# PRODUCTION PLANNING MODEL USING REA ONTOLOGY



**Dominik Vymětal, Miroslav Hučka, František Huňka, Josef Kašík**

## 1. Introduction

Enterprise production planning and control models at operational and policy levels still use standard and in many ways rather awkward planning and accountancy tools. These models or at least their accountancy part are formed by traditional ways and means bringing adequate results. Despite of their success, traditional methods have their limits. The main problem they need to tackle with is an increasing complexity of the Enterprise Resource Planning (ERP). It is more and more difficult to process the relevant data for the enterprise management.

A demand for enterprise resource planning systems exists that would be designed from the scratch using information technologies. This would enable full traceability of all activities that influence the value of the enterprise's resources. Further current demand is to calculate the value of the enterprise's resources on demand, and not only at determined time intervals. On the other side production companies are permanently looking for efficient strategies in order to optimize their operations. During this permanent search many approaches are used. In the core of most activities aiming at business process optimization and reengineering many well known frameworks can be found. Looking at such frameworks two basic approaches can be seen in general:

- Process oriented approach.
- Value chain oriented approach.

The enterprises trying to optimize their operations use process modeling. Process modeling is based on following principles:

- The subjects of modeling are material or information processes in the company.
- The result of modeling is a functional model [15] consisting of:
  Process model of the existing system
  List of events
  Process model of proposed system
  Reality model
  Structure of enterprise organization

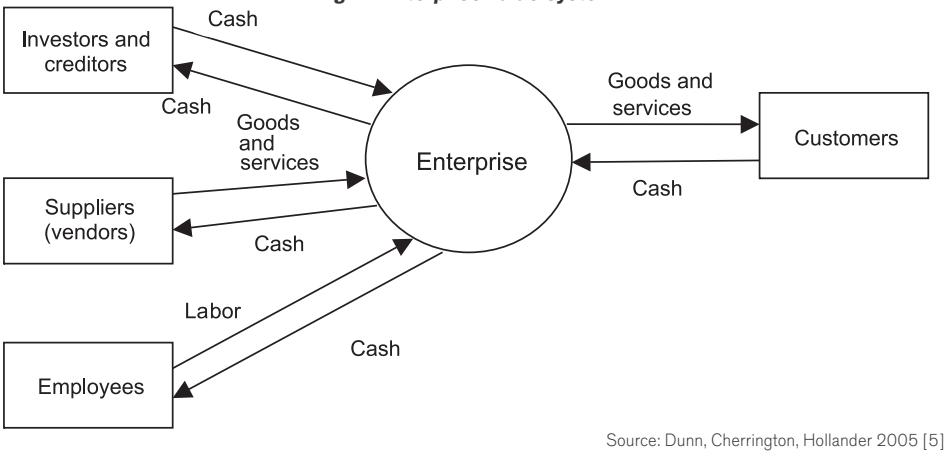
There are many methods and tools for process modeling like e.g. ARIS [2], IDEF0 [1].Process modeling methods are dealt with by several authors e.g. [4], [14] in the Czech Republic. Řepa [16] in his publication analyzed several methodologies including MMABP (Metodika Modelování a Analýzy Podnikových Procesů - Methodology of Enterprise Process Modeling and Analysis) developed at the University of Economics, Praha (VSE).

It is not always sure that by streamlining the enterprise processes the information flows can be optimized. Having the cross-functionality in mind, we should concentrate on common constructs depicting situations in most of enterprises and try to find common patterns. This paper is structured as follows. First we present a value chain oriented approach. Then we proceed to describe basic concepts and relations in the REA model. Afterwards the model of production planning at operational level is introduced. The paper concludes with discussion on the problem and offers some suggestions for further research. Two words for basically the same entities are used throughout the paper. Using the word enterprise we underline its common attributes and events while by the word company we mean a certain kind of instantiation.

