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THE CONCEPT OF PERCEPTION DRIVEN SERVICE PROCESS REENGINEERING BY ENTROPY REDUCTION

Abstract

The topic of rethinking, reorganizing or reengineering dysfunctional business processes has been approached from many aspects. However, methods and techniques are greatly diverse. Service processes do not get as much attention as their importance would deserve. One reason is the usage of production oriented methods for service processes. The other reason is the complexity of stochastic service processes. In these processes, it is usually hard to give strict and consistent parameters, indicators and even object functions. In our research, we offer a unified, heuristic mapping and simulation methodology for process simulation and improvement. In this paper, this problem is analysed from a very new aspect as the observed processes of the system are not considered as an essential argument of the examination. Instead the main elements are the nodes of the system, transactions and transformations. The second important aspect of the methodology is the quality and efficiency perceptions of internal and external users of the processes. Thirdly, not only cost efficiency and lead-times are applied in the object function, but also the reduction of process entropy. Based on empirical and literature researches, the basic conceptual framework is also presented. Examples would be such as the full mathematical model and a possible solution of the computational model with Mealy automatons.

Introduction

The domination of the service sector keeps growing in the world's largest economies as global statistics show in OECD and World Bank databases. Eichengreen and Gupta (2013) argue this as well. More than 63% of world GDP is produced by service sector (CIA, 2013) and this ratio is even greater in countries with higher GDP (more than 75%). This increasing importance has led us to examine recent business process amelioration methods. We also examine their usability and customization for service processes. This topic of business process improvement or re-engineering has a long history in business literature. The discussion topic has been present on the academic side and among managers. There is a lot of confusion and debate on this topic. The reengineering topic has not lost its actuality.

The concept of reorganizing dysfunctional business processes still exists even in the twenty-first century. Usually this is with new, more sophisticated tools and methodologies. Yet, it is still based on old principals. The narrowing markets, increasing competition and the recent economic crisis all stimulate companies towards continuous rationalization, cost reduction and increased efficiency. All of this is in order to gain some kind of comparative advantage which creates a basis for the development of methodologies of process improvement.

We found that these business process amelioration (BPA) methods and techniques are not clearly adoptable to service processes (Gubán & Kása, 2013). Despite the large number of BPA technologies and tools, efforts have tended to emphasize manufacturing applications over service operations. By now it has become apparent that the economies of even the most industrialized countries are becoming increasingly dominated by services. However, producing consistently high quality and efficient services has not received as much attention as in manufacturing firms (Mefford, 1993). The differences in the characteristics of manufacturing and services have led many managers to believe that successful BPA methods used in manufacturing are not applicable in service organizations. There is a lot of evidence, though, of using BPA tools tailored clearly for the service sector (see e.g.: Brahe, 2007; Sánchez-Rodríguez et al., 2006; Wüllenweber & Weitzel, 2007). Due to the lack of service standards, there is general success in the services. This makes the customer-focused approach of BPI inherently attractive for a service organisation. Hence, BPI methodologies have been widely disseminated and adopted, especially in the financial services and healthcare areas (Hammer & Goding, 2001; Hoerl, 2004).

The reason is not only the lack of tools, but also the specifications of services. Human intervention is common practice in services which results in a lot of hidden factors. Thus, the success of BPA in service organizations depends very much on the fit among interdependence. Also, the success depends on the strategy's content and process (Gubán & Kása, 2013).

Literature review

Before starting to elaborate a new technique for process amelioration (or just laying its fundamentals) basic techniques, methods and trends should be reviewed. We have analysed the current literature available in leading international scientific and academic journals. The sample of journals consists of Engineering and Process Economics, Engineering Costs and Production Economics, Journal of Operations Management, International Journal of Production Economics, European Management Journal, Journal of Management, Journal of Supply Chain Management and Production and Operations Management. In these journals, we inspected 1151 papers (between 1978 and 2013) that could be associated with process improvement, reengineering, rightsizing or management. Upon a closer look at the papers, we found 55 that can be associated with business process amelioration. In most cases, these papers show a case when one or more kinds of process reengineering tools were used. We also found many publications on methods and methodologies of process improving and reengineering. Also, a relatively high performance number of the tools and performance change due to this improvement. There is a relatively low number of papers in relevant journals on applications and theory. This might be because of the tendency towards a narrowing development of new tools.

Table 1: Relevant publications on BPA in the most influential journals

Application	Case	Methodology	Performance	Theory	Tools
- Clark & Hammond, 1997; - Jones, Noble, & Crowe, 1997; - Macintosh, 1997; - Williams, Tang, & Gong, 2000	- Arnold & Floyd, 1997; - Choi & Hong, 2002; - Currie, Michell, & Abanishe, 2008; - Done, Voss, & Rytter, 2011; - French & Laforge, 2006; - Houghton & Portougal, 1997; - McFadden & Hosmane, 2001; - Purwadi, Tanaka, & Ota, 1999; - Saccani, Johansson, & Perona, 2007; - Sarkis, Presley, & Liles, 1997; - Shivappa & Babu, 1997 - Ojanen, Piippo, & Tuominen, 2002	- Berry & Cooper, 1999; - Hill et al., 2002; - Perrone, Roma, & Lo Nigro, 2010; - Rolfe & Armistead, 1995; - Seidmann & Sundararajan, 1997; - Simons Jr., Wicker, Garrity, & Kraus, 1999; - Terziovski, Fitzpatrick, & O'Neill, 2003; - Tomlinson & Fai, 2013; - Upton & Kim, 1998; - Wagner & Neshat, 2010; - Weng & Parlar, 2005	- Da Silveira, 2005; - Das & Joshi, 2007; - Droge, Vickery, & Jacobs, 2012; - Goel & Chen, 2008; - Hegde, Kekre, Rajiv, & Tadikamalla, 2005; - Hendry, 1995; Jacobs & Swink, 2011; - Launonen & Kess, 2002; - Stahl & Zimmerer, 1983; - Kim & Jang, 2002	- Chan & Choi, 1997; - Edwards & Peppard, 1994; - Heineke & Davis, 2007 - A. V. Hill et al., 2002	- De Bruyn & Gelders, 1997; - Flynn, 1987; Karvonen, 1998; - Lillrank, Holopainen, & Paavola, 2002; - Lockamy & Smith, 1997; - Neiger, Rotaru, & Churilov, 2009

