THE EPC II THEORY. REVIEW OF BASIC CONCEPTS, OBTAINED RESULTS AND PROBLEMS TO DISCUSS

Mirosław Zaborowski
Academy of Business in Dąbrowa Górnicza, Department of IT, Poland

Corresponding author:
Mirosław Zaborowski
Academy of Business in Dąbrowa Górnicza
Cieplaka 1C, 41-300 Dąbrowa Górnicza, Poland
phone: +048 32 2622805
e-mail: m.zaborowski@neostrada.pl

Received: 10 August 2011
Accepted: 24 September 2011

Abstract
In the paper the basic concepts of the theory of Enterprise Process Control (EPC II), as well as its most important results and directions of future work, have been discussed. It has been shown that in the synthetic picture of EPC II data structure every structural attribute of information elements may be assigned to one of the three general dimensions: knowledge on kinds of processes and resources, enterprise organization and labels of executions of definite business processes. Differences in concepts of business processes, resources and organizational units between the EPC II theory and the current standards have been pointed out. It has been demonstrated that the framework functional structure of integrated management systems is the same for every organizational level. The notions of business transactions have been introduced and then relationships between functional activities and business transactions have been described. Next, the relationships of bookkeeping accounts, entries and transactions with corresponding notions of the EPC II theory have been discussed. It has been shown how the EPC II theory may be applied to solving certain difficult problems of business process control, including the problem of building a universal framework system of management and process control and the problem of automatic adaptation of management systems software to structural changes of business processes.

Keywords
integrated management systems, reference models, relational databases, EPC II theory.

Methodology and current problems of the EPC II theory

The EPC II theory [1–5] is the system of notions concerning information flow in enterprise management and process control systems. The results of analysis of mutual relationships between its facts are presented in the form of sets of objects corresponding to the concepts and relationships between them. The relationships have been defined as subsets of Cartesian products of the UML language [6]. The structures of business processes and organizational systems are also presented in the form of UML activity diagrams [7]. Moreover, these sets of objects and relationships between them may be presented as the tables of the relational database of the framework EPC II system [5].

Basic notions of the EPC II theory have been already described in the previous publications. Other more and more detailed notions, will be introduced in successive publications, dedicated to various aspects of EPC II systems functioning. The first of them, namely the business transactions, including accounting transactions, are presented hereunder, but at first certain new comments are given on the already known notions of functional subsystems.

The new structures of integrated systems of management and process control, which are suggested by the EPC II theory, enable relatively simple solutions of many difficult practical problems. The most important of them concern:

• design of the universal framework system of management and process control for enterprises of different trade and size,
• automatic adaptation of management systems software to structural changes of business processes, i.e. the problem of “business-IT divide”;
• interaction between production, preparatory and administrative processes,
• business process reengineering and virtual organizational systems,
• synchronization of transactions,
• control of continuous and discrete elementary processes in the framework of integrated EPC II systems,
• universal structure of recording parameters of EPC II systems, including various parameters of activities and resources.

All these problems are shortly discussed below. The solutions for the first two of them have been already presented in previous publications [1–5].

Organizational systems

Functional subsystems

In the EPC II theory the enterprise is perceived as the set of nested, one in another, less and less functional subsystems [1]. A functional subsystem is an organizational unit designed for control of its internal processes with a definite degree of specifications. So it belongs to a definite functional layer. Strictly speaking:

• an organizational system (j = 3) is designed for coordination of working (or elementary) activities of its processes,
• a working subsystem (j = 2) – for allocation of its working activities to its organizational units, perceived in lower layers as reengineering, organizational and executive subsystems,
• a reengineering subsystem (j = 1) – for designing processes within its executive subsystem,
• a substitute administrative subsystem (j =0 ) – for data transfer to administrative workflow processes,
• an organizational subsystem (j = 4) – for scheduling its executive activities,
• an executive subsystem (j = 3), which is an organizational system of the lower level – for coordination of activities of its processes.

Each functional subsystem has its own functional unit, which receives decisions from higher layers of the system and send reports on their execution to them. Each functional unit is a control unit for functional subsystems, which are nested in a given functional subsystem. Therefore functional layers are most often presented as layers of the management system (Figs. 1–3). Working (j = 2), reengineering (j = 1), substitute (j = 0), organizational (j = 4) and executive (j = 3) subsystems correspond to layers of allocation (j = 2), reengineering (j = 1), administrative data transfer (j = 0), executive order scheduling (j = 4) and coordination (j = 3). Such a framework structure is the same on each organizational level, except for the highest and the lowest ones. This observation is an important result of the EPC II theory. However the real functional structures may be flatter, so simpler, because control functions, typical for several different layers, may be aggregated in single control units belonging to the highest of these layers.

Transitions from a given layer “j” belong either to the information data processing phase “j” or to the decision phase, whose number is equal to (9 – j). At a given instant of the discrete time the order of data processing phases (j = 0, 1, 2, 3) is in accordance with their numbering. There are as many groups of layers with the same time scale as organizational levels, but the time scale “h” of a given level applies also to the executive order scheduling of the higher level. Counting from the top, successive layers of a given level “h” are identified by pairs (h, 3), (h, 2), (h, 1), (h, 0) and (h–1, 4).

In a typical case an EPC II system has five organizational levels:

- h = 5 global economic system (Fig. 1),
- h = 4 enterprise supply chain (Figs. 1, 2),
- h = 3 sites of an enterprise (Fig. 3),
- h = 2 sections of departments (Fig. 3),
- h = 1 workstations, i.e. elementary organizational systems.

Names “enterprise supply chain”, “site of an enterprise” and “section of a department” replace names: “primary organizational system”, “production plant” and “organizational cell”, which were used in [1].

In the global system only supervisory (reengineering (j = 1), administrative (j = 0) and executive (j = 4)) control units (Fig. 1) are taken into account, because in the market economy there are no central coordination of enterprises. Cooperation of enterprises in the scope of the common supply chain is described as horizontal couplings between management of supplies to the enterprise or to its sites and management of sales and production in supplier enterprises or sites (Figs. 1, 2). In elementary organizational systems (h=1) there are no working, reengineering, administrative, organizational and executive subsystems. Instead of them there are direct control systems (j = 2) and basic control objects (j = 1) or elementary subsystems of data processing (j = 2). The reengineering and administrative layers, which were introduced in [1], will be discussed in detail in future papers. So they are neglected in Figs. 1–3.
A working subsystem (an enterprise (Fig. 2), a department (Fig. 3), a work center (Fig. 3)) may consist of many organizational subsystems (sites (Fig. 2), sections (Fig. 3), workstations (Fig. 3)), whereas each organizational subsystem contains exactly one executive subsystem (Figs. 2, 3) and is a single subsystem in the corresponding reengineering subsystem (which is invisible in Figs. 2, 3). Therefore corresponding subsystems: the reengineering one \((s, 1)\), the organizational one \((s, 4)\) and the executive one \((s, 3)\), may be considered as representations of the same organizational unit “\(s\)” in different functional layers. Moreover, the same organizational unit is the organizational system \((s, 3)\) on the lower organizational level. What is more, if the working subsystem \((s, 2)\) contains only one executive subsystem, then it also corresponds to the same organizational unit “\(s\)”.

The enterprise supply chain

Management of supplies to a given enterprise (or to the site) belongs organizationally to this enterprise (site), but logistically belongs to the suppliers, because decisions, which are taken here, concern processes running outside the enterprise. Therefore executive supply management (Fig. 2) does not influence any objects within the organizational system of its own site (Fig. 3). From the viewpoint of the EPC II theory the purchase orders are orders of producing located resources by the suppliers sites to definite reception points in front of the sites of the enterprise. So they belong to the orders of producing located resources by functional subsystems \((s, j, m, r, n) \in \text{YRSJN}\) (item 156 in the list of the main information kinds [4]). The purpose of procurement management is keeping balance between requirements of the enterprise working system and its own decisions (i.e. orders) concerning supplies to this system. However one should remember that sending a purchase
order does not guarantee its execution. Supply in-
flow to the enterprise is effectively managed with the
sales orders in the supplier sites. The sales orders
also belong to the orders of producing located re-
sources by functional subsystems. Adapting them to
the customer orders, which have been accepted by a
given site, is one of purposes of executive sales man-
agement of this site. In real ERP systems the sales
orders are not copies of the customer orders, because
in the course of preparing them one has to take into
account constraints resulting from the MPS (Master
Production Schedule) and recorded in the file ATP
(Available-To-Promise) [8].
In practice a given purchase order (or a cus-
tomer order) \((s, j, m, r, n) \in YRSJN\) is not called
“order”, but “order item” (in the jargon – “order
line”), whereas the name “order” refers to the docu-
ment \((s, 3, w, n) \in YSJN\) (Table 1), which is sent to a
definite supplier “s” and whose specification contains
orders for individual products “r” that the supplier
should deliver to reception points “m”. The infor-
mation place “w” represents the document type. For
instance it may be used to distinguish purchase or-
ders and customer orders. In the case of a customer
order the number “s” refers to the site of a given
enterprise and the customer number is a non-key at-
tribute of this order. If the collective order \((s, j, w, n)\)
contains different orders of producing the same locat-
ed resource \((m, r)\), then one can distinguish them re-
placing the place number “m” with numbers “mc” of
“analytic” places, whose relationships \((mc, m)\) with
the delivery place “m” are recorded in the table WM
(item 51 in the list of the main information kinds [4]).
It is an example of the often used structure of rela-
tionships between aggregated and detailed informa-
tion, which is similar to relationships between syn-
thetic and analytic bookkeeping accounts. The tables
YSJN and the analogous tables USJN, USJT, YSJT
are new main information kinds. The tables SJN,
SJT, that are introduced previously to their list [4],
refer at present only to plans and orders of burdening
functional subsystems. It is an example of correction
of this list that results from analysis of data struc-
tures occurring in practice.
Fig. 3. Site and section organizational systems.
Table 1

