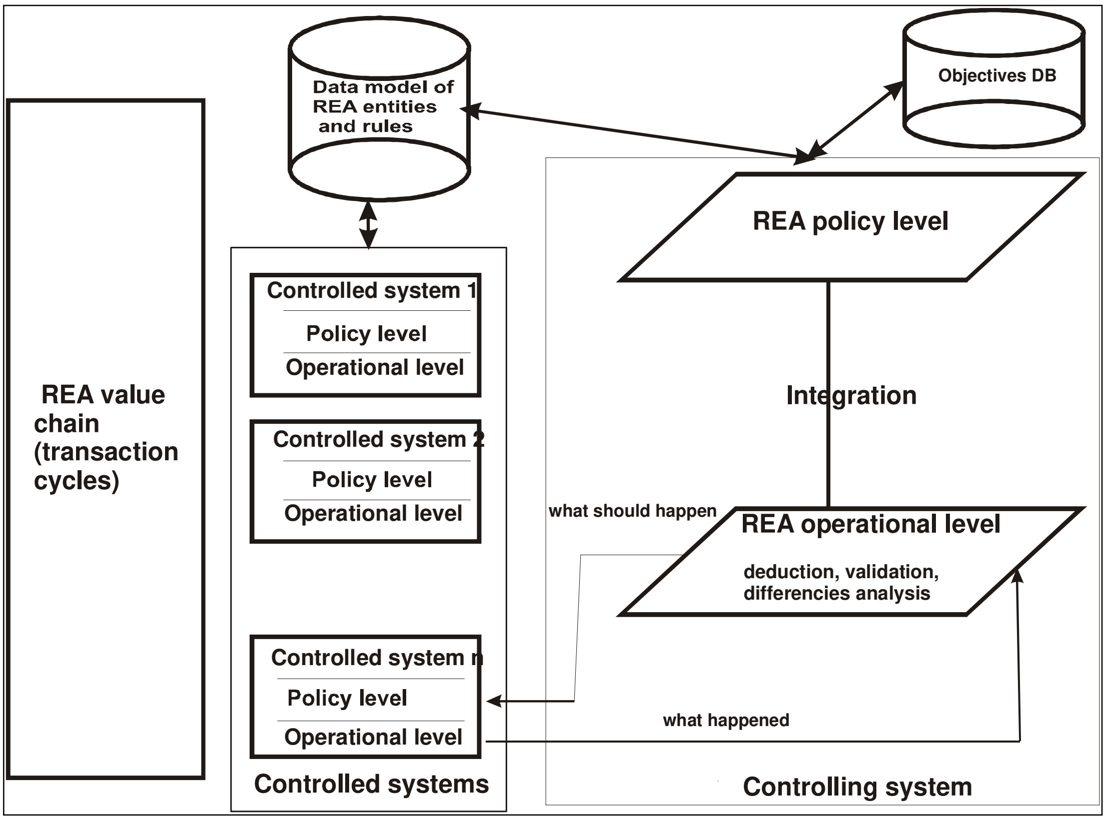

Figure 2.4: Generalized REA scheme of controlling and controlled subsystems
Source: own

3. Dynamization of the REA value chain model

The REA model at operational level represents the lowest decomposition level of value chain oriented model of chosen enterprise domain. It transparently shows value flows among economic agents and economic events taking part in these flows. Nevertheless, it does not give answers to following questions:

a) what is the order of individual economic events;

b) which participant – economic agent started the process and by which economic agent will be the process finished;

c) how to illustrate conditions, joins, forks and eventual cycles in the workflow;

d) consistency checking of the REA model.

Of course, an objection can be raised, that the order of events is visible during the running process or after it had been ended. From the modeling point of view such kind of visibility is not sufficient enough. It is therefore necessary to complement the value chain model by a course of economic events – dynamics of the processes. The method of creating consistent process model based on a REA value chain scheme will be called **dynamization** (Vymetal, Hucka, Hunka and Kasik, 2009). The result of dynamization can be represented by workflow (data flow) schemes, message schemes and state diagrams. Various tools can be used for this task. In our approach, corresponding UML diagrams are used, namely the activity diagrams, sequence diagrams that are complemented by simple process state diagrams. Mainly activity diagrams play an important role in the dynamization processes they enable to describe procedural logic of the REA model. Using of UML notation helps to achieve pattern approach and supports direct link to programming. Extensive literature reviews on UML and patterns usage usage can be found in (Fowler, 1996; Coad, Lefebre and deLuca, 1999; Arlow and Neustadt, 2003; Ericsson and Penker, 2009). The principal difference between them and flowchart notation is that they support parallel behavior. Using UML tools brings following important advantages:

a) the REA models use object oriented perspective so that is why they are typically presented by UML syntax and graphical tools;

b) using UML activity and sequence diagrams enables using object oriented design methods supported by standard IDE tools.

