Entity Flow-phase Analysis for Fast Performance Estimation of Organisational Process Systems

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Abstract: This paper describes Entity Flow-phase Analysis (EFA) which is a method for fast performance estimation of organisational process systems. Entity Flow-phase Analysis extends the approach of the promising Traffic-Flow Analysis (TFA) method – created for the rapid analysis of communications networks – for BP (Business Process) systems. EFA operates on the possibilities determined by the *similarities* between communications networks and BP systems and introduces new solutions for the problems that occur because of the differences between ICT and BP systems. EFA, similarly to TFA, uses the combined approach of simulation and numerical methods. In simulation projects initiated to support the design of Information and Communication Technology (ICT) system and Business Process (BP) system in an organisation the parallel analysis of different systems may be efficient. EFA is a promising evaluation method to be applied for systems with determined BP and ICT subsystems in an organisational environment.

Keywords: Entity Flow-phase Analysis, Traffic-Flow Analysis, Information and Communication Technology, Business Process, process modelling, parallel simulation, discrete event simulation

1. Introduction

1.1. Mixed simulation projects

Simulation projects aimed to support the design of Information and Communication Technology (ICT) and Business Process (BP) systems in an organisation traditionally are independent, separate projects, in spite of the fact that these systems may have significant influence on each other. Common analysis of these systems may have advantages but in this case we need to have methods appropriate for both types of systems.

The Entity Flow-phase Analysis (EFA, first defined in [9]) serves for the fast performance evaluation of BP systems (more generally: organisational process systems) has been derived from Traffic-Flow Analysis (TFA, [7]). This derivation of EFA is based on the formal similarity of DES models of ICT and BP systems. EFA uses the same two phase method as TFA, only the interpretation of the model elements is different.

The *expected advantages* of the new modelling method are:

- EFA – which is a fast (and approximate) simulation like method – is *expected to require significantly less* time for execution then the event-by-event simulation of the BP. This feature, allowing generating a large number of experiments, may help to use the EFA method for increasing the efficiency and effectiveness of the simulation process**,** by understanding the *complex* features of BP systems and by defining the features and *limitations* of *Discrete-Event Simulation models* of BPs.

- EFA may allow of building *online simulation models of BPs* by using data of some enterprise ICT systems.

- EFA together with TFA is a set of methods which may form a homogenous fast modelling and simulation method-environment for *common analysis* of interconnected *ICT and BP systems*.

1.2. Business processes and business process systems

There are some known, basic definitions of business processes:

By the definition given in [4], *processes* are structured, measured sets of activities designed to produce a specified output for a particular customer or market. According to another definition, a *business process* is a partially ordered set of Enterprise Activities which can be executed to realise a given objective of an enterprise or a part of an enterprise to achieve some desired end-result [11]. In enterprise (organisational) modelling, a business process is defined as a network of actions performed in context of one or more organisational roles in order to achieve some goal [6].

According to the descriptions above, for modelling purposes, the business processes may be defined as follows:

Business processes are related to enterprises and they define the way in which the goals of the enterprise are achieved. A *Business Process (BP)* is a set of Enterprise Activities linked together to form a process with one or more kinds of input to produce outputs. A *process system* (BP system) is a set of business processes linked together to perform some Enterprise Function or Subfunction [9].

Business Processes may be characterised by the character of their *structure* (the *ad-hoc* and *permanent* processes) and by the character of their *frequency of execution* (the *cyclic* type processes are executed repeatedly, the *non-cyclic* type processes are executed once). The functional BPs in the decreasing order of their frequency of execution are the following ones: the processes of operations, finance, marketing and R&D [10].

The object of examination is the BP with permanent (or changing in a probability manner) structure and with cyclic execution. (For the analysis of the BPs with ad-hoc structure and non-cyclic execution may be examined using for example the PERT (Program Evaluation and Review Technique) method.