<table>
<thead>
<tr>
<th>i</th>
<th>name</th>
<th>s</th>
<th>j</th>
<th>w</th>
<th>t</th>
<th>n</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>121</td>
<td>USJT</td>
<td>s</td>
<td>j</td>
<td>m</td>
<td>t</td>
<td></td>
<td>collective plans of picking or burdening located resources by functional subsystems</td>
</tr>
<tr>
<td>122</td>
<td>YSJN</td>
<td>s</td>
<td>j</td>
<td>m</td>
<td>t</td>
<td></td>
<td>collective plans of producing or returning located resources by functional subsystems</td>
</tr>
<tr>
<td>151</td>
<td>USJN</td>
<td>s</td>
<td>j</td>
<td>m</td>
<td>t</td>
<td>n</td>
<td>collective orders of picking or burdening located resources by functional subsystems</td>
</tr>
<tr>
<td>152</td>
<td>YSJN</td>
<td>s</td>
<td>j</td>
<td>m</td>
<td>t</td>
<td>n</td>
<td>collective orders of producing or returning located resources by functional subsystems</td>
</tr>
</tbody>
</table>

Quite often customer orders determine not only quantities of ordered products, but also options of their optional features (e.g., the engine power and the color of cars in a car factory). In such cases the organizational system of the site is divided into the sector of Make-To-Stock Production (MTS) and the sector of Sales and Make-To-Order Production (MTO) (Fig. 3), separated by the so-called Customer Order Decoupling Point (CODP) [9]. If both sectors exist in the site, then we talk on ATO (Assembly-To-Order) type of production. If there is only one of them, then we talk on production of the type MTS or MTO.

The following modules of ERP systems:

- SOP (Sales and Operations Planning),
- MPS (Master Production Scheduling) and
- MRP (Material Requirements Planning) [8]

belong correspondingly (Figs. 2, 3), to:

- coordinating management in the enterprise supply chain and to allocating management of sales and production in the enterprise,
- executive scheduling orders for the MTS sector of the site,
- coordinating management in the MTS sector of the site.

Obviously, if the enterprise consists of only one site, then the problem of allocation of enterprise tasks to its different sites does not exist. In the case of ATO- or MTO-production the ATP constraints resulting from the MPS are not compared directly with customer orders, but with requirements of the MTO sector, which are calculated on the grounds of these orders. On the other hand, the future MPS orders, which are tentatively calculated as the spread in time plans, which derive from the SOP module, are corrected on the basis of those future customer orders, which are already known.

Internal organization of the site

In the EPC II theory the meaning of concepts of “department” and “workstations” (Fig. 3) is in accordance with common interpretation. Departments are organizational units, in which subprocesses of site business processes are running. Workstations are elementary organizational systems. The concept of “work centers” is variously defined, but the well known definitions do not describe distinctly their internal structure. In the EPC II theory it is assumed that it is a set of parallel working workstations (Fig. 3). It is in accordance with examples of calculating the capacities of work centers that are placed in the manual of the MRP II standard [8]. The set of workstations organized around machines operated by robots may be an example of a work center. In the case of service processes one can point out the set of cash desks in a self-service shop as an example of a work center.

The “department section” is such a subset of the set of work centers belonging to a given department, in which definite processes of the department may be performed in its entirety (Fig. 3). As examples we can point out assembly lines in the assembly department of a car factory, distillation plants in the crude oil distillation department of an oil refinery or blast furnaces in the blast-furnace department of an ironworks. They are also examples of organizational units performing discrete, continuous and batch manufacturing processes. The problem of distribution of a department burden among its sections is analogous to the problem of a work center burden distribution among workstations of this work center.

The structures of organizational systems presented in Figs. 1–3 correspond to the structures of business processes, whose examples were presented in [3]. In both cases one can see the functional layers of coordinating, allocating and executive management. The analogy would be full, if in Figs. 1–3 one could see places of information on located resources, existing between functional subsystems, as well as places of information on activities performed in individual functional subsystems. They are visible, as places MRK, MRL, MRH and MK, ML, MH, in the exemplary diagram of an organizational system structure [1].

Business transactions

Transitions and transactions

All database transactions \((s,j,a,k,t)\)\(\in TR\) \(\cap T\) are executions of transitions \((s,j,a,k)\)\(\in TR\). The database transaction corresponding to a giv-
en transition may be executed in a given sampling period \((h(s, j), t)\) no more than once [4]. Periodic business transactions \((s, j, a, k, t) \in TRBT \subset TRT\) (in short: periodic transactions) of reading, processing and recording plans or reports concerning executions of functional activities are indexed like all database transactions, because in each planning period they are executed exactly once. Business transactions, which refer to various orders of executing activities and to reports corresponding to them, occur at initial or final instants of order executions. No transition belonging to a given activity functional unit may be executed at both initial and final instants of a given execution of this activity. Therefore numbered business transactions \((s, j, a, k, n) \in TRN \subset TR \times N\) (in short: business transactions) are indexed with the identifiers of the transitions and with the numbers of the activity executions, which the transactions refer to.

The list of the main kinds of information on transitions and database transactions, which is presented in [4], may be simplified. Namely, one can replace each pair of cause-result inputs and outputs of transitions and transactions with an adjacency of the corresponding information place, located information or information element to a given transition or transaction and remove information kinds concerning attributes of information elements. On the other hand, to the list of the main kinds of information on transitions one can add tables of transition adjacencies to those information elements, which are read or recorded by business transactions. Information kinds representing the state of EPC II systems stay the same, but they are moved from the part 5 of the list of the main information kinds [4] to the separate part 8 of this list. After those changes the Table 12 from [4] is replaced with the discussed below Tables 2–4.

<table>
<thead>
<tr>
<th>ii</th>
<th>name</th>
<th>s</th>
<th>j</th>
<th>a</th>
<th>k</th>
<th>m</th>
<th>r</th>
<th>e</th>
<th>i</th>
<th>b</th>
<th>d</th>
<th>u</th>
<th>y</th>
<th>c</th>
<th>l</th>
<th>g</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>TR</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>transitions</td>
</tr>
<tr>
<td>111</td>
<td>UTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>inputs to functional transitions from information places on located resources</td>
</tr>
<tr>
<td>112</td>
<td>YTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>outputs from functional transitions to information places on located resources</td>
</tr>
<tr>
<td>113</td>
<td>URTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>inputs to functional transitions from information clusters on located resources</td>
</tr>
<tr>
<td>114</td>
<td>YRTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>outputs from functional transitions to information clusters on located resources</td>
</tr>
<tr>
<td>115</td>
<td>UERTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>e</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>allocations of reusable resources in definite roles to functional transitions</td>
</tr>
<tr>
<td>116</td>
<td>YERTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>e</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>outputs from functional transitions to information clusters on batches and specimens of located resources</td>
</tr>
<tr>
<td>117</td>
<td>URLTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>118</td>
<td>UERLTF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>e</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>TFC</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>couplings of functional and control transitions</td>
</tr>
<tr>
<td>121</td>
<td>TFF</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>s</td>
<td>a</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>couplings of functional transitions in a definite data processing phase</td>
</tr>
<tr>
<td>125</td>
<td>IMTR</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>adjacencies of located information to transitions</td>
</tr>
<tr>
<td>126</td>
<td>DITR</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td></td>
<td>i</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>adjacencies of information elements to transitions</td>
</tr>
<tr>
<td>127</td>
<td>BDITR</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td></td>
<td>i</td>
<td>b</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>adjacencies of attributes of information elements to transitions</td>
</tr>
</tbody>
</table>
The additional table TFF is a kind of information on couplings between transitions in the same data processing phase. It has been demonstrated that in most cases the order of executing transitions at a given instant of the discrete time is determined by the order of data processing phases [3]. Therefore directions of data flows, which are shown in the functional structure diagrams for transition couplings, whose structure is recorded in tables TFC, UTFC, YTFC [2], have no practical importance. However, attention was directed to the need of declaring the order of executing transitions belonging to the same data processing phase. The table TFF describes transition couplings $|(s, j, a, k, u, c, l)\in TFF|$, in which $(s, j, a, k)\in TR$ and $(u, j, c, l)\in TR$ are corresponding indices of preceding and succeeding transitions from the same phase “j”.