Let us illustrate the dynamization approach by means of simple production order execution as follows. Based on production schedule the production supervisor sends a production order to a worker defining the product-to-be-produced, the production start time and the planned production time. At the same time, the information on product and corresponding Bill of Material is sent to warehouse clerk as an order for necessary tools and material. The warehouse clerk gives out tools and material and the worker starts working. After the product is finished, the worker returns the tools to warehouse clerk (the material was consumed during the production operation) and the warehouse clerk informs the supervisor on the tools return. The supervisor marks the production order as fulfilled.

REA model

A simple REA operational level model can be designed with economic agents: supervisor, warehouse clerk and worker, resources labor, material, tools, schedule information and product. The decrement economic events define labor and material consumption and also tools and schedule information use. The increment product assembly event has conversion duality associations with corresponding decrement events. (see Figure 3.1).

Based on this model following diagrams can be defined during dynamization: production state diagram, UML activity diagram and UML sequence diagram using the operational level items. The formation of above mentioned diagrams is known enough from common practice.

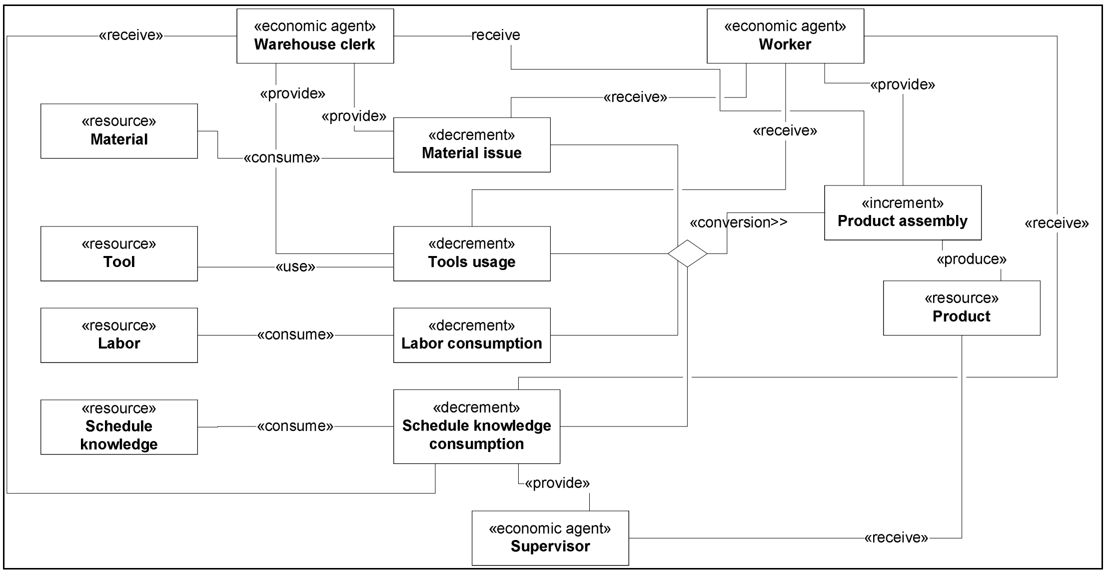

Figure 3.1: Simple production order - REA model
Source: own

Production state diagram

The production state diagram includes six states presented in Figure 6. At the initialization stage all necessary information of production order is sent to the warehouse clerk and to the worker. Using information embedded in the production order, the warehouse clerk supplies material and necessary tool to the worker. The production runs. After the production is finished, necessary information is passed to the supervisor and the order status changes to actualize. In case the order is not fulfilled in time, overdue information is sent to supervisor, the order status is actualized and either the production goes on or the production order is stopped and canceled. The finished production order is marked as finished after all necessary operations were accomplished. As shown in Figure 3.2, all necessary state diagram entities originated in the REA model.