## 2. Value Chain Oriented Approach

The alternative to process oriented approach is orientation towards value - flow patterns in the enterprise. In this paper we will concentrate on a framework based on value - flow. What do we understand under value- flow? In Fig. 1 a general enterprise value system is presented. The enterprise is producing goods and services to customers and receives cash in the value of the goods and services delivered. Working capital (cash)

***Fig. 1: Enterprise value system***



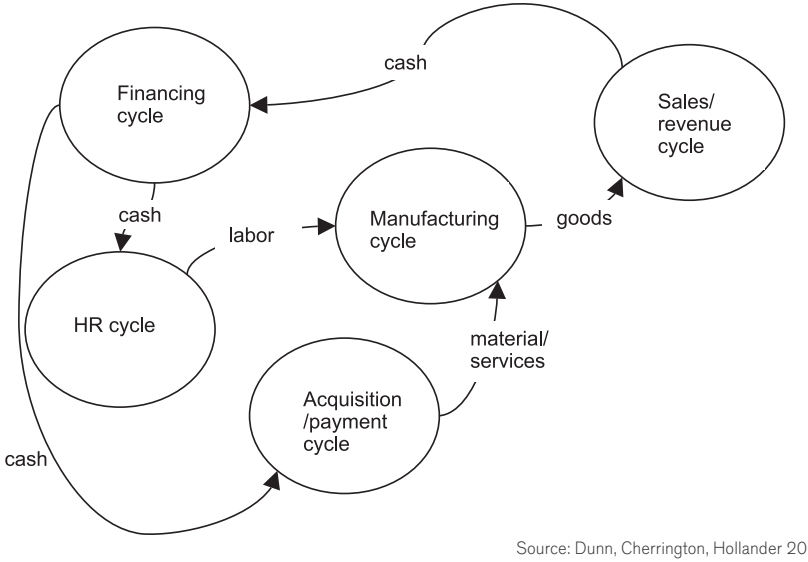

Source: Dunn, Cherrington, Hollander 2005 [5]

coming from the investors or creditors, goods and services from the vendors and labor, both purchased from the suppliers and employees are needed for this process.

This general value system can be expanded into more specific value chain shown in Fig.2. The company is producing goods during conversion (manufacturing) process. Resources like raw materials, tools, third party services etc. are needed to accomplish the conversion. They are obtained and paid for during the acquisition/payment process. In the manufacturing also human resources are needed to produce and supervise the process. Labor is procured and paid for in the human resources and payroll processes. The payments are effected by finance process. The money for the payments is collected from revenue (sales) process. The production planning we are aiming at is obviously a part of the conversion process.

Continuing the expansion into the process level we do not obtain processes from the workflow but from the value point of view. Following this

***Fig. 2: Generalized value chain model of a company***




Source: Dunn, Cherrington, Hollander 2005 [5]

way we can define several basic transaction cycles. These transaction cycles can be generally presented in a form of business patterns, bearing enterprise value system and value chain in mind. The business patterns can be used for knowledge and functionality sharing similar to the well known services oriented architecture of information systems. On the last (lowest) decomposition level the tasks actually performing the transactions can be identified. Here we are again close to the process approach. Nevertheless, a 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.

The approach described hereinabove forms the basis of the Resource - Events - Agents methodology of the information systems design. The model is named REA where R stands for Ressources, E for Events and A for Agents. The basic REA ontology was published by Bill McCarthy in the year 1982 [13] as a general model for accounting system. Ressources, Events and Agents are the basic constructs of this ontology, which was later further developed by many authors e.g. [3], [5], [11]. The original authors of REA ontology define it as a domain ontology for business enterprises [6], [7] and assert that it generally corresponds Gruber [9], [10] ontology definitions as „a specification of a conceptualization" for enterprise business processes domain. We will use this approach for a specific domain, namely for planning and production based on sales orders. It should be stated that there is still no mathematical formalism supporting REA even though some attempts emerged lately.

## 3. The REA Model

Pregnant definition of the REA model was done by Geerts and McCarthy [8]:

„In essence, the REA model is a pattern for the semantic definition of business processes. Phenomena captured by the REA model include the economic activities that take place in a company, the resources that are acquired and consumed, and the agents who are accountable for economic activities."