The BP systems usually are *complex systems* in their nature. In order to exceed naive, poor modelling in *current* (*traditional*) *simulation* of BPs, the *advanced simulation* approach of BPs should be based on the thorough analysis of *secondary (historical)* data (data, logs, models, etc.) and *primary* data on *structures*, *resources, loads* and *timing* relations of BPs too [1]. The *static model* of BPs – containing information on the structure of BPs with the definition of activities – may be described and found in many forms: in forms of Flow Charts, IDEF0 (Integrated Definition for Function Modelling) models, UML (Unified Modelling Language) diagrams, or in form of a model of a modelling and simulation tool (for example ARIS) [11]. Information on *resource*s – both on human and technical resources – allocated to BPs may be found in some systems of MIS (Management Information System) [3]: for example in the ERP (Enterprise Resource Planning) system and in the ABC (Activity Based Costing) system. Data on *load* and *timing* relations for BPs may be got the from CRM (Customer Relationship Management) system, from the WFMS (Workflow Management System) or from the ABC system.

In order to collect the sufficient information for modelling and simulation of BPs, usually primary information should also be collected (it may require, for example, measuring in some system, making interviews, etc.).

1.3. The Traffic-Flow Analysis

The *Traffic-Flow Analysis* (TFA) [7] (about the convergence of TFA: [8]) is a simulation-like method for the fast performance analysis of communication systems. TFA uses statistics to model the networking load of applications.

In the *first part* the method distributes the traffic (the statistics) in the network, using routing rules and routing units.

In the *second part* the influence of the finite capacities (line and switching-node capacities) is calculated.

The important features of TFA:

- The results are approximate but the absence and the place of *bottlenecks* is shown by the method.
- The *execution time* of TFA is expected to be significantly less than execution time of detailed simulation of the system.
- TFA describes the *steady state behaviour* of the network (there is no need for warm-up time definition).

2. DES-P Model Elements in EFA Models

The Discrete-Event Simulation (DES) [2] model of a BP (we call it DES-P model) is for the event-by-event simulation of the BP. The EFA model – which is intended to serve for fast, approximate modelling and simulation of a BP – is a set of functions within the DES program and uses the DES model and the DES engine. Therefore, at this point, the features of DES-P models (important for EFA modelling) are overviewed.

2.1. Activities, links and entitiy generation

The Business Process (BP) model is a set of *activities* and *links* connecting the activities together.

The *entity* represents an *elementary task* (*case*) that is executed by an activity. An entity could be (or could not be) executed by an activity depending on the *type* of the entity.

The *links* are *logical connections* between activities with a *direction* showing the performance order, the direction of the travelling of entities. The links have no capacity limit because of their logical character.

The *entity-load* of the BP is produced by *entity-generators*. The different types of entities are produced by different entity-generators.

The entities enter the BP model at its *entry* points and leave the BP model at its *exit* (*result*) points. The destinations of entities are the *exit* points of the BP model.

Between the entry and exit points of the BP model, *exit-entry* point pairs can be inserted into the BP model for an entity type.

Two or more BP can be connected by links to form a *BP system*. *Internal links* are connecting the activities inside a BP; *external links* are connecting activities of a BP system.

Remark: The entity generation in DES-P may be implemented in a *General Entity Generation Model*. This model should describe the structural and time features of entity generation by a set of *profiles* (for all the *typical* end *extreme* situations) for different entity types. The entity generation may have *offline* and *online* (having input from some ICT system) components.

2.2. Entity routing decisions

Similarly to communication systems, there is a routing of entities in the BP model, according to activities and the links connecting the activities. Entity routing depends on business process decisions. A routing decision may be made using different algorithms:

- *Percentage distribution*: the destination of an entity is decided according to the probability distribution of the possible entity outputs.

- *Entity-feature distribution*: output for an entity is chosen by some *feature of an entity* (for example type, priority, etc.).

- *Load-balancing distribution*: output for an entity is chosen on the basis of some load-balancing algorithm (including some quantity-limit consideration too).

Remark: The modelling of routing in BP systems may be different from those in ICT systems, because routing rules frequently can be defined less exactly, with more uncertainty (for example links between activities may show an uncertain character).