### Table 3

table of information on periodic business transactions

<table>
<thead>
<tr>
<th>ii</th>
<th>name</th>
<th>s</th>
<th>j</th>
<th>a</th>
<th>k</th>
<th>m</th>
<th>r</th>
<th>t</th>
<th>u</th>
<th>y</th>
<th>c</th>
<th>i</th>
<th>d</th>
<th>l</th>
<th>g</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>TRT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>database transactions, including periodic business transactions</td>
</tr>
<tr>
<td>181</td>
<td>UTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>inputs from places of information on located resources to functional database transactions, including periodic transactions</td>
</tr>
<tr>
<td>182</td>
<td>YTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>outputs to places of information on located resources from functional database transactions, including periodic transactions</td>
</tr>
<tr>
<td>183</td>
<td>URTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of picking or burdening located resources by functional activities</td>
</tr>
<tr>
<td>184</td>
<td>YRTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of producing or returning located resources by functional activities</td>
</tr>
<tr>
<td>185</td>
<td>UERTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of picking or burdening batches or specimens of located resources by functional activities</td>
</tr>
<tr>
<td>186</td>
<td>YERTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of producing or returning batches or specimens of located resources by functional activities</td>
</tr>
<tr>
<td>187</td>
<td>URLTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of burdening reusable resources in definite roles by functional activities</td>
</tr>
<tr>
<td>188</td>
<td>UERLTFT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of burdening specimens of reusable resources in definite roles by functional activities</td>
</tr>
<tr>
<td>189</td>
<td>TFGT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>periodic transactions of planning or reporting executions of functional activities within definite readiness variants of functional subsystems</td>
</tr>
<tr>
<td>190</td>
<td>TFCT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>adjacencies of located information to database transactions, including periodic transactions</td>
</tr>
<tr>
<td>191</td>
<td>IMTRT</td>
<td>s</td>
<td>j</td>
<td>a</td>
<td>k</td>
<td>m</td>
<td>r</td>
<td>t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>adjacencies of information elements to database transactions, including periodic transactions</td>
</tr>
</tbody>
</table>

The set of adjacencies of places to transitions $ADJTR = STF \cup UTF \cup YTF \cup STC \cup UTC \cup YTC$ is the union of the sets of adjacencies of activity information places to functional (STF) and control (STC) transitions and also the sets of resource inputs (UTF) and outputs (YTF) of functional transitions and control transitions (UTC, YTC) [2]. The table ADJTR may be replaced in the list of the main information kinds with the tables UTF, YTF (Table 2). The table STF is a projection of the table TF (which is a subclass of the table TR) on its selected columns. Tables STC, UTC, YTC are not counted as the main information kinds, because they may be reconstructed on the basis of the tables STF, UTF, YTF and the table TFC, which is also one of the main information kind.
Cause-result inputs and outputs of transition procedures in the structure of business transactions

In each row of adjacency tables UTF, YTF, IMTR, DITR, UTF, YTF, IMTR, DITR, UTF, YTF, IMTR, DITR one of its attributes should be an indicator of the cause-result input or output. For instance, it can be the number InOut = 0, if the adjacency is a cause-result input, InOut = 1, if the adjacency is a cause-result output and InOut = 2, if the adjacency is both input and output of the transition or transaction. Owing to it each adjacency table replaces two tables of cause-result inputs and outputs of transition or transactions, which appeared in the previous version of the Table 2 [4].

Cause-result inputs and outputs of transition procedures f(s, j, a, k) ∈ F(TR) are attributes of information elements (i, b, d) ∈ BDI (item 54 in the list of the main information kinds [4]). However it should be reminded that neither the tables of inputs of attributes of information elements to transitions (s, j, a, k, m(i, d), i, b, d) ∈ INBDITR and to database transactions (s, j, a, k, m(i, d), i, b, d, t) ∈ INBDITRT, nor the analogous tables of outputs OUBDITR and OUBDITRT, are applied in practice to reading or recording information from or to the database. In instructions SELECT, INSERT, DELETE and UPDATE of the SQL language [10] the names of tables and the names of their key columns are used to pointing tables and their rows, whereas the names of columns are used to point attributes of selected rows.

The columns “i” and “d” are added to all tables in EPC II systems (as well as the column “m”), because they are identifiers of specimens of administrative resources. Therefore the pairs (i, d) may be used, if it is necessary, as the candidate keys instead of primary keys for labeling rows of the tables. The column numbers “b” may not be added to the rows of tables, so the only way of pointing a definite attribute in a definite row of the table is to give its name. For this reason there is a general principle in EPC II
systems that in every information element there are only “standard” attributes, i.e. such attributes that have to appear there because of generally accepted rules (e.g. the value of a parameter, the unit of measure and the data type). All other variables, which in contemporary database systems may appear as row attributes in the tables, are recorded in tables of parameters of definite information kinds, where each of them corresponds to an individual information element. Therefore in EPC II systems the only attributes, which are used for identifying information in a definite table, are attributes of its primary or candidate keys, which point definite information elements.

Consequently, attributes of information elements as cause-result inputs and outputs of database transactions should be replaced with information elements themselves. Therefore instead of the tables INBDITRT, OUBDITRT to the list of the main information kinds the tables INDIRT, ODITRT and corresponding tables INDIR, ODITR have been introduced. Next, the tables of cause-result inputs and outputs have been replaced with the adjacency tables DITRT, DITRN and DITR (Tables 2–4).

Information from the tables INBDITR, OUBDIR, INBDITRT, OUBDIRT are still stored (in the properly modified form) within database system tables, which are not used by most of database users. This information is useful for solving certain problems of implementing database systems, but for the EPC II theory, which describes information systems from the viewpoint of their users, it has no importance.

Each “passive information element” (i, d)∈DI, which may be read, updated or recorded by a transaction, belongs to the information cluster [1] identified with a definite information place, the resource one mr(i, d) or the activity one ma(i, d). However one should remember that passive information element (i, d) belonging to the information cluster “m” is itself an identifier of the cluster of those information elements from other tables, whose keys contain among others key attributes of the element (i, d) (cf. Fig. 3 in [4]). Moreover it is possible that a given database transaction (s, j, a, k, t) is picking the whole information cluster (i, d) for processing or recording, not only its top information element. Therefore, apart from the indicator InOut, each row of the adjacencies tables UTFT, YTFT, IMTRT, DITRT, UTFN, YTFN, IMTRN, DITRN should contain a cluster indicator, e.g. with the name Clust, where Clust=1, if the transaction (s, j, a, k, t)∈TRT or (s, j, a, k, n)∈TRN is picking, processing or recording the cluster pointed correspondingly by (m), (m, i) or (m(i, d), i, d), whereas Clust=0, if the transaction refers only to single rows in tables M, IM or in any tables with the candidate key(i, d).

The main information kinds UTFT, YTFT, as well as the tables STFT, STCT, UTCT, YTCT, which may be reconstructed on the basis of the main information kinds TRT, TFC, UTFT, YTFT, are all tables of adjacencies of information places (and corresponding information clusters) to periodic business transactions. Analogously, on the basis of the main information kinds TRN, TFC, UTFN, YTFN (Table 4) one can create all tables of adjacencies of information places to business transactions concerning orders and reports on their executions.

Business transactions in the business process control systems

The tables IMTRT, DITRT, IMTRN, DITRN represent adjacencies of business transactions to all information kinds and to all information elements, which refer to any table containing plans or orders and corresponding reports except for the table of information places M. However, their key attributes are not comprehensible from the viewpoint of the management engineering. This condition is satisfied by all other information kinds from the Tables 3 and 4. They contain all transactional records, i.e. all feasible associations of passive information elements with business transactions that refer to any orders or periodic plans. One can justify it analyzing relationships of kinds of information on adjacencies of passive information elements to transitions with kinds of information on the structure of business process control systems, as well as on batches and specimens of resources (Tables 10, 11 in [4]).

Tables TR, URTF, YRTF, UERTF, YERTF, URLTF, UERLT, TFG, TFC correspond directly to information kinds SJA, URSJA, YRSJA, UERSJA, YERSJA, URLSJA, UERLSJA, SJAG, SJAC. The primary keys of compared here information kinds differ only in the number “k”, which is a transition number within transition units of functional activities, as well as in the interpretation of the number “j” of data processing phases. For kinds of information on functional activities the number “j” refers to the layers and it is equal to the number of information data processing phases (j = ji, ji = 1..4), whereas in the case of transitions it is a number of all data processing phases, including decision phases (j = jd = 9 – ji, ji = 1..4).

The current contents of the tables SJ, USJ, YSJ, URSJ, YRSJ, SJU, URLSJ, UERSJ, YERSJ, UERLSJ may be changed with transactional records
corresponding to adjacencies from the tables TR, UTF, YTF, URTF, YRTF, YERTF, UERTLF, in which the activity kind “a” is a kind of organizational units gg ∈ GG ⊂ A [3]. The only reason of changes of information on the current state of information places m∈M, on located resources (m, r)∈ERM, on located resources in their definite roles (m, r, g)∈RLM and on their specimens (m, r, e)∈ERM, (m, r, e, g)∈ERLM may be business transactions, whose adjacencies to these passive information elements have been already discussed.