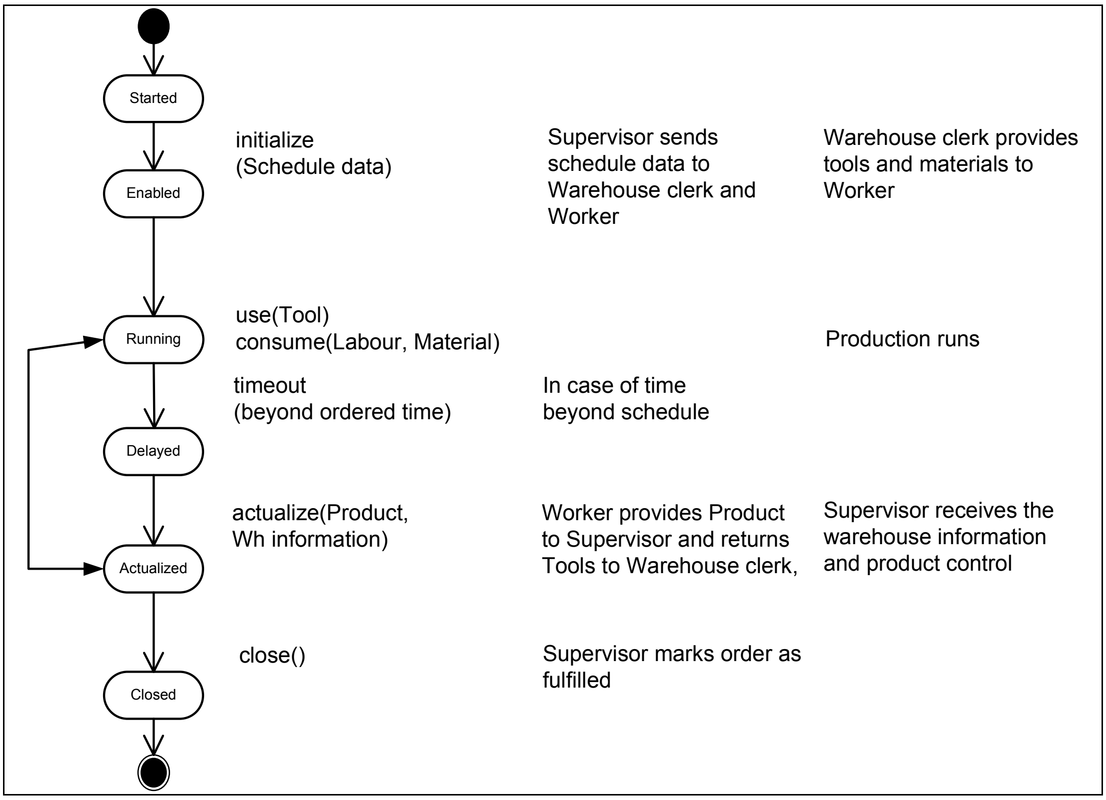

Figure 3.2: Production order state diagram
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Activity diagram

Activity diagram is used to show the REA entities and associations at operational level from the resources and activities point of view. The activities take part in conversion and exchange dualities. The significant activity diagram feature is that it defines the process participants (economic agents), starting and ending point of the process and the relation of individual resources to economic agents and events. To facilitate creation of activity diagrams from REA models there are several guidelines of mapping REA model concepts into activity diagram concepts. They follow:

a) each economic agent is mapped into a single partition (called swim line in UML jargon). This approach makes it clear who does what;

b) each economic event is transformed into a frame with its name in the heading of the frame;

c) each economic resource is transformed into activity diagram object and is placed either in a defined swim lane or on the swim lane boundary between two economic agents;

d) individual relation of the REA model is mapped into an activity within the frame; the relations between frames correspond to REA dualities;

e) standard UML stencil are used for joins and forks;

f) the activities must follow the basic REA succession “provides – resource – receives”.

The consequences of the rules are as follows:

a) the REA inherent but not direct visible economic event flow logic is visible in the activity diagram;

b) it is possible to start sequence diagram composition if necessary;

c) the swim lane principle orders the economic agents into transparent tabular form what makes the model more understandable;

d) activity diagram composition imposes REA model consistency check.

The resulting activity diagram is shown in Figure 3.3. As can be seen from this figure there are three partitions (swim lines) corresponding to three agents in the REA model (worker, warehouse clerk and supervisor). The resources are expressed at the borders of the swim lines. Economic events correspond to the frames in the figure. Proposed mapping between REA model and activity diagram enables consistency checking of the previous REA model. The entities of the REA diagram presented in Figure 3-1 are all represented by corresponding activity diagram entities. Hence, the dynamization of the REA diagram is possible.