As we look at the temporal distribution of these publications, two trends seem to dominate. The first one is associated with the total number of publications on this topic. There was a major growth in 1990 after Michael Hammer published his article in the Harvard Business Review. He claimed that the major challenge for managers was to obliterate forms of work that do not add value rather than using technology for automation. (Hammer, 1990). This launched an avalanche in major journals. The number of papers is still growing after a peak in 1995 when the U.S. created Frankenstein Economy was implemented (Janszen, 1996). There was also major growth after the global financial crisis started to expand. The second trend seemed to begin in 1997. A great number of process improvement applications and tools were developed.

These were a product or summation of the strong interest in this topic in 1995 (Ettlie, 1997).

Temporal Evolution and the Development of Process Orientation of BPA Techniques and Methods

There is no doubt about the importance of the continuous amelioration of business processes. The driving forces of these radical changes can be interpreted as the extension of Porter's competitive advantages (Porter, 1980, 1985, 1990) summarized by Hammer and Champy (1993) and confirmed by O'Neill and Sohal (1999):

- customers who can now be very diverse, segmented, and are expectant of consultation,
- competition that has intensified to meet the needs of customers in every niche,
- change that has become pervasive, persistent, faster and in some markets a pre-requisite.

The evolution of BPA dates back to the first appearance of rudimentary process orientation between 1750-1970 with the beginning of the industrial period. The main focus of this embryonic process improvement phase was on labour division, cost reduction and productivity with technologies. Examples of these technologies were mechanisation, standardization and depth records. Their main tools were PDCA improvement cycle and financial modelling. Rightsizing and restructuring were also used for achieving changes in formal structural relationships. Their focus on business processes was pretty low (Grover & Malhotra, 1997). Their orientation is mainly functional, the improvement goals are usually incremental, and the frequency of application is isolated in time (Grover & Malhotra, 1997).

The next generation of process improvement is the first phase of information period dated from 1970-90. This is the era of quality management and work efficiency with such technologies as material requirements planning (MRP) and management information systems (MIS). The main tools of this period were computer automation and statistical process control. These tools refer to the typical application of technologies. The application focuses mainly on automating existing procedures without questioning their appropriateness or legitimacy (Grover & Malhotra, 1997).

The third generation is the second phase of the information period with business process improvement (BPI) dating back to the '90s. This is the era of process innovation and best practices with such slogans like "better, faster and cheaper". At this time, technologies such as ERP, CRM, supply chain models and enterprise architecture models were introduced. New tools were developed and used like Six Sigma, TQM, BPR and Best Practice Benchmarking (BPB). These tools and techniques have their focus on processes, and bottom-up improvements in many places with continuous and incremental scope.

The fourth generation is the third phase of information period with business process management (BPM) dating from the 2000s. The main focus of this era was on continuous transformation, flexibility and modularity. Enterprise application integration (EAI), service oriented architecture (SOA) and semantic object model (SOM), performance management systems (PMS) and BPM systems are the major technologies of this era. Tools also vary from customization to BPM procedures like integrated design-build framework (IDBF), benchmarking-oriented process reengineering (BOPR), business process standardization (BPS) and event-condition-action (ECA) computation. Some of these tools have a very intensive service orientation (especially SOA and ECA) while others tend to be adapted to services with general success (see Gubán & Kása, 2013 for more details).

This literature review suggests that numerous techniques and methods are available for business process amelioration. All of them are based on the concept of BPR. This concept is the creation of a blueprint of the process structure. Then, significant changes are made to reach better performance and a more harmonized process structure. In our terms, BPA means something different which can be described by *process logistification*.

Globalized Service Models affecting our research

Manufacturing and service companies differ mainly in the communication and interaction with customers. This results in a new approach because in production firms, corporate activity produces tangible, clearly identifiable and manifested goods (Réthi & Illés, 2012). Also, very often service companies are trying to establish cultures based on frequent interactions. As a consequence of this attitude, 'moment of truth' experiences multiply and front office employees will face substantial conflicts (Heidrich, 2006; Veres, 1998).

The global market expansion of standardization is called McDonaldization, based on Ritzer (Ritzer, 1993). The system in this case follows the work organization principles of Fordism and Taylorism. The company acquires competitive advantage from the productivity cost-benefits. The service providers standardize their processes so the output of the service is constant and always equal to the consumers' expectations. In this case, the higher volume of sales is crucial to reduce costs. This provides comparative advantage for the company. Consumers have pretty much accurate information on the standard service due to advertisements. Also, the information is based upon their own and their acquaintances' experiences. McDonaldized business processes can be repeated. Due to this, problems and errors arising in business activity can be effectively solved. However the reparability assumes the existence of trust, meaning that the provider will not commit an error again. The operating logic of McDonaldization as a system is basically divided into four dimensions: efficiency, predictability, reliability and control by technology (Heidrich, 2008; Ritzer, 2004; Veres, 2009).

Through the extremes of standardization of service processes, McDonaldized companies are getting increasingly similar to production-like companies. In the early 80s, the production approach related to the classical and neoclassical economic theories was dominant in the organization of work and corporate marketing. According to this dominant approach, the value is located in the material and generated through the manufacturing process (value added, utility, exchange value). Therefore goods and products should be considered as a standardized output (Réthi & Illés, 2012; Vargo & Lusch, 2004).