Other information kinds from Tables 10, 11 in [4], namely H, HJ, S, KSI, SU, HJU, SJP, ER, ERL, do not contain any information on the current state of an EPC II system. The same refers to all main information kinds belonging to knowledge on kinds of enterprise processes and resources (Table 8 in [4]). Attributes of information elements of these kinds (and also deleting or creating these information elements) depend on reengineering transactions, but they do not depend on any business transactions. So presented above Tables 2, 3 and 4 contain all the main kinds of information on the structure of adjacencies of passive information elements to transitions and business transactions and consequently on the structure of cause-result inputs and outputs of all transitions and transactions. In classification presented in [4] the main information kinds of the Table 3 and 4 belong to information on periodic plans and reports or to information on orders of executing activities (parts 6 and 7 of the list).

Among key attributes of every transactional record related to a given activity execution, planned (s, ji, a, t)∈SJAT or ordered (s, ji, a, n)∈SJAN, there are always corresponding attributes (s, j = ji or j = 9–ji, a, t or n). However the attribute “k” of corresponding business transaction (s, j, a, k, t)∈TRT or (s, j, a, k, n)∈TRN, may be different in these records, because the inflow (or the outflow) of different groups of resources to (or from) the given activity may be controlled by different transitions. Many transitions in one transitional unit enable many transactions referring to the start or finish instant of a given activity execution, although no transition may be executed more than once in one sampling period.

Finally, it should be noticed that in some cases the relationship between transactions and executions of functional activities does not appear in a natural way. As examples one can point out inventorying material stores or the transfer of cash from one account to the other. In EPC II systems such transactions may be assigned to the group activities (s, j, gg)∈SJA, where “gg” is the kind of an organizational unit, which is adjacent to all information places (accounts) taking part in a given transaction.

### Accounting in EPC II systems

#### Synthetic accounts as information places

Accounting is the oldest and the most common technique of gathering, processing and presenting information required for making decisions in enterprises. Therefore presenting the theory of Enterprise Process Control one cannot neglect the problem of its conformity with commonly accepted rules of accounting [11–13]. In particular, one should verify, if the structure of information recorded by bookkeeping transactions is compatible with presented above structure of transactional records of business transactions.

In the cycle of business activity of an enterprise one can distinguish [13]:

- receiving financial resources (not only in the form of cash) from owners and creditors,
- purchasing resources required for production and/or sales,
- producing and/or selling goods and/or services and collecting cash from customers,
- repaying financial resources obtained from owners and creditors.

So apart from suppliers of goods and services also equity owners and creditors are suppliers in the enterprise supply chain (Fig. 1, 2). Among suppliers of services one cannot neglect the employees of the company.

Resources, which are made available to the enterprise by owners, i.e. the equity, are still their property. The initial equity is turning into other kinds of resources, but their value – increased by receivables and decreased by liabilities of the enterprise – is in each time considered as the equity value. All resources, which are at the enterprise disposal, are called assets. Among them, because of the role in settlings between the enterprise and its environment, financial resources are distinguished. One counts among assets not only cash, but also receivables of any kind [13]. Then at each instant of time the value of assets is equal to the sum of equity value and value of enterprise liabilities. In other words, total assets are always equal to total liabilities.

Aggregated values of definite categories of assets, equity and liabilities that one can see in the enterprise balance sheet may be recorded in those resource information places m∈MR, which appear between the enterprise and its environment (Fig. 2). The balance sheet refers to a given instant of time. However not only the state of resources at a given instant, but
also their flows, as well as related to them revenues and expenses (costs), in the period preceding this instant, are important for the financial accounting. The statement concerning revenues and expenses is called the income statement or the profit and loss account, because the income, i.e. the enterprise financial result, is the difference between revenues and expenses.

Individual items of the income statement refer to aggregated sources of costs and revenues. In a given EPC II system these variables may be recorded in those activity information places $m \in \mathbb{M}$, which correspond to the enterprise (or its sites) and to its suppliers as to cost arising centers, as well as to the customers as to revenue arising centers (Fig. 2). Those organizational units may be considered as income arising centers, because the profit increase may be attained increasing revenues or decreasing costs.

In EPC II systems the balance of a given component of assets or liabilities in the place “mc”:

$$X(mc) = X_0(mc) + Y(mc) - U(mc)$$

may be written down to the row “mc” of the table $M$ (item 50 in the list of the main information kinds [4]), which contains the record $(mc, X_0, Y, U, X)$, where $X_0$ – the value of the balanced component before the transaction, $Y$ – the increase and the decrease of the value as a result of the transaction, $X$ – the value after the transaction. If for a given transaction $U > 0$, then $Y = 0$ and if $Y > 0$, then $U = 0$.

In accounting systems those information places, in which one can record changes of the balanced components of assets or liabilities as well as their values before and after changes, are called balance-sheet accounts. The value of the balanced variable $X$ is called account balance. In the case of assets the increase of the balance $Y$ is called debit, whereas the decrease of its value $U$ – credit. In the case of liabilities the debit is a decrease of the balance $U$ and the credit is its increase $Y$.

Information places, in which one can record revenues, costs, profits and losses, are called income accounts. In the case of costs and losses the balance increase $Y$ is called debit and its decrease $U$ – credit. The case of revenues and profits is an opposite one: the balance increase $Y$ is called credit and its decrease $U$ – debit. If the total revenue is greater than the total cost, than the profit is positive and the loss equals zero. In the opposite case the loss is greater than zero and the profit is equal to zero. At the end of the reported period the profit or the loss is recorded in the enterprise balance-sheet and then the values of the income accounts are reset.

The debit and the credit are historically shaped and widely applied concepts, but the terms of increase and decrease of the balance are more comprehensible for people that are not accountants.

The above discussed accounts are synthetic accounts, which belong to the general ledger and concern aggregated amounts, which are recorded in the balance-sheet and in the income statement of the whole enterprise. In the EPC II systems these accounts belong to information places. The balance-sheet accounts are resource places, whereas the income accounts – activity places. Apart from them there are analytic and subsidiary accounts. Certain of them are places of information on resources, which are located inside the sites, or on functional subsystems, which belong to the organizational structure of the sites. Other accounts are not information places, but their contents always correspond to information, which is recorded in information clusters [1, 4] that are identified by resource information places $m \in \mathbb{MR}$ or by activity information places $m \in \mathbb{MA}$.

The employees as organizational units

The problem of assigning records from the analytic and subsidiary accounts to corresponding data structures of EPC II systems will be discussed on the example of recording costs of using human resources. By the way, the difference between the employees of the enterprise and its human resources will be explained. The human resources are made available to the enterprise by its employees. It is assumed that there is a place $mh \in \mathbb{MR} \subset \mathbb{M}$ of recording human resources in the enterprise environment. Furthermore, there is a place of company’s receivables from its employees $me \in \mathbb{MR}$, a place of company’s liabilities towards them $ml \in \mathbb{MR}$ and a place grouping their bank accounts $mb \in \mathbb{MR}$.

The signing an employment contract is a reengineering transaction (so it is not a bookkeeping transaction). As a result of it the organizational unit of the employee $sh \in \mathbb{S}$ arises in the enterprise environment. At the same time the transaction creates a specimen of human resources $(mh, rh, e) \in \mathbb{ERM}$ (item 91 in the list of the main information kinds [4]) in the place “mh”, as well as elements of information on company’s receivables from the employee $(me, rf, e) \in \mathbb{ERM}$, on company’s liabilities towards him $(ml, rf, e) \in \mathbb{ERM}$ and on his bank account $(mb, rf, e) \in \mathbb{ERM}$, located correspondingly in the places “me”, “ml” and “mb”. We assume (for simplicity of the example) that all financial resources belong to the same kind “rf”. The same is assumed on the kind of human resources “rh”. The specialties of employees are modeled as roles of resources $(rh, g) \in \mathbb{RL}$ (item 21 in the list of the main information kinds [4]). The discussed here specimens of human
Costs of using human resources

All resting places of human resources inside the site organizational systems, e.g. in the system (ss, 3)∈SJ of the site ss∈S, exist in the enterprise organizational structure regardless of contracts with specific employees. Among them there are places mr∈MR, from which human resources are burdened by functional activities of business processes. In these places, like in other places of reusable resources, one records times of burdening resources by functional activities, as well as resulting from it components of costs of executing activities. More exactly, the transactional record (s, 3, a, kc, mr, rh, e, n) ∈ YERTFN (item 236 in the table 4) contains the report on burdening the specimen “e” of the human resources (of the kind “rh”) from the resource place “mr” because of execution “a” of the activity “n” by the executive subsystem (s, 3) ∈ SJ. This report contains among others the fields (s, 3, a, kc, mr, rh, e, n, B, Xo, Y, X), where B is the time of burdening the considered resource in the considered order, Y – the cost of this burdening, X – the value of cumulated costs of this burdening after execution “n” of the activity (s, 3, a), Xo – the value of X before the activity execution. Such information may be used not only to calculation of the cost of the activity execution, but also to calculation of payments for the employees.