2.3. Special elements for entity routing and generation

There may be some other *special elements* in the model influencing the generation and routing of entities:

- *Fork* element makes copies of an entity (this is a parent-child relationship) and routes the copies to outputs in a parallel way. The pair of the Fork is the *Join* element that collects the entities divided by Fork element into one entity. The delay of an entity collected by Join equals the maximum delay of entities routed by Fork.

- *Split* element also makes copies of an entity and routes the copies according to the output links of the element but the split entities will not be collected into one entity again. Split generates entities, which will have separate ways in the process.

- *Transform* element may change the features of an entity in the process.

Remark: The influence of the Fork-Join, Split and Transform elements may be taken into account by inserting an *exit-entry point pair* for the entity.

3. EFA model elements

The EFA method uses the same *two-stage* organisation of work like TFA:

- In the *first stage, the entity-load* (the statistics) is distributed (using routing rules) in the business process.

- In the *second stage,* the influence of the *capacities of activities* is calculated.

3.1. Modelling the entity-load in EFA

In EFA, the *entity-load* is modelled by *throughput* and *delay* distributions: the *entity-load* is described by the throughput distributions of the *original entity-throughput* ($p_T^{\{o\}}\,[l]$), the *steady state* entity-throughput ($p_T^{\{s\}}\,[l]$) and of the *resulting* entity-throughput ($p_T^{\{c\}}\,[l]$) and by the delay distribution of the *entity-delay* ($p_T^{\{d\}}\,[i]$).

The *original* entity-throughput distribution (1) denotes the probability that l entities *arrive* to the activity in T time where L is the random variable of the *load* which assumes values denoted by l ($l = 0,1,2, \ldots$).

$$p_T^{\{o\}}\,[l] = P_T^{\{o\}}(L = l),\ \sum_{l=0,1,2,\ldots} p_T^{\{o\}}\,[l] = 1 \tag{1}$$

The entity-throughput distribution of *steady state* (2) denotes the probability that l entities *require execution* (*service*) by the activity in T time after the distribution of the entity-load. The entity-throughput distribution of *steady state* shows the result of summation of the distributed entity-load.

$$p_T^{\{s\}}\,[l] = P_T^{\{s\}}(L = l),\ \sum_{l=0,1,2,\ldots} p_T^{\{s\}}\,[l] = 1 \tag{2}$$

The *resulting* entity-throughput distribution (3) (calculated by taking into account the finite capacity of the subsystem performing the activity) denotes the probability that l entities are *executed* (*serviced*) by the activity in T time.

$$p_T^{\{c\}}[l] = P_T^{\{c\}}(L = l),\ \sum_{l=0,1,2,\dots} p_T^{\{c\}}[l] = 1 \tag{3}$$

(The three throughput distributions defined above – similarly to TFA[1] – represent different stages of the execution of the EFA method but there is only one type of throughput used in EFA while TFA has bit throughput for lines and packet throughput for nodes.)

The *delay* distribution denotes the probability that entities – taking into account the finite capacity of the subsystem performing the activity – are *delayed* by i number of T long time intervals where D denotes the random variable of entity-delay.

$$p_T^{\{d\}}[i] = P_T^{\{d\}}(D = iT),\ \sum_{i=0,1,2,\dots} p_T^{\{d\}}[i] = 1 \tag{4}$$

The *T parameter*[2] in the formulas above describes the size of the *throughput collection interval* and gives the *resolution* of the examination. If the value of T is defined too big compared to the change of the speed of entity generation then it will not show the change within the interval and if it is defined too small than it may result in too big amount of data for modelling. In the process analysis, a typical value to describe the speed of entity generation is an hour, but for example in case of Callcenters it may be one minute and in case of ICT-BP connections the typical value may be measured in seconds too.

The entity-load model of EFA should meet the following requirements:

- The *entity-load model* should describe the intensity and the time distribution of the entity-load.
- The entity-load model should have the feature of to be *closed* for the operation of *addition* that is the result of addition is of the same type as of its components.
- The entities of the same type, *between the entry and exit points* of the given entities can be handled together, in arbitrary order, in units of arbitrary size, grouped in an arbitrary way as *aggregated entity-load*.