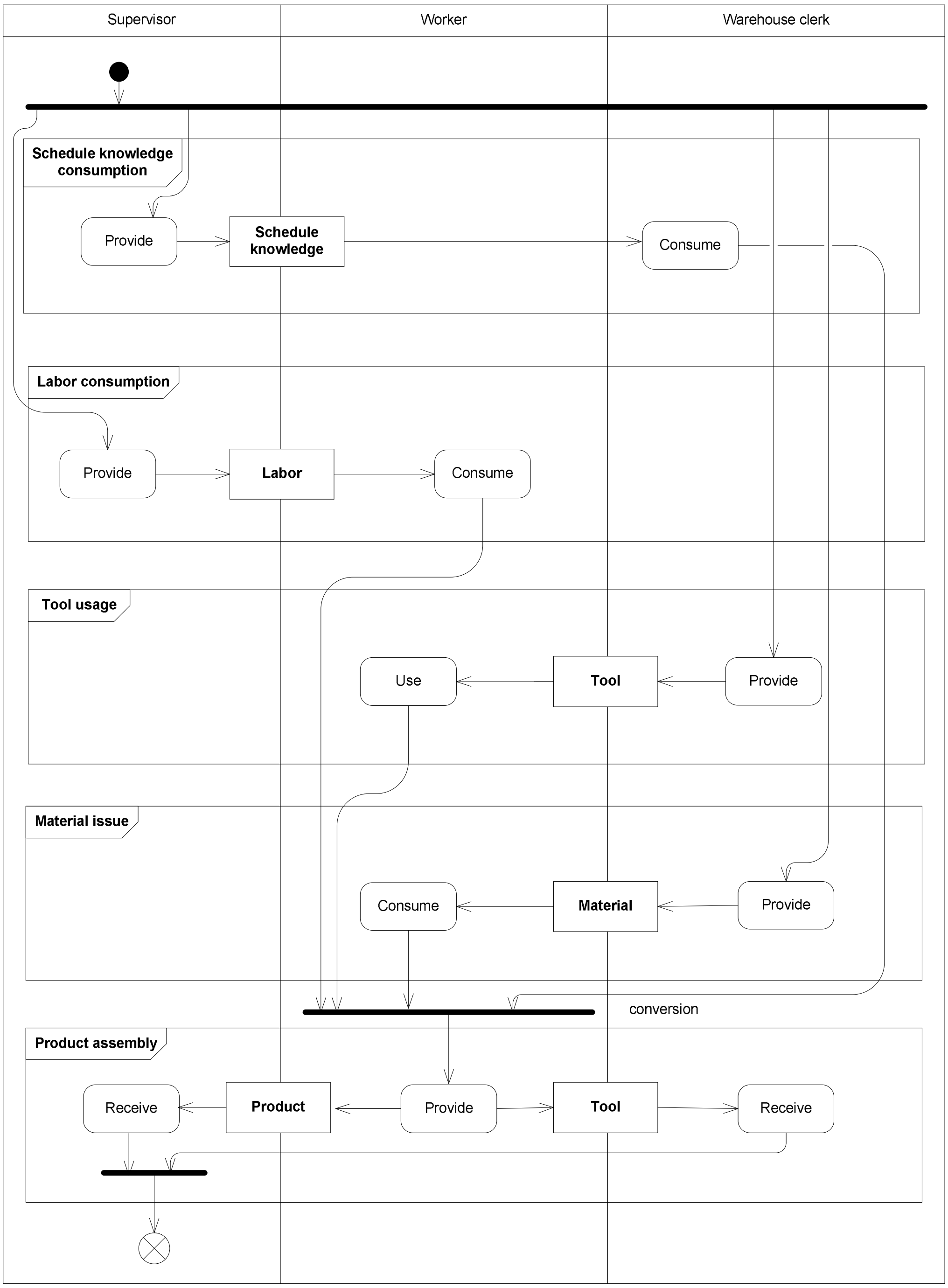

Figure3.3: Activity diagram of a simple production order
Source: own

Sequence diagram

Sequence diagrams are used to present sequence of activities and messages that invoke them. The sequence of activities is presented by a set of uncontinuous graphical objects recording activities of individual economic agents. The activities are placed in swim lanes of individual economic agents. The economic agents exchange messages registering operations with economic resources. The economic resources serve here as parameters of exchanged messages. In this sense the REA sequence diagrams fulfill principles of object oriented programming. The individual messages represent methods called by economic agents in order to accomplish activities at REA operational level. The sequence diagram composition is not necessary condition for REA dynamization; however it complements it and enables further consistency check of REA models. Figure 3.4 presents the sequence diagram of simple production order.