The discussed transactional record belongs to the cluster of information stored in the resource place “mr” (Fig. 3 in [4]), which is the resting place of all human resources used among others by the executing subsystem (s, 3). Each increase Y of cumulated costs X because of executing a definite activity in the executive subsystem adjacent to the place “mr” is at the same time the increase of the analogous cost of burdening all human resources from the place “mr”, as well as the increase of the cost of burdening a given specimen of located human resources (mr, rh, e) by all feasible activities. So the information element (s, 3, a, kc, mr, rh, e)∈YERTF (item 116 in the Table 2), is used as the analytic account “mc” for the account of the higher level “mz”, corresponding to the information element (mr, rh, e)∈ERM, in which the cost of burdening a given human resource is cumulated.

In an accounting system the record (mc, B, Xo, Y, X) in the row “mc” of the table, which will be called here e.g. COSThr, is the record of the above discussed increase of costs of burdening a given specimen of human resources. Although the account “mc” is not an information place, everyone knows (if he understand the verbal description of this account), what are corresponding values of attributes (s, 3, a, kc, mr, rh, e). If these attributes would be added to all rows of the table COSThr, then this table would have columns (mc, s, 3, a, kc, mr, rh, e, B, Xo, Y, X). For such complemented table apart from the primary key (mc) one can point the candidate key (s, 3, a, kc, mr, rh, e), through which this table is related by the specialization relationship with the table YERTF. It demonstrates compatibility of the structure of the exemplary table COSThr with the structure of the corresponding table YERTF of the framework EPC II system. Analogously one can demonstrate compatibility of structures of other tables taken from real accounting systems, as well as all other data structures of other systems of management and process control, with the structure of EPC II systems.

If the account “mc” contains many records of costs of particular executions “n” of a given activity (s, 3, a), then in the database they are stored as rows (mc, s, 3, a, kc, mr, rh, e, n, B, Xo, Y, X) of the table COSThrN, which corresponds to the discussed above table YERTFN from the EPC II system. For each account “mc” the table COSThr contains information concerning only the last transaction from the table COSThrN.

The analytic account “mc” is a subsidiary account for calculating costs of activities performed
inside the site \((ss, 3)\) and recorded in the activity information place \(ma(ss, 3) \in MA\). Indeed, when in the table \(COSThR\) the record \((mc, s, 3, a, kc, mr, re, e, n, B, Xo, Y, X)\) arises, then the value of \(Ya\), i.e. the cost of the execution “\(n\)” of the activity “\(a\)” by the functional subsystem \((s, 3)\), and the value of \(Xa\), i.e. the cumulated cost of executions of the executive activity \((s, 3, a)\), increase by the value of \(Y\). The variables \(Ya, Xa\) are attributes of the record \((s, 3, a, kc, n, ma(s, 3), Xao, Ya, Xa)\) belonging to the table \(TRN\) (item 230 in the Table 4). It is easy to notice that the increase of the value \(Xa\) for any activity \((s, 3, a)\) is also the same increase of the total cost of activities performed in the subsystem \((s, 3)\) and recorded in the place \(ma(s, 3) \in MA\). The executive subsystem \((s, 3)\) is one of subsystems of the site \((ss, 3)\). So if the cost of its activities increases by the value of \(Y\), then the total cost of all activities performed in the site \((ss, 3)\) also increases by \(Y\). So one can see that the exemplary account “\(mc\)”, corresponding to a transactional record from the information kind \(YERTF\), is a subsidiary account for calculating the site costs recorded in the synthetic account \(ma(ss, 3) \in MA(SJ)\).

The periodic payments for the employees of the site “\(ss\)” are executed at instants “\(t\)” belonging to the time scale \(h(ss, 3)\), which corresponds to planning periods of coordinating management \((j = 3)\) in this site. They are preceded by periodic business transactions \((ss, 3, gg(ss), kh, h(ss), t) \in TRT\) (item 180 in the Table 3), which in this case are transactions reporting on burdening human resources in the periods \((h(ss), t)\) by the organizational group of activities \(gg(ss)\) of the site \((ss, 3)\). These transactions, in their transactional records \((ss, 3, gg(ss), kh, mc, rf, e, h(ss), t) \in UERTFT\) (item 185 in the table 3), decrease the company’s receivables \(Xo(mc, rf, e)\) from the employees \(sh(rh, e)\) by the values of the costs of their burdening \(Yh(mh, rh, e, h(ss), t)\), whereas in records \((ss, 3, gg(ss), kh, ml, rf, e, h(ss), t) \in UERTF\) (item 186 in the table 3) they increase the company’s liabilities \(Xl(ml, rf, e)\) towards these employees by the same values. The key attribute \(gg(ss)\) is the number of the kind of the site organizational unit “\(ss\)” in the numbering of activity kinds [4]. The payments themselves are periodic business transactions \((ss, 3, gg(ss), kb, h(ss), t) \in TRT\), which in transactional records \((ss, 3, gg(ss), kb, ml, rf, e, h(ss), t) \in UERTFT\) decrease the company’s liabilities \(Xl(ml, rf, e)\) by the previously calculated values \(Yh(mh, rh, e, h(ss), t)\), whereas in records \((ss, 3, gg(ss), kb, mb, rf, e, h(ss), t) \in UERTFT\) they increase the state of the employee accounts \(Xb(mb, rf, e)\) by the same cost values.

The periodic values of the costs of burdening the individual employees \(Yh(mh, rh, e, h(ss), t)\) of the site “\(ss\)” are earlier calculated on the basis of analogous values \(Xr(mr, rh, e)\), read at instants \((h(ss), t)\) from information elements \((mr, rh, e) \in ERM\), which belong to information clusters identified by internal resource places “\(mr\)” of a given site. So the discussed above analytic accounts “\(mc\)” , “\(nz\)”, corresponding to the information elements \((s, 3, a, kc, mr, rh, e) \in YERTF\) and \((mr, rh, e) \in ERM\), are subsidiary accounts for calculating payments of employees of the site \(ss \in S\).

Transaction records in the journal

The transactional records in accounts referring to the costs of using human resources, as well as in related to them accounts of activity costs and the accounts of settlings with the employees, are examples of transactional records of accounting in EPC II systems. In real systems of financial accounting the transactions are recorded in the journal and afterwards the transactional records are moved into the proper accounts of other books. In the simplest case the journal is single and the transactions are recorded in it chronologically, together with their numbers and dates [13]. The effects of each transaction are recorded by a double-entry change in the accounts called a journal entry. In other words, a single journal entry comprises two or more transactional records, whose structures are like in the following example:

\[(n, t, mc1, D1), \quad (n, t, mc3, C3), \quad (n, t, mc2, D2),\]

where \(n\) – transaction number; \(t\) – transaction date; \(D1, D2\) – debit amounts; \(C3\) – credit amount; \(mc1, mc2, mc3\) – names or numbers of accounts. Each of these transactional records has the structure \((n, t, mc, Y)\) or \((n, t, mc, U)\) depending on whether the debit or credit is an increase or decrease of the account balance. In each accounting transaction “\(n\)” the state of at least two accounts has to change and the total debit is always equal to the total credit (in the example: \(D1 + D2 = C3\)). The state of accounts \(Xo(mc, n), X(mc, n)\) before and after transactions is recorded in other books, not in the journal.

The presented above example demonstrates that in two tables \(YBTRN, UBTRN\), with columns \((mc, n, t(n), Xo, Y, X)\), \((mc, n, t(n), Xo, U, X)\), one can record not only all information from the journal, but also all information on the changing state of accounts. In the rows of these tables, i.e. in transactional records, the numbers of accounts and transactional records are placed in the first fields, because they are their key attributes. The tables \(YBTRN, UB-\)
TRN may comprise also other columns, including the column with identifiers of the source documents of individual transactions. As an example of the table YBTRN one can use the discussed above table COSThrN, containing transactional records (mc, n, t(n), B, Xo, Y, X).

It has been above demonstrated that adding the attributes (s, 3, a, kc, mr, rh, e) to each row of the table COSThr one can prove the compatibility of its structure with the structure of the main information kind YERTF. It is easy to notice that adding the same attributes to the rows of the table COSThrN one obtains the transactional records in the form:

\[(mc, s, 3, a, kc, mr, rh, e, n, t(n), B, Xo, Y, X)\].

The part \((s, 3, a, kc, mr, rh, e, n)\) of this record is a candidate key of the table COSThrN and at the same time it is a special case of the primary key of the main information kind YERTFN (Table 4).

The present state of the EPC II theory

The main administrative information kinds

Development of the EPC II theory [1–5] consists in analysis of facts from the area of management and business process control in enterprises. Conclusions from this analysis lead to defining successive concepts of the theory and relationships between them, as well as to organizing couplings between elements of process control systems and to discover new regularities in their functioning. Classes of the system elements and classes of couplings between them correspond to the concepts and to relationships between the concepts of the EPC II theory. What is more, these relationships themselves are concepts of the EPC II theory too. Therefore it is important to know all concepts of the EPC II theory correspond to definite tables of the relational database of the framework EPC II system [1]. The state of the work on designing this database may be considered as the measure of the theory development.