Remark: The Size of Routing Unit (S_{RU}) is a feature of the entity-load model and describes the size of the unit of entity-load of a given type of entity that can be handled together.

[1] TFA uses a *continuous* approach in which the PDF (probability density function) of throughput (and PDF of delay) is approximated by a histogram, while according to the *discrete* approach in EFA, throughput (or delay) distribution is a PMF (probability mass function).
[2] The considerations about the value of the T parameter for TFA can be read in [7].

3.2. Modelling the capacity of activities in EFA

3.2.1. Activities, resources, capacities

Now, let us examine the *capacity of activities* from the point of view resources assigned to the activity.

Activity in the BP model may be viewed as a *subsystem* with its assigned resources performing the activity. In general, for the execution of the elementary task (represented by an entity) there should be allocated the necessary *technical resources* and a *set of human resources* to the subsystem (activity). The resources are used in a specific way determined by the activity to create the capability – which can be characterised by the capacity of activity – for the activity to be able to execute the elementary tasks.

The *capacity* of an activity is the *measure* of the *performance* of the subsystem in the execution of the elementary tasks.

The set of human resources act as a *group* – using the necessary and provided technical resources assigned to the activity – cooperating in a way depending on the activity in order to perform the activity. The *capacity of an activity* depends on the set of human resources allocated to the activity supposing that the *necessary technical resources are assigned* to the activity. The set of human resources of the activity may be characterised by the *type* and *quantity* of resources (as general features) and also by *activity-specific features* both on personal and on group level (for example features that can be described by *learning curves*). The *influence* on the capacity of the same type and quantity of human resource may be different in different activities.

The *transformation* of *a set of human resources* with given *types* and *quantities* into the capacity measure of a given activity (supposing that the required condition of technical resources for the performance of human resources is provided) requires a careful approach. The *calculation* of the capacity of an activity can be based on the analysis of *historical data* about the performance of the given activity with its assigned resources. (The historical data for the analysis may be for example, data collected by the ABC (Activity Based Costing) and CRM (Customer Relationship Management) systems.)

The *availability* of human resources required by an activity is changing in time and may be described in a probability manner in the following way:

- $P_{R_n}(R_n, week, day)$ – is the *Available Resource Value* of *type n* – for a given week of the year, and for the given day of the week, (this probability may be determined by the analysis of historical data for a longer time interval)
- $E(R_n)$ – *Expected Value* of the *Available Resource* of type *n* – for a given period

3.2.2. Analysing the behaviour of resources in BPs

The behaviour of resources assigned to the activities from the point of view of human resources will be examined below.

The BP is *embedded* into the environment formed by the *organisational structure*. Let us examine the *resource assignment* of an enterprise department which is a structural unit of the organisation (*Example 1*). In this case let the department be the *subsystem* dedicated for performing an activity of a BP. A frequent way of improving the efficiency is that a department – assumed critical – may *borrow* resources *temporarily* from other department(s) assumed non-critical. The result is that the amount of resources of the non-critical department(s) temporarily will *decrease*. In this case, it may be *observed* – if the loads of departments (entity-loads of activities) are independent – that the amount of resources of the non-critical department(s) will change *independently* from its load.

Let us examine the *change of resources* assigned to activities as the result of influences between business processes (*Example 2*). Let us analyse the following example: There are two *business processes* which have a common part in the set of resources (resources of their activities), some common elements in the set of loads, and may have different priorities for the access to the common set of *resources*. In this case, there may be *observed* different types of *correlation* between the change of the load and the amount of resources of the processes (thus in the amount of resources of their *activities*): for the process with *higher* priority for the access to the common set of resources there may be a *positive correlation* between the load and the amount of its resources, and at the same time for the process with *lower* priority for the access to the common set of resources there can be observed a *negative correlation* between the load and the amount of resources that can be used. The mutual influences between these processes may lead even to *curvilinear correlation* between the load and the amount of resources: negative type correlation and positive type correlation may exist between the load and the amount of resources used by a process for subsequent periods if the *priority* for the access to the common set of resources is changing (for example depending on some state of the BP system).