Customization is the exact opposite of McDonaldization. It is based on the foundations of marketing and service management. The user of the service expects to receive adequate service that meets his or her demands. The main difference from McDonaldization is that its objective is to satisfy the requirements and quality need of customers as accurately as possible. However, this needs special knowledge. In most of the cases, at the beginning of the process there are no known patterns to fulfil such requirements. Neither the provider nor the customer knows which solution will lead to the desired result. As the consumer does not have a certain idea about the service's output, he will simply accept the service process as a result. A further difference is that the methodology of the customization is based on special knowledge and high professional qualifications.

Workaround for the above mentioned two opposite approaches is the modularization (Sundbo, 2002). In this case, the firm that provides the service combines standardization and customization methods. Namely, products are manufactured and sold in large quantities, and on a fairly high price. The viability of the system requires that the company's process shall be build up by standard modules and these small changes create a sense of personal, customized service to consumers (Heidrich, 2008; Veres, 2009, 310-322). These services are in fact only partially tailored. Their preparation is standardized and becomes personalized only when consumer enters into the process. This model greatly relies on the evolving information technologies which allow the perfect functioning of the system. Apparently Disneyalization (Bryman, 2004) is the opposite of McDonaldization. However, the productivity-based service providers increasingly place their services at a physical and human environment resulting in a unique perceived consumption. The challenge of organizational operation and management is to make the service unique while productivity-based economic logic also can be observed. Disneyalization is not based on the principles of customization, but rather on the above-mentioned modularization. It re-packs such standardized service modules with some peripheral service combinations, which has low unit costs due to frequent use, thus providing a sense of customization (Heidrich, 2008).

A Disneyalized service gives the impression of uniqueness to the consumers. Thus it combines the features of a productivity-based economic activity and customization. With the rethinking of traditional products, the company can sell successfully in new industries. Also, this is true with low unit costs of the extra activities due to frequent usage. The performance of such complete services, though, requires a highly qualified workforce. This is in contrast to McDonaldization.

Research preliminaries and framework

The processes of economic systems, depending on their location in the system, may be different both in structure and in operating characteristics. Processes according to their location in the organization can be either production processes or logistical, information technology, information, business, management or marketing processes, and so on. However, they seem to show very large differences. In fact they have one fundamental thing in common: at least one object flows through each of the processes or sections of processes consuming partially or entirely the resources of the processes (Hammer & Champy, 1993; Lepmets, McBride, & Ras, 2012).

During our examinations, it was noticed that the efficiency of a process is exclusively determined by the object flowing in it and not by the functional department which it partly or fully incorporates. (Gubán & Kása, 2013; Kása & Gubán, 2013) It has been recognized that in many cases the explored processes of a system are not featured by the internal characteristics of the system, rather by earlier inheritances or bad habits which makes them dysfunctional and ineffective. A system works optimally when it involves only necessary and real processes and get rid of redundant, unnecessary elements (Buavaraporn, 2010). If these unnecessary elements could be "carved" from the system – like in sculptures- a really effective process system will arise which will be controlled and determined by the flowing elements of the system.

The hereby outlined research of effective system reorganization was started at the beginning of 2013 and a research team was formed with the name of LOST (Logistification and Simulation Technologies) in Services. The scope of this recent paper is the conceptualization of our findings on internal and external customers' perception driven research framework. This is in regards to business process amelioration (BPA).

Methodology and conceptualization
Perception driven processes

The very first task of our research is to clarify the key terms of the concept. For this, the notion of business process should be specified as it forms the basis of the research. As it is specially used in our research, the definition will be built up in several stages.

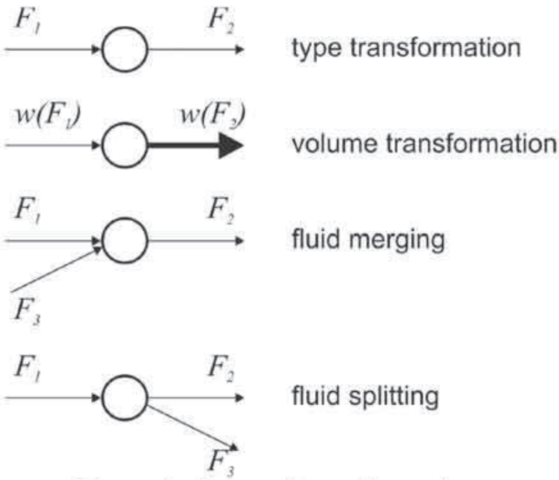

Figure 1. Types of transformations

Definition 1: A **node** is such an object of a system which is able to store *data* on any kind of transformation (input-output transformation or type transformation such as information → data) of any element. Also, a node is able to perform actions on related *functions* and *procedures* (creation of new elements, merging and even separating elements and eliminating). Hereinafter, these abilities are called node **transformation** (I/O transformation, new element, storage, merging, separating, eliminating). Such transformation where the type of input element and output element is different is called **type-transformation**. These possible transformations are shown in figure 1 below.

Definition 2: **Fluid** is such a tangible or intangible object which may *flow* between two not necessarily adjacent nodes of a system or may *develop* or *perish* (expire) on a node. Or, it may undergo a quantitative and/or qualitative *transformation*.

Definition 3: **Fluid flow** is a finite set of examined fluids that includes a determined *node sequence* (where the end-node of a fluid is a start-node of another fluid) in a specified *time interval*, the sequence of node transformations, the entry and exit type-transformations and the time structure together. A fluid flow in $[t_s; t_f]$ time interval can be described by the following sequence:

$$F(d;\tau;w)_{[t_s;t_f]} = \langle (c_{i_0 j_0};\tau_0;w_0;t_{s0};t_{o0});(c_{i_1 j_1};\tau_1;w_1;t_{s1};t_{o1});\dots;(c_{i_m j_m};\tau_m;w_m t_{s1};t_{o1})\rangle \quad (1)$$

where $(c_{i_l j_l};t_{sl};t_{ol}): l = 1;\dots;m+1$ means that the fluid entered into the $c_{i_l j_l}$ node of a certain process with τ and τ_{l-1} status and with the type's w and w_{l-1} weight value. The outgoing fluid has τ_l type and w_l weigh. The other two parameters represents the time of node entry and exit, where $t_{sl} \leq t_{ol} \in [t_s;t_f]$ as well as $t_{ol} \leq t_{sl+1}$. Obviously in sequence $\check{C}(F) = \langle c_{i_0 j_0};c_{i_1 j_1};\dots;c_{i_m j_m}\rangle$ a certain node may appear several times, however as a connotation of definition 3 the sequence of nodes is finite. Thus $|\check{C}(F)|$ refers to the number of nodes in the sequence.