The REA ontology is based on four levels of abstraction:

- Value System model (see Fig. 1).
- Value chain level model which focuses on the resource flows between processes. The basic process types used on this level are finance, acquisition/payment, conversion (manufacturing), sales/collection and human resources process (see Fig.2.).
- Business process level model handling the transaction cycles running in all process types mentioned above.
- The task level as the most detailed one. The tasks can be perceived as individual steps needed to realize the events within the business processes. The task level modeling is aimed to represent the data flow in the enterprise.

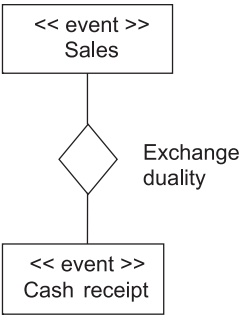
As we are handling business process level modeling, we should mention following fundamental entities used in the REA methodology:

- **Economic resource** with the following examples: products, services, labor, money (cash) etc.
- **Economic event** representing increment or decrement of resources value under company control such as production run, product sale, cash disbursement etc.
- **Economic agent** as an individual, organizational unit or company controlling its resources and capable of transferring the resource value to another agent. (Company is an economic agent. From its point of view the REA model is constructed).

Using the REA methodology leads to business processes organization into repetitive value transaction cycles. In case of production planning two important cycles can be defined: the **revenue** cycle and the **production (manufacturing)** cycle. Other cycles to be looked into, are namely the purchase, human resources and finance cycles. Looking at the cycles on the highest conceptual level we can see a pair of basic transaction entities related to each other by certain duality relationship.

Fig. 3. shows the generalized view of the revenue cycle. Each sales **event** is related to a certain cash receipt event. Each event is performed or controlled (supervised) by a certain **agent**. Agents use **resources** to accomplish events. The basic statement regarding REA ontology method says that economic agents give up some resources (values) during the **decrement** economic events in order to increase their other resources (values) during **increment** economic event. The revenue cycle is in more detail depicted by Fig.4.

***Fig.3: Generalized revenue cycle***

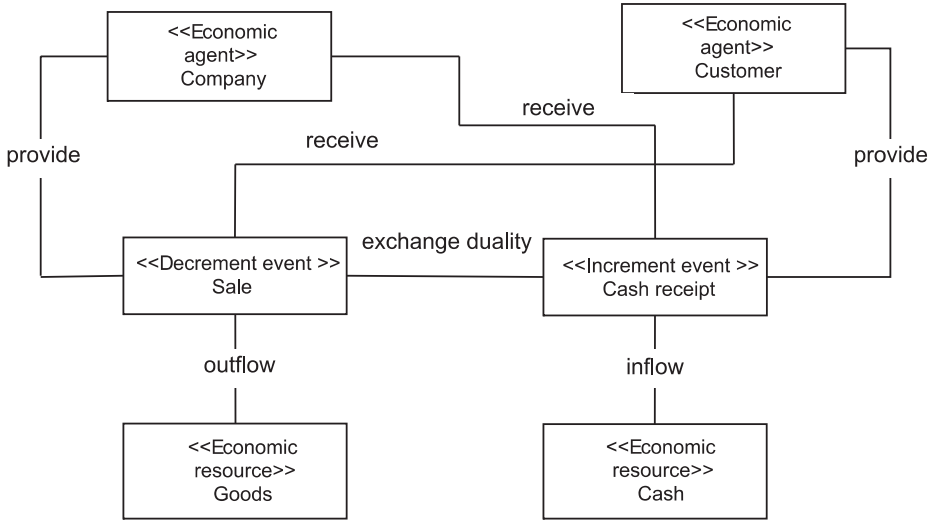



Source: Adapted from Chang and Ingram 2007 [3]

The agent ***company provides goods*** (resource) to agent ***customer***. Due to sale the value of resource goods on the ***company*** side decreases (decrement event - **outflow**). The agent ***customer receives goods*** (resource) and ***provides cash*** (resource) to the ***company*** (increment event - **inflow**). The relation between sale decrement event and cash receipt is called **exchange duality**. The selling party gave up the goods sold value but gets the cash value from the customer increasing its resources value. In this sense an exchange duality exists between increment and decrement economic events sale and cash disbursement. Using these basic assumptions, production processes independent of organizational structures of various companies can be modeled using REA conversion process.