3.2.3. Requirements for the resource and capacity model of activities

The *resource and capacity model* of EFA should satisfy the following requirements:

- The effect of a given value of the *capacity of an activity* (capacity of the subsystem performing the activity) on the *time distribution of the entity-load* can be calculated.

- The *capacity of an activity* is defined by and can be calculated taking into account the *resources* assigned to the activity (to the subsystem performing the activity).

- The model of *resources* (measuring the quantity of resources) should be closed for the operation of addition in the case of resources of the same type.

- The *resource quantity* assigned to an activity can be decreased and the *subtracted* resource can be added to the resource of the same type assigned to other activity of the BP model.

- The quantity of a resource assigned to an activity cannot be negative.

- The same resource cannot be assigned to two activities at the same time.

Remark: The requirements above concerning the resources are formulated with the assumption that the *necessary technical resources are provided for the activities* thus they describe the requirements for the *human resources*.

3.3. Activity-Capacity Model

The *capacity of an activity* may be defined in the following way: The *capacity C* of an *activity* takes the value *K* if the (*maximum*) number of the *elementary tasks* (entities) that can be *executed* by the activity in the *T* interval is *K*.

3.3.1. Activity-capacity modelling: Constant capacity model

If the value of the *capacity* of an activity is a *constant* then the *resulting entity-throughput* ($p_T^{\{c\}}[l]$) and *delay* distribution ($p_T^{\{d\}}[i]$) can be calculated according to the formulas described for TFA:

$$p_T^{\{c\}}[l] = \begin{cases} p_T^{\{s\}}[l], \ l < K \\ \sum_{l=K}^{\infty} p_T^{\{s\}}[l], l = K \\ 0, \ l > K \end{cases} \tag{5}$$

$$p_T^{\{d\}}[i] = \begin{cases} \sum_{l=0}^{K} p_T^{\{s\}}[l], i = 0 \\ \sum_{l=iK+1}^{(i+1)K} p_T^{\{s\}}[l], i \geq 1 \end{cases} \tag{6}$$

where *K* is the value of the constant capacity of the activity

3.3.2. Activity-capacity modelling: Probability distribution model

Let us examine the possibility when *the capacity of the activity* is *not a constant* and the *capacity* and of the activity is *changing independently* from its load (see Example 1 in 3.2.2.).

In this case, a *probability distribution of the capacity of activity* may be used to model the changing capacity of the activity:

$$p_j = P(C = K_j), \ \sum_{j=1}^{N} p_j = 1 \tag{7}$$

where p_j is the probability that the random variable of the capacity *C* assumes the value K_j, *N* is the number of different values that the capacity of the activity can take, and the set of events that the capacity of the activity takes one of the values $K_1, K_2, \ldots, K_N$ is *jointly exhaustive*. For the modelling, the value of *N* should be limited to a reasonably small number. For this purpose, the capacity values with low probability may be replaced, for example, according to the following formulas (supposing that the capacity values $K_1, K_2, \ldots, K_{N-1}, K_N, K_{N+1}, \ldots, K_n$ are ordered according to the decreasing probabilities ($p_1 \geq p_2 \geq \ldots \geq p_{N-1} \geq p_N \geq p_{N+1} \ldots \geq p_n$) :

$$K_N^* = \frac{\sum_{j=N}^{n} p_j K_j}{\sum_{j=N}^{n} p_j}, \ p_N^* = \sum_{j=N}^{n} p_j \tag{8}$$

where K_N^* is the value replacing the low probability values $K_N, K_{N+1}, \dots, K_n$ and p_N^* is the probability of K_N^*. (Thus, the expected value of the capacity will not change.) If the replaced capacities have very different values then there can be used different replacing values for different intervals (clusters).