In the framework EPC II system one should distinguish the main administrative information kinds [4], because all other tables may be created as subclasses or natural joins of other tables or as projections of other tables on their key columns and other selected columns. The requirement, that all key columns of a given table must belong to the columns selected for its projection, causes that the set of the main information kinds is wider than in the case of rules assumed in [4]. E.g. according to this condition the relationship of activity order in definite process-

es, which has been discussed in [4], is a main information kind.

All concepts of the EPC II theory come from the basic concepts that correspond to the main information kinds. The number of the main information kinds is finite and relatively small. They are kinds of information:

1. belonging to knowledge on kinds of processes and resources,
2. on information places and information elements,
3. on the structure of business process control systems,
4. on batches and specimens of resources,
5. on transitions,
6. on periodic plans and reports of enterprise activities, as well as on periodic business transactions,
7. on orders of executing activities and on business transactions related to them,
8. on the state of EPC II systems.

It seems that the length of the list of the main information kinds will be less than 200 items, but one will never be able to exclude the need of its supplements. The present list includes 131 items, which have been presented in [4] together with their key attributes, the 42 items, which are new among the ones presented in the Tables 1–4, the above mentioned relationship of activity order in definite processes and 23 other main information kinds, which will be discussed in the next publications.

The structural attributes

The key attributes of the main information kinds belong to the set of 26 structural attributes (Fig. 4), whose specification is presented below.

**Dimensional attributes**

- \(h\) item number of time scales and organizational levels, \(h \in \mathbb{H}\),
- \(s\) item number of organizational units, \(s \in \mathbb{S}\),
- \(j\) item number of functional layers and data processing phases for a definite time scale “\(h\)”, \(j \in \mathbb{J}\),
- \(a\) item number of activity kinds, \(a \in \mathbb{A}\),
- \(k\) item number of transitions for a definite activity kind “\(a\)”, \(k \in \mathbb{K}\),
- \(m\) item number of information places, \(m \in \mathbb{M}\),
- \(r\) item number of resource kinds, \(r \in \mathbb{R}\),
- \(e\) item number of batches or specimens of resources of a definite kind “\(r\)”, \(e \in \mathbb{E}\),
- \(q\) item number of parameters of activities and resources, \(q \in \mathbb{Q}\),
- \(o\) item number of options (values) of a definite enumerative parameter “\(q\)”, \(o \in \mathbb{O}\),
- \(f\) item number of activity procedures, \(f \in \mathbb{F}\),
- \(i\) item number of information kinds, \(i \in \mathbb{I}\).
Management and Production Engineering Review

Fig. 4. Dimensions of the structure of Enterprise Process Control systems.

b item number of attributes of a definite information kind “i”, \( b \in B \),
d item number of information elements of a definite kind “i”, \( d \in D \),
t time, \( t \in T \), e.g. in notation (year-month-day-hour-minute-second-0.1sec),
n item number of orders of executing a definite functional activity (s, j, a), \( n \in N \).

Other structural attributes

u item number of superior organizational units or statistical groups of organizational units, \( u \in U \subset S \),
y item number of data processing phases and functional layers of control units, \( y \in Y \subset J \),
c item number of superior activity kinds (including process kinds \( p \in P \subset C \)), \( c \in C \subset A \),
l item number of transitions for a definite superior activity kind “c”, \( l \in L \subset K \),
g item number of activity groups (including activity families, resource roles and readiness variants of functional subsystems), \( g \in G \subset A \),
w item number of aggregated information places (including synthetic accounts in an enterprise chart of accounts), \( w \in W \subset M \),
v item number of categories of resource kinds or their organizational groups or kinds of complex resources, consisting of other resources, \( v \in V \subset R \),
z item number of complex resource specimens of a definite kind “v”, \( z \in EX \subset E \),
nm item number of aggregated orders, \( nm \in NN \subset N \),
qx item number identifying parameters of definite options of enumerative parameters or identifying parameters which compose associative parameters, \( qx \in QX \subset Q \).

The first 16 of them are dimensional attributes, whereas the other 10 are second appearances of dimensional attributes in the keys of certain information kinds.

Dimensions of the structure of EPC II systems

The first of the above eight parts of the list of the main information kinds concerns structural knowledge, which may be used not only in a given enterprise, but it may be delivered, for a fee or gratis, to other enterprises. The parts 2, 3, 4 and 5 group information kinds referring to the structure of organizational systems in an enterprise and to the structure of processes located in those systems. The parts 6, 7 and 8 concern executions of processes, activities and procedures, which are located correspondingly in organizational systems, in functional subsystems and in transitions. It is obvious that information kinds from the last group should be defined on the grounds of information kinds from the second group, which, in turn, should be defined on the grounds of information kinds from the first group.

The only structural attributes, which appear in the keys of information kinds belonging to the knowledge on kinds of processes and resources are (a, k, r,
q, o, f, i, b, c, l, g, v, qx). The attributes (h, s, j, m, e, d, u, y, w, ex) of the second group do not appear in the keys of the first group, whereas the attributes (t, n, mn) appear only in the keys of the third group (Fig. 4). These groups of attributes represent in the database the three general dimensions of EPC II systems:

- knowledge on kinds of processes and resources,
- enterprise organization,
- labels of executions of definite processes.

### Business processes

Developing the EPC II theory one should discuss, in the first place, concepts of business processes, resources and organizational units. Although they are the most important notions of the management engineering, they may arouse doubts, because they are variously defined in different standards (MRP II / ERP [8, 14], ISA-95 [15], BPMN [16], WFMC [17], YAWL [18], IFRS [11], FASAB [12]) and in well known process modeling tools (e.g. ARIS [19]), while in the EPC II theory they are defined yet another way. It is not only the question of different names (e.g. “task” or “function” instead of “activity” and “workflow participant” or “asset” instead of “resource”), but also the problem of substantial differences between the notions.

The fundamental concept of the business process was developed in previous publications on the EPC II theory [1–4]. In the last of them it was assumed that:

- the name “business process” refers to the kind of a process, understood as a set of activities and separating them resources, without any relationships with organizational systems and subsystems, in which processes and activities are performed,
- the name “system business process” is applied to a process considered as a whole and allocated to a definite organizational system; on the higher organizational level the system business process is an executive activity,
- the name “functional business process” means an ordered set of functional activities (allocated to definite functional subsystems) and separating them resource information clusters, i.e. clusters of information on located resources (belonging to definite resource information places) and refers to processes, which are performed in different functional layers of a given organizational system or in the layers of its subsystems from lower organizational levels.

In the EPC II theory the essence of the business process definition is that it consists of activities and separating them resources, whereas in other definitions resources are not mentioned. Obviously, in all well known standards concerning enterprise management the resources are taken into consideration but their relations with business processes are different.

From the viewpoint of the EPC II theory it is vital that each business process in its entirety is performed within a definite organizational system, while its inputs and outputs may not belong to the inside of this system. In particular, if a semi-finished product of a given site of an enterprise is partly designed for sale, then it is located outside the site and it is both an output and an input of this site.

### Organizational units

There is a wrong belief that organizational units are sets of reusable resources, which are permanently allocated to them. It would be the argument for considering them as complex resources consisting of other resources. However, relatively permanent affiliation of definite resources to definite organizational systems is in essence their location in internal resource places of these systems, which causes that they become unavailable for other systems. Besides, affiliation of definite specimens of reusable resources to definite organizational units may change as a result of preparatory activities (overhauls, changeovers and the like) executions. This problem will be discussed in detail in the papers on interaction of production, preparatory and administrative processes. However deciding arguments, which exclude counting organizational units as resources, result from managerial functions of organizational systems and their functional subsystems.

The functional unit of a given functional subsystem contains transitions, which are sites of procedures of making decisions for subordinate subsystems and reporting on executions of the superior decisions. So the structures of relationships between functional subsystems, between functional activities and between transitions (simplifying: organizational structure, process structure and management structure) are univocally related. It refers not only to individual business processes, but to the whole multilevel and multilayer system [20] of management and process control, from the supervisory unit of an enterprise to basic activities, which are objects of direct control inside workstations.

Unfortunately, it should be noticed that in current standards organizational units, besides with various names, are counted as resources. E.g. in the WFMC standard an organizational unit is a special case of a “workflow participant” [17], whereas in the ISA-95 standard it is a more or less complex “equip-
ment element” [15]. In this approach resources may be both active (e.g. workstations) and passive (e.g. all materials) entities. In both cases resources are something that is allocated to activities by an outside decision-maker and that itself is not allowed to decide on the scope of its using in the enterprise. In the EPC II theory the organizational unit is not allocated to activities, but it performs them, whereas resources may be allocated not only to activities, but also to organizational units. In other words, organizational units are active entities, whereas resources are always passive entities. It refers also to human resources, which in the EPC II theory are not identical with employees, but they are reusable resources, made available to the enterprise by its employees. It has been shown above that employees are organizational units of environment and in the enterprise supply chain (Figs. 1, 2) are counted among suppliers, like owners of enterprise equity and suppliers of goods and services.