The operation "Supervisor activities" starts with two asynchronous messages sent to the worker and to the warehouse clerk. Both messages delivers information needed to start and run production. On message delivery the warehouse clerk gives out necessary material and tools to the worker, who starts production. On finishing the product the worker informs the supervisor and returns the tools to the warehouse clerk, who sends confirmation to the supervisor. Having received both messages the supervisor marks the production order as finished. All necessary messages in this diagram originate from the basic REA model. Thus the sequence diagram can be also inferred from the operational level REA model.

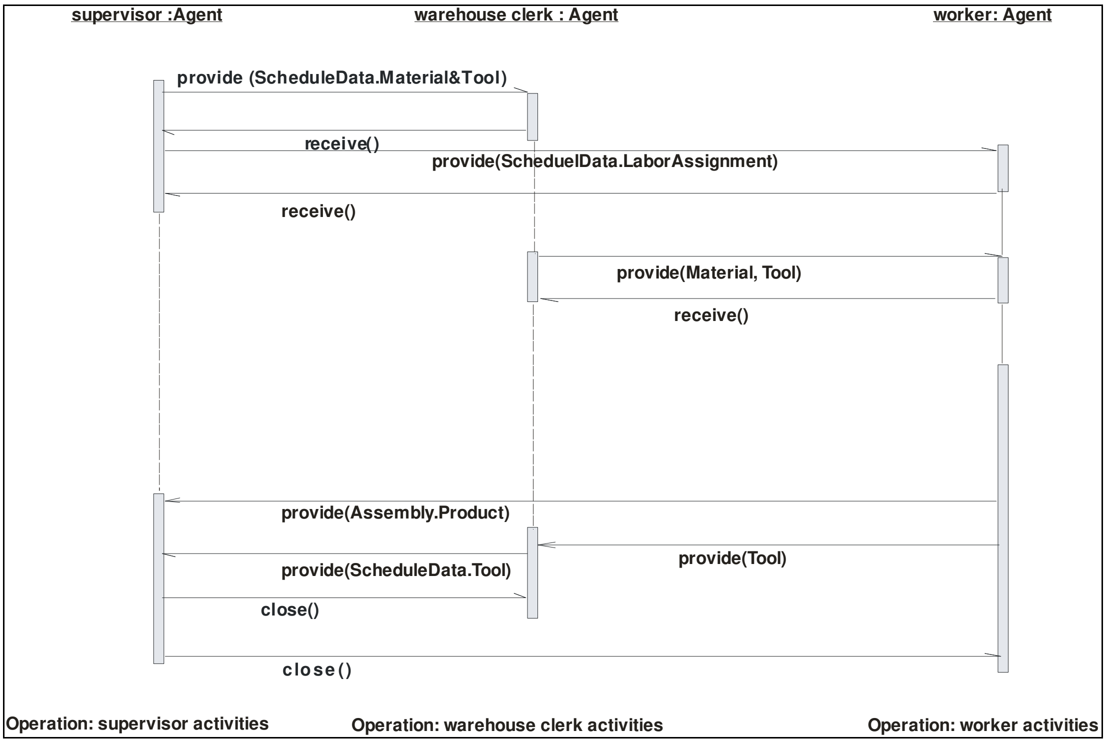

Figure 3.4: Sequence diagram of a simple production order
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Presented extended REA modeling is summed up by Figure 3.5.