Depending on the *speed of the change of C (quick or slow)* there can be used different approaches. The change of C is *quick* if C *may* take different values in the examined time interval of the throughput distribution. For the case of the *quick* change, the *total probability theorem* may be applied for the *resulting entity-throughput* distribution:

$$\left[p_T^{\{c\}}\,[l]\right]_{K=K_j} = \begin{cases} p_T^{\{s\}}\,[l],\ l < K_j \\ \sum_{l=K_j}^{\infty} p_T^{\{s\}}\,[l]\ , l = K_j \\ 0,\ l > K_j \end{cases} \tag{9}$$

$$p_T^{\{c\}}\,[l]\ = \sum_{j=1}^{N} \left[p_T^{\{c\}}\,[l]\right]_{K=K_j} p_j \tag{10}$$

(where N is the number of different values that the capacity of the activity can take in case of the quick change)

and for *the delay* distribution too:

$$\left[p_T^{\{d\}}\,[i]\right]_{K=K_j} = \begin{cases} \sum_{l=0}^{K_j} p_T^{\{s\}}\,[l]\ , i = 0 \\ \sum_{l=iK_j+1}^{(i+1)K_j}\ p_T^{\{s\}}\,[l], i \geq 1 \end{cases} \tag{11}$$

$$p_T^{\{d\}}\,[i] = \sum_{j=1}^{N} \left[p_T^{\{d\}}\,[i]\right]_{K=K_j} p_j \tag{12}$$

If the change of the value of the capacity of an activity is *slow* then the capacity of the activity may be determined for each simulation run using the *probability distribution of the capacity of activity* distribution. (The change of C is *slow* if C is changing but it may be approximated by different constant values for the examined time intervals of the throughput distribution.)

If the *variance* of *the capacity of an activity* is small, then the expected value of the capacity (m) may be used:

$$m = E(C) = \sum_{j=1}^{N} p_j\, K_j \tag{13}$$

In this case, for example, the distribution of the *delay* may be calculated as:

$$p_T^{\{d\}}\,[i]\ = \begin{cases} \sum_{l=0}^{[m+0.5]} p_T^{\{s\}}\,[l]\ , i = 0 \\ \sum_{l=[mi+0.5]+1}^{[m(i+1)+0.5]}\ p_T^{\{s\}}\,[l], i \geq 1 \end{cases} \tag{14}$$

(In the formula, the value $[m+0.5]$ is used which is the value of m rounded to an integer.)

3.3.3. Activity-capacity modelling: Regression model

For the case, described in *Example 2* (in 3.2.2.), a *regression model* – based on the *analysis* of *historical data* – may be used to establish the relationship between the capacity and the load of the activity.

For this case, the *simple regression linear model* has the following form:

$$C = (\alpha + \beta L) + \varepsilon \tag{15}$$

where C is the capacity of activity (dependent variable), L is the load of the activity (independent variable), α is the population intercept, β is the population regression coefficient, and ε is the error term.

The observed value of activity capacity in *j*-th observation may be expressed by the equation:

$$c_j = \hat{c}_j + e_j \tag{16}$$

where c_j is the observed (measured) value of the capacity of activity, $\hat{c}_j$ is the *estimated* (calculated by regression) capacity for the given (observed, measured) load of activity, and e_j is the random error. The *estimated* capacity may be expressed as:

$$\hat{c}_j = a + b\, l_j \tag{17}$$

where *a* is the least-squares intercept (*estimator* of α), *b* is the least-squares regression coefficient (*estimator* of β), and l_j is the *j-t*h observed value of the load of activity (*j=1,2, ..., n*, where *n* is the number of observations).

For the values of *l* different from the observed values, the capacity of the activity may be *predicted* using the regression for interpolation or extrapolation.

A possible way of improving the quality of the regression model of the activity-capacity may be to include the load of other activities into the set of independent variables in order to take into account influences between activities. For this case, the *multiple regression linear model* may be described as follows:

$$C_i = (\alpha + \beta_1 L_1 + \beta_2 L_2 + \ \dots + \beta_v L_v + \ \dots + \ \beta_k L_k) + \varepsilon \tag{18}$$

where C_i is the capacity of activity *i* (dependent variable) in the BP model, $L_1, L_2, \dots, L_v, \dots, L_k$ are the independent variables (where L_v is the load of activity *v*, *v=1,2, ...,k*, *k* is the number of independent variables), α is the population intercept, $\beta_1, \beta_2, \dots, \beta_v, \dots, \beta_k$ are the population regression coefficients, indicating the mean effect of each *L* on *C* (in the population), holding all other *L* constant, and ε is the error term.