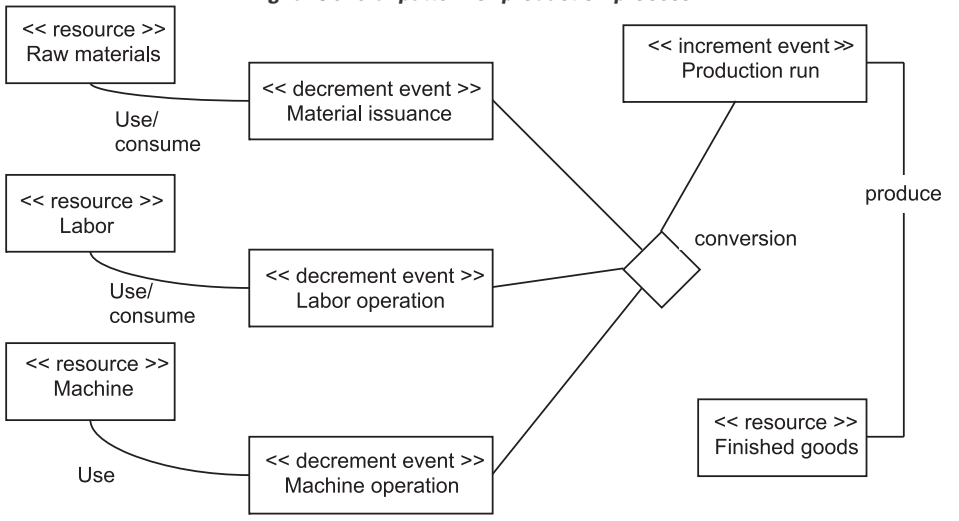
The production in the REA model is based on semantic components of REA **conversion process**. The purpose of the REA conversion process is to create new economic resources by using or consuming other economic resources. The most general pattern of the conversion (manufacturing) process is presented in Fig. 5.The resources Raw materials, Labor, Machine, (and e.g. Tools etc.) are used (consumed) by decrement events Material issuance, Labor operation and Machine operation. The decrement events are related to increment event Production run increasing the value of Finished goods resource. Finished goods inventory is created during Production run event which is incrementing value of finished product resource. During conversion labor operation, machine operation, tools usage and material consumption are performed in **conversion** relation diminishing thus resource value of labor, material, tools and machines. Following the general pattern of production process the Production run can be planned. There is obvious necessity to plan materials, labor and tools consumption as well as the machine operation. The planning can be generally based on the resource reservations. However, reservation does not pro-

***Fig.4: Customer receives goods and pays cash***




Source: adopted from Hruby [11]