By means of the above definitions the relevant (business) processes can be described. (Hereinafter the term process will be used instead of business process. It is not ambiguous, since process is used only in this sense.)

Definition 4: **Process** is a batch of a fluid flow with its interconnections that is arbitrarily and/or intentionally treated as a single unit by a business organization. Process is an abstract notion in all cases which includes a model showing the structure of the process. This model will be the subject of examination in our research.

Definition 5: A **process item** is real series of activities implemented on the basis of real demands.

The above definition for process items fits in our framework, but seems to be too general. The reason is that business organizations develop their processes by some kind of management methodology techniques. This is also true for production, logistics, and even financial and accounting processes. Our previous studies have proved that every process is guided by users' perceptions. Whether external or internal users, their requirements guide processes in every node of the system. Similarly, there is a (not necessarily human) user in any node (like a robot on the assembly line) whose needs, "orders" must be satisfied on the input side and provides different outputs.

Definition 6: **User** is an entity who may establish a claim to a process or a process section even from outside, either from inside of a system.

Users in the system cannot be considered simply as a regular customer. These users (which may be either machines, or robots) like to be influenced by their perceptions determined by their characteristics in their requests and orders. Obviously the interpretation of costumers' perceptions is necessary here whereas the concept of the notion of social perceptions is too rough for us.

Definition 7: A **users' perception** is a collective system of (potential) customers' feelings about knowledge (data and information) that is or may be derived from internal processes of the company and has an impact on their (future) demands, orders and preferences.

The term itself seems to be fairly subjective and follows from the fact that customers also have their own abilities. These have significant influences on the quantity and quality of information absorbed from the process. They make interdependencies with preliminary knowledge and capabilities. (E.g. an elderly woman and a young guy have different perceptions on smartphone's and analogue telephone's service.)

Question arises whether the perceptions of customers of a system count in developing and operating its processes. Especially when the inside feelings say everything is all right. Obviously, inner perspectives are narrow and process items produce many internal uncertainty. Thus, the operation of the system cannot provide the required optimum.

Definition 8: Processes whose operation are much affected by intra- and inter-perceptions shall be called **perception driven processes (PDP).**

Hereinafter, processes identified in a system will be examined and such process attributes are given. Fluid flow can be constructed by further process examinations.

Let:

- $n \in N^+$ be the number of processes discovered in a system and P_i $(0 < i \leq n)$ be a single process of this system.
- D denote a finite set of fluids (such generalized above) of this system; if the fluid in a certain point of time belongs to process P_i than in case of $d \in D$, $d \uparrow P_i$ notation shall be used.
- τ denote fluid type set occurring in the system, or the role that it entrusts in a certain test section, for example a document on the input of a process, a data on a certain node or it can be a waiting element as well. Typesets has general elements as well as specific components regarding the system or subsystems of the processes.

Furthermore let:

- $[t_s; t_f]$ be the system test time intervals
- $R[r_{ij}]$ hyper-matrix shows, that P_i process somehow supplies fluids to P_j process $(0 < i,j \leq n)$. Then $r_{ij} \coloneqq \{((d;T)|d \in D; T \in \tau)\}$ is a fluid relationship set. (Obviously the matrix is non-symmetric.)

It is important to define inputs, outputs and interfaces of the processes as well as all significant flow features.

- $I(P_i) = \{(d;T;t)|d \in D; T \in \tau; t \in [t_s; t_f]\}$ is an input fluid set of a process (meta-process) where the input fluid, type and time of appearance on the input (which may be sub-intervals as well) are noted
- $O(P_i) = \{(d;T;t)|d \in D; T \in \tau; t \in [t_s; t_f]\}$ is an output fluid set of a process (meta-process) where the input fluid, type and time of appearance on the output (which may be sub-intervals as well) are noted
- $C(P_{ij}) = \{(d;T;t)|d \in D; T \in \tau; t \in [t_s; t_f]\}$ is fluid set of the j^{th} interface of a process where the fluid, type and time of appearance (which may be sub-intervals as well) are noted. There may be such specific fluids here like 'waiting for … time', 'connection without waiting', etc…
- $(T_i; T_j)_d$ is the transformation on fluid d, which may happen in the process or on a node as well. (However, transformations on processes can be omitted. If a transformation happens during a flow, then a virtual node should be created in this process and transformation should be assigned to this node.)

- T_d means a possible typeset of fluid d $(0 < i; j \leq |T_d|)$. (Hereinafter for the sake of simplicity, the transformations are denoted by $\hat{T}$, and $\widehat{\emptyset}$ means blank transformation when no type change occurred.)

Logistification

In the previous chapter, those terms were prepared and organized. They will be used in deeper understanding of results of process examination. The technique of logistification will be used as a modelling and analysing tool for processes. Appellation comes from the well-defined, well-modelled logistics and supply chain processes. All other kinds of processes can be considered as logistical process because of the flowing fluids. Thus, a unified process analysis can be performed at the whole process system of business organizations.

Definition 9: **Logistification** is the modelling and analysis in terms of efficiency, sensitivity and optimality. Logistification is based on the temporal and spatial changes in related data of the processes of any kind of systems by means of fluids flowing in processes.