In the EPC II theory approach there are no decisions made outside an EPC II system. Moreover, executing decisions concerning a given activity is related with taking decisions on its subordinate activities, whereas the transitions, in which corresponding decision procedures are located, belong to the functional unit of this activity. So they belong also to the functional unit of the functional subsystem performing this activity [2]. Such a tight relation of executing activities with processing information would not be possible (and, consequently, one could not solve the discussed below problem of business-IT divide), if organizational units, together with their internal control functions, would be allocated to activities as resources.

Resources

In the EPC II theory the notion of resources is much more important than in other approaches to the systems of business process control. First, the functional business processes are defined as ordered sets of functional activities and separating them resource information clusters. It means that resources are not something that exists aside from processes, but they are immanent elements of process structures. In other words, processes have not only active stages, but also passive stages. Second, resources are always passive elements in structures of processes and in structures of organizational systems as well. Third, only resources are passive stages of processes and only resource information clusters are passive stages of functional business processes. All these principles are not conformed with current standards of modeling business processes, but without them the presented below results of the EPC II theory would not be achievable.

For stressing the importance of the presented here principles it is suggested that passive stages of service processes will be called “stage resources” instead of the previous “service resources” [4]. After this change the classification of resource kinds [4] encompasses:

- consumable resources,
- reusable resources, including human resources,
- stage resources, including organizational resources [3],
- financial resources, including cash and receivables,
- information resources, including administrative resources.

It should be noticed that specimens of information resources, including the administrative ones, are information elements [4]. Among administrative resources of the enterprise one should distinguish resources of knowledge on kinds of processes and resources. Analyzing the corresponding to them part of the list of the main information kinds (Table 8 in [4]) one can divide this knowledge into:

- information on the structure of processes and on the rules of aggregating activities and resources,
- information on parameters of activities and resources as well as on system parameters,
- information on transition procedures, as well as on administrative information kinds and on their attributes and also on relationships of transition procedures with activity kinds.

From the viewpoint of accounting the value of resources is their most important attribute. In the case of resources appearing between the enterprise and its environment (financial accounting deals mostly with those resources) there are no doubts how to measure their value. In the case of the internal resource of a process or processes its value may be calculated as the total cost of executing all activities preceding the passive stage, in which this resource occurs. It should be noticed that such a way of calculating the value of resources does not depend on their category. In particular, it is the same for the stage resource in a service process and for a consumable resource (e.g. a material) in a manufacturing process.

The framework EPC II system

The EPC II theory organizes notions and rules of functioning of integrated management and process control systems. It also integrates certain parts of knowledge from management engineering, production engineering, automation and software engineering. However it is equally important that the EPC II theory may be considered as a description of the framework enterprise process control system, which
may be built as a real information system. Such a system may be used, after filling it with detailed information concerning a given application [4, 5], in an enterprise of any trade and size. Therefore it is necessary to present the general description and typical examples of applications of the framework EPC II system.

As it was already shown [5], the framework EPC II system may be applied
• as a skeleton of a new system of integrated management and process control,
• as a kernel of an EPC II system comprising also the existing database and servers of Web Services,
• as an add-on of the existing enterprise management system for reducing problems with adapting software to changes of business process structures,
• as a tool of modeling and simulating business processes and their control systems, which enables the more detailed analysis than in the case of currently available software.

It is planned to present the MRP method [21] as the first example of well known management methods functioning in the structure of the framework EPC II system. It would be a good example, because the MRP module is not only a well known, but also an important subsystem of contemporary ERP systems [22].

Descriptions of other applications will be, from necessity, presented later. Anyway, because of generality of the EPC II theory, everyone, who understand the structure of data, which are processed in any subsystem of any information system for management or process control in any enterprise, and who knows the general description of the data structure in EPC II systems [4], is able to present such an example. Analysis of compatibility of real management systems with the EPC II theory does not require extensive knowledge of information technology. To point out structural attributes that may be used to compose the keys to the tables of the existing database (and to explain it), one needs the profound knowledge of user’s problems and only elementary knowledge from manuals concerning databases, e.g. [10]. The example of such an analysis has been above presented for the problem of recording costs of using human resources.

**The problem of business-IT divide**

The problem of business-IT divide [23] may be solved by demonstrating the way of automatic adaptation of structures of management systems software to changes of business process structures. In the opinion of Smith and Fingar this problem is so important that its expected future solution will be a transition to “the third wave” of BPM [23], after “the first wave” (since about 1920), in which BPM was based on the Taylor’s Management Theory, and “the second wave” (since about 1990), in which the process approach dominates, but business process reengineering is still “manual”, although processes are partially automated. Such reengineering, although supported by various tools of modeling and designing processes, often does not fulfill business expectations and moreover it is too expensive. For this reason it is performed too rarely, in spite of the need of adapting enterprises to frequent changes of their functioning conditions [23].

For solving this problem Smith and Fingar call for designing such structures of management information systems, in which business processes would be basic building blocks of these systems. Then changes of processes would be also changes of their software. So enterprises, perceived as systems of business processes which integrate both technology and information circulation, would achieve substantially higher level of business agility. The solution, which has been presented in [2, 3, 5], satisfies these demands and, what is more, demonstrates, contradicting Smith and Fingar predictions, that it is achievable on the basis of well known relational databases, without necessity of developing new information technologies.

In EPC II systems the transitions, which are sites of data processing procedures, are basic building blocks of the software. These transitions act like transitions of CPN [24], whereas in UML activity diagrams [7] they are modeled as actions. However, each EPC II transition belongs to a definite activity functional unit, which in the EPC II system represents a definite functional activity. Therefore, from the viewpoint of a designer of a business process management system the basic building blocks of this system are functional activities and among them – executive activities, which are business processes of the lower level. Consequently, one can design (and then modify) the framework structure of software of this system without knowledge of information technologies, as the structure of business processes and the structure of vertical couplings between functional activities belonging to different functional layers [3].

In the framework EPC II system, more exactly – in its relational database, one can store not only the structure of all feasible couplings between functional activities and the structure of all feasible associations of information places with functional activities, but also the structure of all feasible couplings between transitions and all associations of information places with transitions. For recording the de-
The problems to discuss

Interaction between production, preparatory and administrative processes

In the EPC II theory the simplified model of an activity, whose execution is divided into the setup time and the run time, is not applied. If an organizational unit should be prepared to a definite “readiness variant” [25], i.e. such an organizational group of one or many activities that switching between them requires no preparation, then a separate preparatory activity is executed. So, like in practice, one execution of the preparatory activity (performed by the preparatory organizational unit) may prepare a given organizational unit to one or many executions of one or many production activities. The main product of the preparatory activity is an organizational resource, whose occurrence [3] in the one of input resource information places of a given organizational unit represents its readiness to performing activities belonging to the definite organizational group. There are 1 to 1 relationships between corresponding preparatory activities, organizational groups of activities and linking them organizational resources.

The organizational group of activities and the organizational group of processes belong formally to the kinds of activities and processes, so they are also called “a group activity” and “a group process”. The organizational resource of a given group process is a complex resource, composed of organizational resources corresponding to its group activities. The executive preparatory activity is a preparatory process of the lower level, whose activities may be preparatory, administrative or production ones. Between preparatory processes, group processes and complex organizational resources there are 1 to 1 relationships, analogous to the relationships between their component activities and resources. Through these relationships the group processes may coordinate the preparatory activities, and the constraints, resulting from the planned executions of preparatory processes, influence the plans for production processes belonging to the corresponding group processes.

Administrative activities are substitute activities for transitions that call them. Their results are received by receiving transitions, which belong to the same transition units as calling transitions. The considered transition units (the decision or the information ones) correspond to definite superior production activities. So interaction between administrative activities and production processes, which they belong to, is accomplished through couplings of functional transitions of administrative activities with calling and receiving transitions, which are control transitions in functional units of superior activities. The transition execution time is neglected, whereas the execution time of its substitute administrative activity is not less than one planning period, belonging to the time scale of this activity. It justifies the discussed hereunder assumption that the execution time of transactions is equal to zero. Administrative activities may be grouped into functional administrative subprocesses belonging to superior production or preparatory processes, but there are no administrative processes which would be administrative activities of the higher level.

Interaction between preparatory, administrative and production processes is connected to coordination of administrative activities by superior production and preparatory processes and coordination of preparatory activities by superior group production processes. This coordination is accomplished through couplings of special structures, what requires separate publications.

Business process reengineering

In the EPC II theory reengineering of functional business processes is not a problem for decision-makers watching EPC II systems from outside, but it is performed by transitions inside these systems, on the grounds of information, which is available in them. Recording reengineering results is not difficult. It consists in deleting and inserting the proper rows.
into the tables of the database of a given EPC II system. It concerns among others creating or liquidation of organizational units, including virtual organizational systems, which are created only for a definite time or for executing definite tasks. It should be noticed that although recording itself of reengineering results is easy, working out the proper decisions may be difficult. Also their practical implementation, which requires executing the above mentioned preparatory activities, may be difficult and expensive. However it is important that owing to above discussed separating preparatory and production activities there are no structural obstacles against parallel running previously designed production processes and preparatory processes which implement reengineering decisions.