***Fig. 5: General pattern of production process***

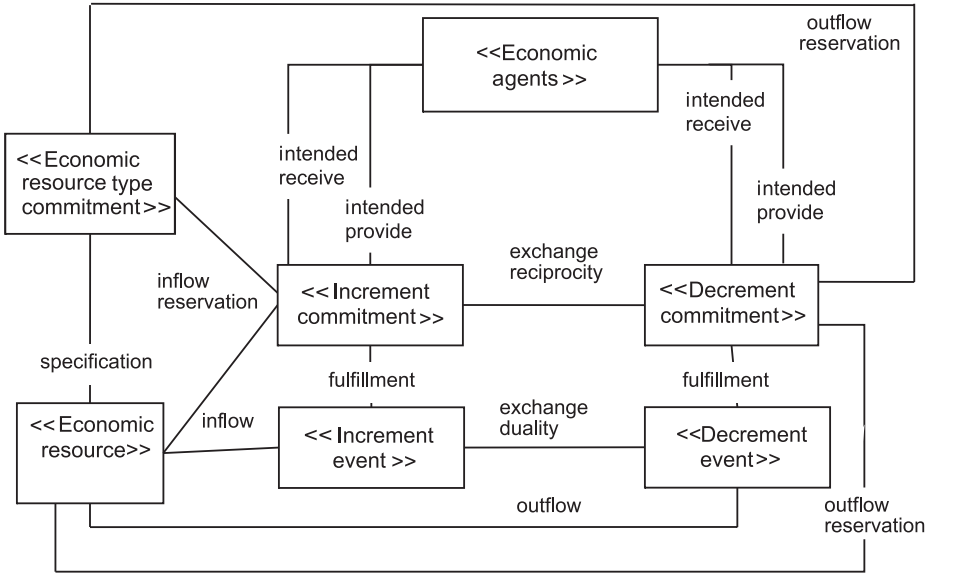



Source: own

duce any flow of values. In order to include planning oriented entities and relationships the REA ontology on the process level was enhanced. Analyses of business patterns reveal that companies commit themselves to economic events before they really start the actions. Typically, in a sales cycle one party commits itself to deliver goods or services while the other party commits itself to pay for the deliveries.

The extended REA ontology (see e.g. [5, 11]) proposes to add a **commitment event** into the set of REA entities. A commitment event prece-

***Fig. 6: Extended REA model***




Source: Hruby [11]

des the economic event. Every commitment event that would lead to decrease of the resource on one side is related to opposite commitment event that would cause an increase of another resource. The relation between commitment events is called **reciprocity**. As the commitment does not realize any resource increments or decrements, but only promises to do it in the following economic events, the relation between commitment and resource is achieved by **reservation**. The relation between commitment and economic event is called **fulfillment**, while the relation between committing parties (agents) in the REA ontology is called **participation**. It was thus necessary to add following REA entities:

- **Economic commitment** as a promise of agents to realize economic event in future.
- **Contract** defined as a set of increment and decrement commitments and terms.

Using these basic concepts a general conceptual REA model on the process level can be presented (see Fig.6).

## 4. Production Planning

In the REA ontology a greater attention is devoted to the REA exchange processes than to REA conversion processes. In this section we would like to describe simple example of production planning at operational level using REA concepts mentioned hereinabove. The scope of this paper does not allow to go into detailed description and to discuss all open questions. Our aim is to show the overall picture and possibilities of relations (connections) between **economic events** describing the real value flows and **economic commitments** mirroring the contract and planning part of the model. A production plan in a company is made up based on the customer's orders. Single **Production order** as a commitment can be connected to single customer order. Production order mirrors economic event **Production run**. **Production run** is related to **Production order** by **fulfillment** relation. During production the planning resources such as labor, materials, tools and machine operation time must be planned. This is accomplished by **reservation** relation. During the planning stage not single instances of resources but resource types are planned. On the production order level the resources are related to the production order commitment by decrement commitments Labor requisition, Material requisition, Tool requisition and Machine time (Workplace) requisition. The increment commitment **Production order** relates to decrement requisition commitments by conversion reciprocity. On the production order level the increment economic event **Production run** is related to the decrement consumption and usage economic events by conversion duality. In this sense, fulfillment relation between planning and production running level in the REA approach is achieved. The situation is presented in Fig.7. We simplified the production run part because of space and showed the relations among reserved resource types and consumed resources of Labor and Material during planning and production stage.