The set of *necessary* independent variables is proposed to include the loads of activities in the model of BP (system). The number of the *necessary and sufficient* explanatory variables can be determined in the *regression diagnostics* procedure. In the regression diagnostics, the *goodness of fit* of the regression model and the *statistical* *significance* of parameters is examined, for example, using the following methods (Siegel 1994): *R-squared analysis* to determine the variability in C explained by the L variables as a group, *F-test* to check the statistical significance of the overall fit. If the *F-test* is significant then *t-test* can be used to examine individual regression coefficients, to see whether a particular L variable has an effect on C, holding the other L variables constant, to decide about the load of a particular activity as an explanatory variable to remain in the regression model.

In case of *non-linearity* in regression, in order to decrease the amount of computing, a *segmented linear regression* method – for example the method of the *multivariate adaptive regression splines* [5] – is proposed to be used.

Remark: In the capacity models, the availability of resources of a given activity should be taken into account too (see 3.2.1.).

4. Executing the EFA method

4.1. Stages of the EFA method

The work of the EFA method is divided into *two stages*:

Stage I: Distribution of the entity-load in the process (*spatial distribution*)

- Generation of entity-throughput statistics and sending them to the activities according to the routing decisions of the process in units determined by the S_{RU}

Stage II: Calculation of the influences of capacities of activities

- Summation of the distributed statistics

- Determination of the capacities of activities (Depending on the behaviour of resources in the process there may be used *constant* or *changing* capacities of activities. To model the changing capacity the *probability distribution* model or the *regression* model may be appropriate.)

- Calculation of the influences of the defined capacities (calculation of the resulting entity-throughput and delay distributions)

4.2. One-phase and multi-phase execution of EFA

The *spatial distribution in EFA* (*Stage I*) may be executed in two ways:

According to the *One-Phase Method,* the entity-load is distributed to every activity in one phase

According to the *Multi-phase Method,* in one phase the distribution of the entity-load is performed for activity group featured with equal distance from the entry point (The distance is determined by the number of activities on the route.) In Multi-phase Method, the step *Stage II* is executed for every phase. (The *Multi-phase Method* can be an efficient, for example, in case when the routing in BPs should take into account the changing capacities of activities.)

For the *Multi-phase Method*, it is proposed to take into account some constraints: There should be one entry point for the entity generation, the BP model proposed to be built in a way that there could be no big differences between the execution times of activities in one phase and the activities of one phase should get all their distributed entity-load.

Remark: The feed-back in the model may be taken into account as an entity-load proportional to the input of the related activity.

4.3. Features of the EFA method

- The method has the possibility of *parallelisation*: the calculations for different activities may be executed parallel by multiple processors.
- The speed of EFA can be increased using Routing Units. Changing S_{RU} is a tool to find the compromise between *accuracy* and *speed.*
- The results of EFA are approximate but the *critical paths* may be determined by the method.
- EFA shows the *steady state work* of the process (thus there is no need for warm-up time definition). The transient behaviour of processes may also be examined using a series of EFA runs.

4.4. The power of the EFA method

The combination and interworking of EFA method with TFA and DES models of ICT and BP systems may result in more accurate modelling, better simulation results and may also give a good chance to efficient parallel execution of the simulation of a system containing ICT and BP parts, both in the phases of preliminary and detailed modelling and both for critical and non-critical parts of systems.

5. Conclusions

In this paper, we have introduced a new method for the fast performance analysis, EFA. The EFA method extends the TFA approach for business processes.

We have overviewed and analysed the usual DES elements in EFA models: activities, links, entity generation and entity routing.

We have defined model elements for EFA:

- we have defined entity-load model as the entity-throughput model,
- we have given formulas and methods for delay-time calculation by introducing *a new model of the capacities of activities of BPs*.

Using the introduced elements we have outlined two versions of EFA method: One-phase method for rapid analysis and Multi-phase method for a more precise fast evaluation.

We have given solution to the problem of possible feed-back loops in the examined process.

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