Reengineering transitions require their own discussion (and separate publications) because of special structure of their couplings with other transitions. In particular, it should be noticed that reengineering functional layers are the only ones, which have direct couplings with places of knowledge on kinds of processes and resources, and the only ones, whose information layers, namely layers of allocative information, are information layers of other functional layers, namely layers of executive scheduling.

Reengineering transitions may change any table, which stores information on the structure of EPC II systems. To formally describe such changes one needs relationships of reengineering transitions \((sx, jx, ax, kx) \in TRX \subset TR\) with information elements belonging to all main information kinds from the first five parts of their current list. So one should point out the main information kinds, from which the tables of these relationships could be derived. If it would be impossible, then one should define the new information kinds and discuss the need of introducing attributes \((sx, jx, ax, kx)\) to the set of structural attributes, that would increase their number from 26 to 30.

**Synchronization of transactions**

The order of executing transactions in a complex database system may affect results of data processing. The wrong order may lead not only to mistakes, but also to stopping a given computer system. In the EPC II theory it is assumed that at a given instant of the discrete time the order of all transactions is definite in principle. It is free only in such subsets of transitions that any order of their executions may not cause wrong results. The proper order of transactions belonging to the same data processing phase is determined by the described above table TFF. The order of data processing phases in a whole EPC II system is controlled by its synchronization subsystem, whose description requires a separate publication.

**Control of continuous and discrete elementary processes**

The internal organizational structure of workstations, i.e. elementary organizational systems, is different than in the case of described above systems belonging to higher levels. Therefore controlling elementary business processes, both continuous and discrete ones, requires separate publications. However, one can already claim that in the EPC II theory, unlike in classic manuals of automatic control (e.g. [26]), discrete event control systems may be presented as feedback systems, whose structure is the same as for continuous process control systems (cf. the example of Fig. 8 in [2]). This unified approach to controlling continuous and discrete processes [4] results from the assumption the time is discrete and from the same, for both cases, structure of relationships of functional activities with their decision and information transition units. The only difference consists in that in the case of continuous activities decision and information transitions of their activity functional units act at each sampling instant (e.g. at beginning of each planning period), whereas in the case of discrete activities only at start and finish instants of their executions.

**The universal structure of recording parameters of EPC II systems**

For the great diversity of parameters of business processes and organizational systems it is often impossible to record them in form of attributes of information elements describing activities, resources and the like. Therefore in practice they are often stored in separate information elements, associated with described entities by a relationship “many to 1”. In the EPC II theory such a way of recording parameters is a norm. The proper structures of information on parameters of various entities have been introduced in [4]. It has been noticed that options of enumerative parameters may be used also to label distinct values of continuous process parameters. Furthermore, the new concepts of associative parameters, as well as parametric (option) activities and resources, have been introduced. Certain kinds of information on parameters were introduced in [4] with a shortened, out of necessity, justification. Therefore next publications on that topic are needed. In particular, one should verify if the lists of associative parameters of activities and resources are the main information kinds.
Comparisons of the EPC II theory with current standards of business process modeling and management

Introducing new results of scientific research always requires comparisons with the current state of knowledge. If research belongs to one, definite field of science, then all its results should be immediately referred to concepts and regularities, which are already known. However in the case of the interdisciplinary theory the multilateral comparisons of all details would change publishing new results into comparative analysis of different points of view on well known problems. The EPC II theory belongs partially to management engineering, production engineering, automation and software engineering. Therefore in previous publications it has been paid more attention to the integrity of successively presented results, whereas comparisons with other approaches to discussed problems have been left to future work. The first comparative papers should be dedicated to relations of the EPC II theory with

- the MRP II standard [8],
- the ISA-95 standard [15],
- the standards of BPMN [16], WFM [17] and YAWL [18].

From the thesis on generality of the EPC II theory one can conclude that all concepts defined in standards MRP II, ISA-95, BPMN, WFM and YAWL have their own representations among its concepts. One can prove it (or demonstrate a counterexample), because the sets of concepts defined in these standards are – like the set of the main information kinds – finite and known. Moreover each of these concepts formally corresponds – like for concepts of the EPC II theory – to a definite class of entities. Therefore it is enough to demonstrate that each of these classes is mutually univocally related with the table already belonging to the framework EPC II system or with the table, which may be created as a subclass or a natural join of tables selected from this system or as a projection of such a table on its selected columns [10].

The last edition of the MRP II standard [8] has been published in 1989, but it is still relevant, because MRP II systems are kernels of all contemporary ERP systems [22]. The set of files, presented in the part IX of the manual [8] together with their columns, is a formal picture of concepts of this standard.

Functions, which are described in the ISA-95 standard [15], belong in the EPC II theory to administrative activities. So their list is a subset of the table of activity kinds A, which is one of the main information kinds [4]. Most other concepts of the ISA-95 standard correspond to classes of objects presented in the object models [15, 27], which are a simplified form of the class diagrams in the UML notation [6].

The standards of BPMN, WFM and YAWL may be compared with the EPC II theory together, because their mutual relations have been widely discussed in [18]. Definitions of concepts, which are specific for these standards, are presented in [16–18]. Also chapters 13 and 14 from [18], which are dedicated to comparisons of the YAWL standard with the BPMN standard and with the EPC (Event-Driven Process Chains) method of modeling business processes [19], are a good source of information for their comparisons with the EPC II theory.

The state of EPC II systems

The state variables in the classic control theory [26, 28] are coordinates of the state vector, whereas in the EPC II theory – they are attributes of information elements, i.e. fields of rows in tables of a database [4]. In the relational model it is easier to formulate relationships between different state variables and to modify the structure of these relationships. However it is more important that in the description of the state changes in EPC II systems there are no other variables apart from state variables. Their values are read and written to the database by transactions which are executions of transitions.

The execution time of transactions is neglected and theoretically it is equal to zero. On account of transactions and data processing phases [1] one should distinguish

- the state at a given instant of the discrete time, which is the state after executing all data processing phases at this time instant,
- the phase state – after executing a given phase – and
- the transaction state – after executing a given transaction in the database of a given EPC II system.

The tables of corresponding to them state variables are the main information kinds. Cause-result dependencies between variables are recorded in the form of transition procedures, whose inputs are state variables read from the database and outputs – state variables recorded to the database in the course of transactions. So apart from the state variables there are no other inputs neither outputs.

On account of specificity of the EPC II systems state one should verify, whether definitions and statements of the classic control theory, referring to stability and controllability of control systems with the discrete time, apply also to the EPC II systems. Incorporation of EPC II systems to the research area of
the control theory could lead to creation of tools for precise evaluation of quality of operational management in enterprises, including precise evaluation of their stability. At present most statements concerning stability of management systems have intuitive nature, whereas attempts of scientific analysis of this problem are fragmentary in character. As an example one can point out the thesis on stability of the follow-up scheduling of repetitive production [25].

Conclusions

According to the thesis on generality of the EPC II theory each system of management or process control, irrespective of the trade and size of the enterprise, in which it is implemented, may be replaced, retaining all its functions and data, with a corresponding EPC II system, whose structure is the same as for the universal framework EPC II system [4]. The way of verifying compatibility of both data structures has been presented above for the example of recording costs of using human resources in subsidiary accounts of a financial accounting system. Analogously one can demonstrate (or show counterexamples) that all concepts defined in current standards of business process modeling and management, including standards of MRP II [8], ISA-95 [15], BPMN [16], WFM [17] and YAWL [18], are special cases of corresponding notions of the EPC II theory.

On the other hand, in the EPC II theory classification of these notions and relationships between them are different than for those standards. Certain differences result from the interdisciplinary nature of the EPC II theory, which enables recognizing relationships between concepts derived from different standards. There are also differences resulting from the lack of simplifying assumptions, concerning relationships between notions of processes, resources and organizational units. Furthermore it should be noticed that the notion of the state of EPC II systems is defined in a new way, which is beyond the area of the classical control theory.

Owing to specific definitions of the basic concepts the EPC II theory better explains the structure and the rules of acting of real business process control systems. In particular

- it explains relationships between business processes and business transactions,
- it demonstrates that the framework functional structure of integrated management systems is the same on each organizational level of an enterprise,
- it presents clear rules of business process reengineering and designing virtual organizational systems,
- it demonstrates that for control of continuous and discrete manufacturing processes one can apply systems of the same structure, but with different decision procedures,
- it presents simple rules of control of transactions order, including controlling the order of data processing phases,
- it presents a unified description of various parameters of activities and resources.

Consequently, the EPC II theory enables solving certain practically important problems, which previously seemed to be too difficult. The most important of them are the following ones:

- designing the universal framework system of management and process control for enterprises of different trade and size,
- automatic adaptation of management systems software to structural changes of business processes, i.e. the problem of “business-IT divide”,
- control of interaction of production, preparatory and administrative processes.

From the viewpoint of practice the EPC II theory may be considered as a description of the framework EPC II system. The results of the EPC II theory that have been obtained till now fully justify practical usefulness of this system and moreover they show how to start work on its prototype.

References