The explored processes of the system shall be examined in a flow perspective. Then the entry (input in flow aspect) and exit (output in flow aspect) nodes should be found in order to explore how processes are connected to each other and to identify the types and characteristics of these interfaces. The system may include only a finite number of processes. Otherwise, if possible, a finite number of the most important processes in terms of the investigation should be selected. Models carried out as a result from this type of analysis can be skeletonized about confusing and not relevant items supplied by the economic environment.

In term of flow, the fluid-flow can be divided into two groups: it can be either nodal flow or continuous flow. In case of nodal flow, the fluid transformation is visible/measurable and has effect only on process nodes. In cases of continuous flow, the effect of fluid transformation can be realized and measured at any point of the process. In terms of our investigation, nodal flows will be important and give an overview of this kind of flow as we prepare to carry out simulation of service processes

Let $d \in D$ be a fluid (where D is a finite set), and let P_0 be the process at t_0 initial time of fluid analysis (observation) whose input involves the fluid and be the initial type of the fluid T_0.
Then $(d, T_0, t_0) \in P_0 \cup I(P_0)$.

The flow of this fluid can be described at $[t_s; t_f]$ period of time with the following sequence:

$$F(d)_{[t_s;t_f]} = \langle \hat{T}_0; (c_{i_0 j_0}; t_{s0}; t_{o0}); \hat{T}_1; (c_{i_1 j_1}; t_{s1}; t_{o1}); \dots; \hat{T}_m; (c_{i_m j_m}; t_{sm}; t_{om}); \hat{T}_{m+1} \rangle \quad (2)$$

where

$$\hat{T}_l \in \left\{ (T_i; T_j)_d \right\} \cup \{\hat{\emptyset}\}: l = 1; \dots; m+1 \quad (3)$$

and in equation (3) $(c_{i_l j_l}; t_{sl}; t_{ol}): l = 1; \dots; m+1; c_{i_l j_l}$ is node; $t_{sl} \le t_{ol} \in [t_s; t_f]$ and $t_{ol} \le t_{sl+1}$.
t_{sl} represents the time of node entry and t_{ol} represents the exit time. The total duration of fluid flow in $[t_s; t_f]$ interval is $[t_{s0}; t_{om}]$.
Comment: Obviously in sequence

$$\check{C}(F) = \langle c_{i_0 j_0}; c_{i_1 j_1}; \dots; c_{i_m j_m} \rangle \quad (4)$$

a certain node may appear several times, however the sequence of nodes is finite (as follows from the definition).

The fluid flow is homogenous if $F(d)_{[t_s;t_f]}$ is a fluid flow and $\hat{T}_l = \hat{\emptyset}: l = 1; \dots; m+1$.
For proper classification of fluid flow, the fluid weight function is introduced. Since this value can vary along the process, it should be incorporated in the transformation.

Let $(T_i; T_j)_d$ be a type transformation and $w(T): T \in \tau$ be a weight function which is assigned to fluid type. This measure can be positive or negative sign as well. Negative measure refers to opposite direction of flow.

Then a transformation is:

$$\hat{T}_{ij} = \left((T_i; w_i); (T_j; w_j) \right)_d \quad (5)$$

where weights are assigned to the actual type of fluid. This solution allows quantitative and qualitative changes in fluids in case of materials.

Since the typeset may include values with discrete and continuous types (the definition does not contain any restrictions on this issue). Therefore, a discrete material flow can be handled just like a continuous information flow as the amount of information can change. This can be compared to the change of the size (amount/dimensions) of material during elaboration.

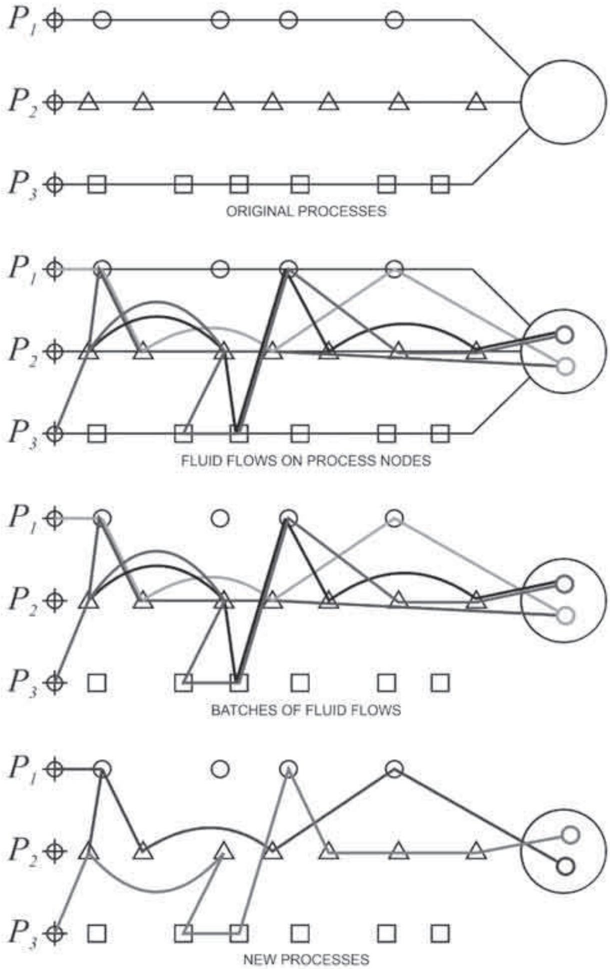

Fig. 2: Logistification of processes.