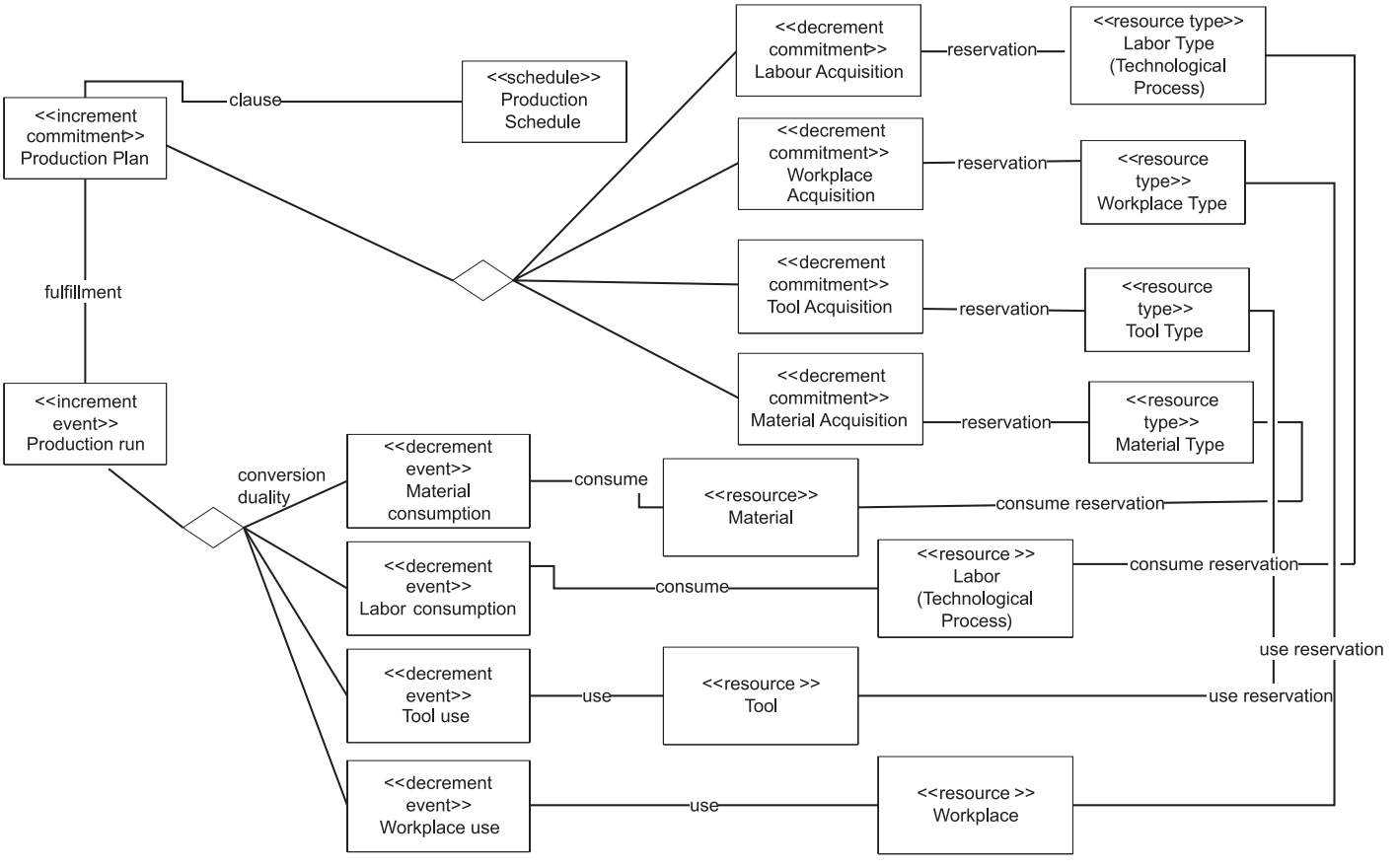
## 5. Discussion

During our research of REA possibilities in the specific domain of production planning some open issues were analyzed. One of two abstraction levels in REA ontology is the operational level, depicting what is currently occurring or what has occurred in the past.

An open question was found on the operational level, namely: „Could resource be concurrently schedule according to the REA ontology?" The production plan is a **resource** or **resource type** in the REA model because it was created by the planner - **Initiator** for the production manager - **Terminator**. At the same time the production plan is used as a **schedule** in this way for managing when events occur in the conversion process. In this context, the production plan (resource) contains **commitments**. This entity seems to be a controversial one as it may be viewed as a **resource** and as a **schedule** too. This construction is not allowed in the REA ontology. An answer to this question was proposed in [12].

Contract - Commitment enhancement of the REA ontology enables a conceptual modeling of sales - production processes on the business process level using semantic definition of business processes and value flows. The simplest relation of the type „one sales order - one production run" can be modeled without any problems. Situations when 1:1 relation cardinality does not exist are more complicated ones. If the cardinality of the sales - production run relation is *:1 (using UML notation), more constructs and ideas are to be used. Such cases require an extension to the

***Fig.7: REA relations between Production run and Production order***




Source: own

REA enterprise model with a **policy infrastructure** that describes what should, could, or must be occurring sometime in the future, concepts of typification and grouping used for description of resource and agent types, bill of materials etc. Geerts and McCarthy proposed such concepts in [8] as a part of policy infrastructure.