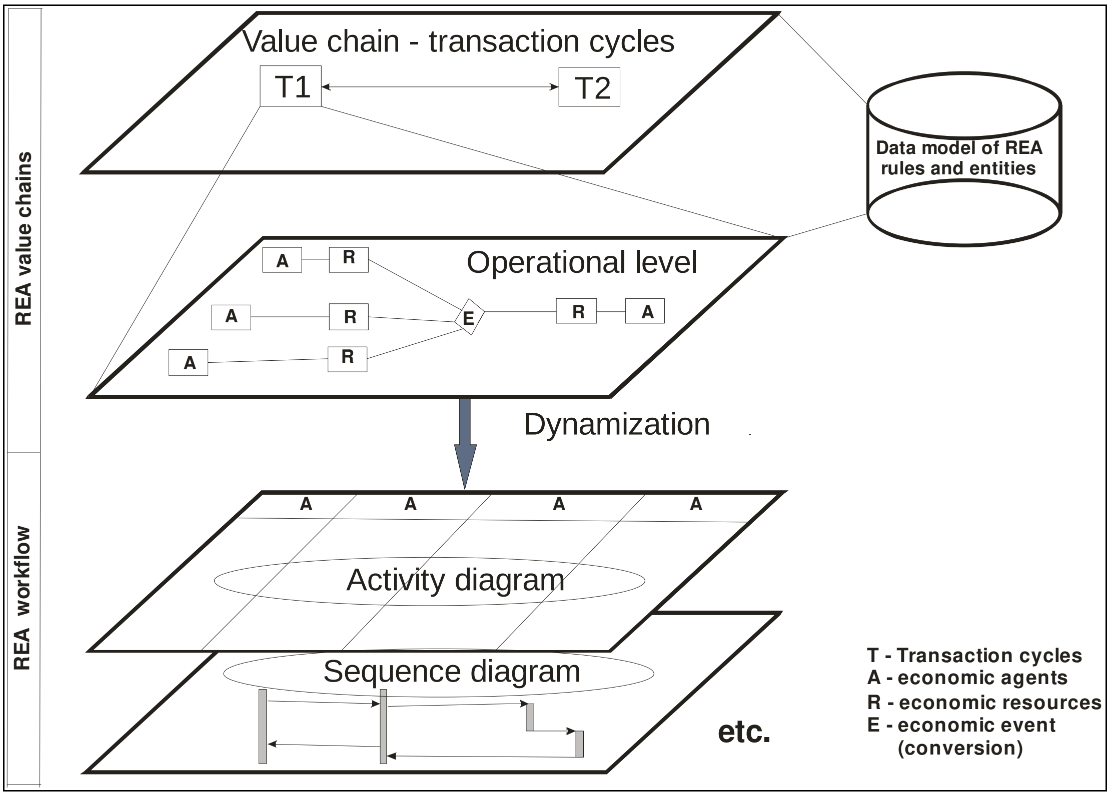

Figure 3.5: Extended REA modeling overview
Source: own

The individual transaction cycles are successively decomposed into REA operational and policy level entities following corresponding business patterns. These steps result in static REA diagrams consisting of REA entities and relations among them. Using dynamization the activities of economic agents taking part in economic events are defined and corresponding message flow is inferred. Resulting model constitutes a basis for transition to programming. The individual economic events do not depend on processes and organization structure of the enterprise, but on the value flows. In this sense the REA dynamization results in a process model that is consistent with value flows in the enterprise.

4. Closing discussion and conclusion

In this paper we presented closed up modeling method based on the REA framework. The original static REA modeling was extended by means of stepwise dynamization consisting of REA model transition to UML activity, state and sequence diagrams. During transition, all REA entities were used and consistency check of original REA model was accomplished. UML activity, state and sequence diagrams thus create the bottom level of the whole model. The crucial issue is a transition form the level of REA model into UML activity diagram. To facilitate the process and make it more transparent, unique mapping between both perspectives was designed and verified. Each agent is mapped into a single partition which is important because agents play decisive roles in those processes. Each event is transformed into a unique frame. The frames are named after events. So the simple checking of transition is that the number of frames has to comply to the number of events. Resources are illustrated in the border lines between two neighboring agents. The activity diagram also reflects relations between entities in the REA model. Finally, each activity diagram has its starting point and point of terminations that are also illustrated in the diagram. UML state and sequence diagrams utilize UML activity diagram for describing different views on the problem. Transition described in the paper shows potential for introducting the commitments into the activity diagram too what could lead to modeling of cycles. But this is a task for further research. Thus, it can be seen that business process modeling based on value chain is possible and advantages of value chains can be used. However, there are still questions open for further research. Firstly, no iterations or cycles were modeled. The production schedule normally consists of more production runs planned what leads to necessary modeling of cyclic operations. Secondly, we used a very simple model leaving other processes like planning, reservations, co-operations of more workers or machines beyond model scope. Thirdly, like majority of REA models, our model was created from the single company perspective which makes it difficult to use it to model networks of collaborating trading parties. These questions represent the next research challenges.

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