The extended nodal flow of fluids in $[t_s; t_f]$ time interval is amended as follows:

$$F(d)_{[t_s;t_f]} = \langle \hat{T}_0; (c_{i_0 j_0}; t_{s0}; t_{o0}); \hat{T}_1; (c_{i_1 j_1}; t_{s1}; t_{o1}); \dots; \hat{T}_m; (c_{i_m j_m}; t_{sm}; t_{om}); \hat{T}_{m+1} \rangle \qquad (6)$$

sequence, where

$$\hat{T}_l \in \left\{\left((T_i; w_i); (T_j; w_j)\right)_d\right\} \cup \{\widehat{\emptyset}\}: l = 1; \dots; m+1 \tag{7}$$

and $((c_{i_l j_l}; t_l): l = 1; \dots; m+1; c_{i_l j_l}$ interface; $t_l \in [t_s; t_f]$.

Further processes associated with the fluid can be discovered for the explored processes of the above detailed fluid flow system. These processes are much more informative than the initial ones.

Let there be $F_1 = F(d_1)_{[t_{s1}; t_{f1}]}; F_2 = F(d_2)_{[t_{s2}; t_{f2}]}$ two process flow. It is said, that $F_1 \leq F_2$ or F_1 is a process section of F_2 when $[t_{s1}; t_{f1}] \subseteq [t_{s2}; t_{f2}]$ and $\check{C}(F_1) \subset \check{C}(F_2)$ viz. subsequence. This definition can be refined if we do not expect the whole series to be part of the other series $\left(\check{C}(F_1) \subseteq \check{C}(F_2)\right)$.

Logistification is illustrated in figure 2.

Entropy of fluid flows

It is very interesting to examine how uncertainty aroused and increased in the system of fluid flow by intra-users (internal customers) or inter-users (external customers). Is there any rate of reliability of fluid-systems? If so, is it possible to add limits to this measure? These issues suggest that a kind of entropy concept should be introduced. The entropy of fluid flow can be compared the most to the Shannon's entropy (Kannappan, 1972a) and can be inspected from several aspects:

1. External (inter) users' perspective
2. Aspect of the real internal uncertainty of the system

Economic systems are always open systems, so their uncertainty (reliability) is highly influenced by external world and internal users. It is equally true that an economic system has no demand for its products or services, and no apparent activities. Despite these facts, it should keep contact with the social, legal, etc. aspects of the economic environment. Consequently, they have both inter- and intra-users (customers) with their demands. This is true even in this special case. Examples also include economic systems, tax authorities, reporting requirements and accountability.

Accordingly, these passive systems can be treated as the active ones. So it can be stated that there is an impact of increasing external uncertainty in all of the studied systems. On the other hand, the level of uncertainty can be also increased by the demands and outputs of intra-users in nodes. The effect of these two influences should be complied to create a degree of reliability for process systems.

Nodal entropy

In business literature can hardly be any evidence found for process entropy. However Shannon in his works has laid its fundamentals (Moore, 1956; Shannon, 1948). These studies were followed by some supplements and critics (Asl, Khalilzadeh, Youshanlouei, & Mood, 2012; Kannappan, 1972b). Managerial entropy was also introduced and discussed by many authors (Peiyu, Zhang, & Yong, 2009; Shiyou & Yu, 2009; Wanhua, 2002; Yao & Yu, 2008) but they cannot face with such issues we need to develop our model.

Jung et al. also dealt with this issue (Jung, Chin, & Cardoso, 2011). Although in our interpretation, multiple nodes may provide and accept fluids or some nodes may be ignored. On the other hand, the importance of fluids is not necessarily proportional to its likelihood. The work of Jing (2012) cannot form the basis of our concept of entropy. Neither nodal nor process entropy can be inferred from Jing's entropy definition.

To define perceptional entropy, the first step should be the drafting of the actual (real) entropy of the fluid system. Let c be a node and the set of fluids entering this node be $D_I(c) = \{d|d \in D; d \in \text{input}(c)\}$ and $D_O(c) = \{d|d \in D; d \in \text{output}(c)\}$. Let $D_c(d)$ be a fluid set determined by a given $d \in D_O(c)$ output fluid on the c node and let $n_d = |D_c(d)|$. Let the probability of a d fluid to appear on node c in an appropriate manner (type, value and time) be $P_{Oc}(d)$. This probability is determined by arrival probabilities of dominant input fluids and the probability of node transformation. Our investigations show that this probability which means internal uncertainty depends on the uncertainty of input fluids. Let $P_I(d_j)$ be the probability that d output fluid determined by $d_j \in D_c(d)$ ($j = 1; 2; \dots; n_d$) input fluid adequately (entirely and timely) enters into a node. As input fluids differently affect the adequate appearance of output fluids, therefore probability of input fluids has also different weights on outputs.

Accordingly, the impact probability of input fluids can be described by

$$P_i(d) = \sum_{j=1}^{n_d} \lambda_j P(d_j) \tag{9}$$

equation, where

$$\sum_{j=1}^{n_d} \lambda_j = 1$$

and λ_j is the influencing factor of the input fluid.

Let A_j $(j = 1; 2; \dots; n_d)$ be an event when the $d_j \in D_c(d)$ input fluid adequately enters. It is not sure that the fluid is entirely received, but is sufficient in processing terms, In other words, the output fluid meets the completeness axiom to a node. Accordingly, the probability of nodal uncertainty can be introduced and described (i.e. what is the probability that the node does not make an A_d mistake) by:

$$P_c(d) = P\left(A_d \middle| A_1 \cdot \dots \cdot A_{n_d}\right). \tag{10}$$

Consequently, the completeness probability that an output fluid leaves the examined node can be specified with the following equation:

$$P_{Oc}(d) = P_i(d)P_c(d). \tag{11}$$

So as the entropy of an output fluid of a node:

$$H(c_d) = -\log_2 P_{Oc}(d), \tag{12}$$

and accordingly, the nodal entropy can be interpreted in several ways. It may be weighted- similar to impact probability as the significance of a fluid may be important. Since it is not easy to pre-measure, it will be interpreted on the "weakest" output fluid of the node:

$$H(c) = -\log_2 \min\{P_{Oc}(d_k) | k = 1 \dots m\}. \tag{13}$$

where m is the number of output fluids of a node.