Analysis of the present policy infrastructure from the production planning point of view shows that existing relation definitions of Bill of Material need further development. In our point of view, production scheduling and planning needs more precise structuring what can lead to further REA extensions.

Further challenge for future research is the needed possibility to define the REA constructs supporting production schedule, plan of final products and corresponding relations to be able to formulate the REA concepts concerning production planning and runs in lots and batches.

## 6. Conclusion

In this paper there are two main goals. The first one is to introduce a value oriented perspective into business process modeling. In particular we focused on the REA modeling framework. The other one is to demonstrate the utilization of the value oriented framework on particular domain of production planning modeling at operational level. The REA modeling framework proved to have several benefits (advancements) worth mentioning. The whole framework is built on a few more general concepts that are easily comprehensible also to the employees of the modeled domain. The value chain model, specified in the REA modeling framework, can be used as a catalogue of common business processes. Users themselves, without intervention of a consultant or developer, are able to customize their business processes using the interactive modeling environment, and support distributed business processes. The applications will be able to integrate with company-wide or cross-company business processes by means of the REA business ontology. The other advantage of the framework is that it provides basic answers to the basic questions e.g. why does the enterprise carry out a given activity in a certain way? This feature of the framework can be helpful in the modeling process as it may act as a process modeling guide. This is one of the answers to the question, why REA should be used. It is tailored to information technology tools especially for model-driven design. On the other side, as there is still no formalism supporting REA this framework does not suggest any technology of implementation. Therefore its benefits strongly depend on, who is trying to solve some problem: an analyst, a programmer or some consultant. The greatest benefit we see in the fact that the REA framework helps to model company processes from the long term point of view avoiding thus organizational changes impacts leading necessarily to information system changes.

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**Ing. Dominik Vymětal, DrSc.**
Slezská univerzita v Opavě
Obchodně podnikatelská fakulta v Karviné
Katedra Informatiky
vymetal@opf.slu.cz

**prof. Ing. Miroslav Hučka, CSc.**
Vysoká škola báňská - Technická univerzita Ostrava
Ekonomická fakulta
Katedra podnikohospodářská
miroslav.hucka@vsb.cz

**doc. Ing. František Huňka, CSc.**
Ostravská univerzita v Ostravě
Přírodovědecká fakulta
Katedra informatiky a počítačů
frantisek.hunka@osu.cz

**Ing. Josef Kašík**
Vysoká škola báňská - Technická univerzita Ostrava
Ekonomická fakulta
Katedra podnikohospodářská
josef.kasik@vsb.cz

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***ABSTRACT***

***PRODUCTION PLANNING MODEL USING REA ONTOLOGY***

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*The paper focuses on the enterprise production plan at operational level modeling using the Resource-Event-Agent (REA) modeling framework. The REA modeling framework belongs to value oriented perspective modeling tools rather than to process oriented perspective modeling tools. Its prevailing application area has been accountancy domain. The aim of the paper is to utilize this framework also to other standard domains. Enterprise production planning at operational level is an important part of business process modeling. The paper gradually utilizes value chain oriented approach to the issue. The results are illustrated on the included figures. Then the basic concepts and relationships of the REA modeling framework are described and illustrated. The REA modeling framework distinguishes between two elementary processes. They are the exchange process, mostly used in the areas of sales and purchases and the conversion process meaning creation of some new materials or goods. The most important part of the paper is a creation of simple enterprise production planning model. The production planning model is based on the resource reservations. That is why the extended REA ontology had to be introduced with commitments and reservations. In the conclusion the main advantages of the REA model approach are emphasized.*

***Key Words:*** *REA ontology, Production planning, Process modeling, Value chains, Business semantics*

***JEL Classification:*** *L15, L23, M11, O21.*