Process entropy

Theoretically process entropy is readily determined using nodal entropy. The conception here is that fluids appear in process inputs flowing through the nodes of the process. An output fluid appears in one or more nodal inputs with the same completeness probability as it was at the output. So let the c_i node provides the d fluid to the c_k node. In this case $P_{Oc_i}(d) = P_{Ic_k}(d)$ will be satisfied.

Let P be an explored process of a system. Let us take the $I(P)$ set of input fluids. Than process entropy is determined by a constructive way.

Step 1:

Let us denote identified nodal fluid that one, whose nodal completeness probability is known. Their set is denoted by $E(P)$. Initially $E(P) = I(P)$.

Step 2:

Let us take those nodes leaving output fluids, which are clearly, defined by $E(P)$ fluids and their completeness probability can be determined by input fluids and nodes. Their set is denoted by $T(P)$.

Step 3:

$$E(P) := E(P) \cup T(P). \tag{14}$$

Step 4:

Examine that the completeness probability is determined or not for all output fluids:

$$O(P) \subset E(P)? \tag{15}$$

If this condition is not satisfied, get back to step 2.

Step 5:

Every completeness probability for all output fluids are determined. This enables us to express the process entropy with the following equation:

$$H(P) = -\log_2 \min\{P_{Oc}(d) | d \in O(P)\} \tag{16}$$

Intra-user entropy

Users do not necessarily experience the real entropy of a process, but rather they have very different perceptions of the process. Intra-users (internal users and customers) are situated in a node and manage and/or execute transactions. They have some kind of knowledge on input fluids that are important to them due to their perceptions. They determine the complete probability of these fluids. This probability cannot be 0, since in this case transformation wouldn't be started in the node and it cannot be part of the process. So in the case of perceptional entropy the impossible event does not cause a 0 entropy.

Let $D_c(u)$ be the set of input fluids used by an intra-user and let $n_u = |D_c(u)|$. Furthermore let $d \in D_c(u)$ be the completeness perception of fluid (the completeness probability perceived by the intra-user, i.e. how likely they feel that fluid arrived accurately, in the right quality and the right quantity), and the perceptional entropy of the intra-user is:

$$H(c) = -\log_2 \sum_{j=1}^{n_u} \lambda_j P(d_j) \left(d_j \in D_c(u)\right)$$

(17)

where

$$\sum_{j=1}^{n_u} \lambda_j = 1$$

and λ_j is the perceptional influencing factor of input fluid.

Inter-user entropy

The uncertainty of an inter-user always depends on user demands. For instance, a demand for fulfilling a production system deadline, a quality demand or the reliability of a user (simple parameters). Variations with any of these priorities are also included (complex parameters). The uncertainty of a system for an inter-user is determined by the collected data from system feedback information. Uncertainty can be terminated either by the system or by the users (e.g. on the occasion of the completion of the process) with a definite answer on the output (termination) of the process. In any other time uncertainty depends on inter-user's perceptions.

So the less the inter-user knows the processes of the system, the less they will be able to make safe decisions. Thus there is a high degree of uncertainty. As the process system of a business organization is stochastic, the demands of other users, the performance limitations of the system and the internal structure of processes also influence the uncertainty.

From this aspect, inter-user uncertainty is determined by the rate of information on the system. On the other hand, is determined by the perceptions of the users. So it does not make much sense to the users if they get complete information on processes and they are not able to detect or interpret it via their perceptions. Therefore, the concept of inter-user entropy will be composed of these two features. More specifically, the inter-user entropy is the perceptional distortion of Shannon's entropy (Moore, 1956). To define it, the fluid flow provided set of information should be specified as a Shannon's sample space (Shannon, 1949).

Let p be a parameter (simple or complex) whose value is relevant for an inter-user in time t_d.

Let the actual time be $t_0 (< t_d)$ and let $t \in [t_0; t_d[$. Furthermore let all the fluid flow sets be known according to eq. (6): $\Phi_{[t_0;t_d]} = \{F(d)_{[t_0;t_d]}\}$. A fluid flow is characterized by its fluids, types, weights, transformations, etc. Let c be a virtual node where there is a certain inter-user. Fluids necessary for them are the input fluids of this node. Thus, the inter-user entropy is the perceptional distortion of

Shannon's entropy (or shortly perceptional entropy) in accordance with eq. (17) is:

$$H_u = H(c) \tag{18}$$

which is denoted as the uncertainty measure of the fluid flow system.

At all other times, the uncertainty is at a minimum value which is adjusted by the user according to their system-related perceptions (obviously this is greatly influenced by their experiences).

Discussion
Empirical research

In order to get some impression of the modelling issues, objectives and conditions in a two-step empirical research were implemented in November 2013. Primarily, four focus group interviews were performed among the population to have some insights on service process perceptions. Secondarily, 12 in-depth interviews were performed among experts of service companies. This was to have some impressions of the special characteristics of financial service providers' nodes and processes. These initial empirical researches are resulted in a complete questionnaire which is to capture users' perceptions of financial service processes. Also, the questionnaire results form the basis of a future experimental model. This empirical framework is illustrated in Figure 3.

During the *focus group interviews,* consumers above 18 were asked of their relationship with financial institutions and they can provide us useful answers to our questions. During the research, we carried out 4 focus group interviews that means altogether 30 people were asked (7-8 persons/interview). The youngest respondent was 18 years old while the oldest one was 59 years old. Furthermore, all the "age groups" were represented during the interviews from the youth and middle-aged through the mature, experienced age group. Composition according to the occupation of the participants also shows considerable heterogeneity There were university students, lecturers, blue collars, white collars, managers, entrepreneurs as well as job seekers. First, two interviews were carried out at the MIM Research Student Office at the University of Miskolc. The other two interviews were carried out in the Focus Laboratory of the Budapest Business School Research Centre. The interviews were done in the interval between 13th and 21st of November 2013. They were documented by video record and reports were made on the given issues. This served as a basis for the research results.

During the *in-depth interviews,* experts working for commercial banks were asked for a good overview of their own company's business processes and to provide us with valuable information. Twelve persons were asked throughout the in-depth interviews. Interviews were made – after asking for appointment on phone, email – at the location and date assigned by the respondent. After asking permission, conversations were documented by sound recording and on the basis of the provided information. Reports were made that also served as a basis of the research.

Results of focus group interviews

During the focus group interviews, we were interested in the services respondents buy during their everyday life. When answering this question we discovered that respondents use many kinds of services. These include public utility services (electricity, water, gas), community travel, catering (café, pub, restaurant), post, telecommunication services (phone, internet), banking services, healthcare, education, sport, cultural services (cinema, theatre, concert) and personal services (hairdresser, beautician, masseur). We have to remark that commerce and insurance are not considered as services.

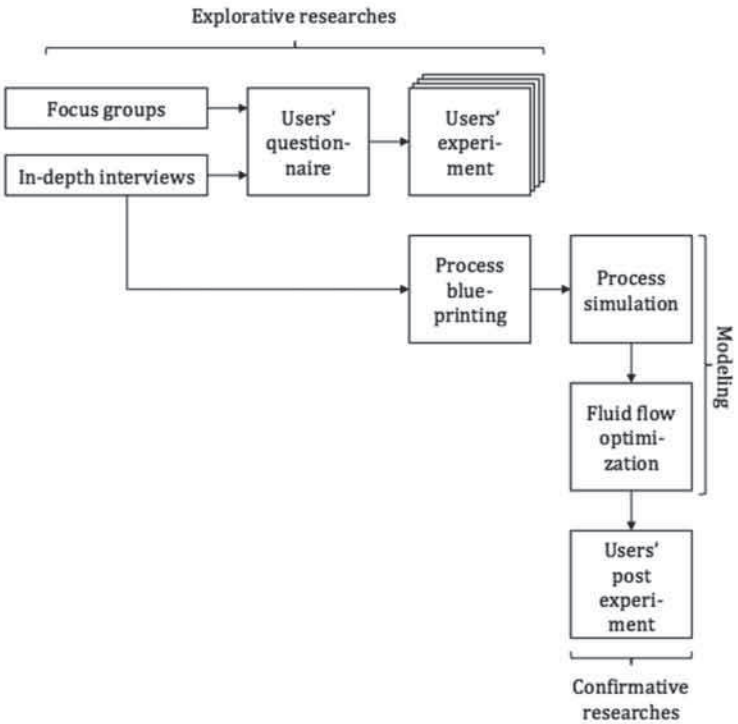

Fig. 3. Empirical framework

When asking details about the frequency of service utilization, it was revealed that public utility services, telecommunication (phone, internet), community travel and education are continuously used, or at least once on a daily basis. However, financial services and insurance are not considered continuous services.

In answering the question of which three service providers are regarded as the most important in our lives, respondents had identical opinions. The most important service providers in our lives are public utilities (electricity, water, gas, district heating) and the second is telecommunication service providers (phone, internet, TV). The third were banks and transport service providers in a dead-heat. Also, mentioned were educational institutions and catering units.

On the basis of what they chose as their present services, why were the above factors considered the most important? Answers were also in harmony with these issues. They were the most important because they are used most often and there is no life without them. As there is no alternative in the case of public utility service providers and public transportation, they chose what was available. In other cases, price, service and quality were the most important factors. Personal experiences were critical factors as well as recommendation of the family members (parents), acquaintances and availability (banks, catering establishment). Consumers do not meet "internal issues" of the organisation providing services. Therefore, these factors do not directly influence them. However, features of the service providers like physical elements, processes and the human element are important influential factors. Only a few people thought that during choosing their present service provider that their impression and preconceptions were determinate.

In the second half of the focus group interview, financial institutional services were put in the scope of the research. To start this part of the interview, we used the questions of Critical Incident Technique (CIT). Respondents could characteristically give details about their negative experiences. The sources of negative experiences were of providing basic services in an inappropriate way, improper attitude and defects in expertise of employees. Further problems were long waiting time or unilateral modification of the contracts at the expense of the client (payment instalments, costs). However, interviewees could also share their positive experiences. Sources of positive experiences were quick administration, nice front office workers, and potential complete online administration. To sum up, negative experiences were more permanent for the respondents than positive ones.

After negative and positive examples, we asked questions about the reputation of the commercial banks. We ascertained that spontaneous bank awareness of the respondents can be considered explicitly high. They can mention 6-7 banks on average in a minute, but there was also a group where the average was 10 banks. Interviewees characteristically bought services of one commercial bank, but it also occurred that someone was in connection with two banks. The choice of the account-manager bank was a free decision for everyone. Younger people typically chose their bank according to popular opinion, the bank's offer and advice of their parents. Indeed, they were not solely the ones to make this decision. On the other hand, older people were more conscious and engaged during the process of bank choice. In their decision, elements like availability, negative experiences at other banks, offered services and list of conditions were factored. The switch to another bank usually happens on a rational basis.

In connection with having banking services, it can be ascertained that more and more arrange their financial affairs through netbank. This is the most often used service. Transactions, buying with credit card, cash withdrawal with bankcards, currency exchange, bank deposits, loan payments, and group order for collection. As for the intensity of using financial services, different respondent profiles seem to be outlined. Although bank account management is a continuous service offered by the banks, it is important to remark that no one mentioned the management of a bank account. This is probably because it does not require consumer intervention and collaboration.

We also examined in what form consumers get in contact with their bank. However, in this issue we have to make difference between active,-passive establishment and communication. Consumers characteristically get in touch with their banks on the internet or personally. Those who have closer acquaintance or a counsellor do this on phone. (Others do not like phone administration because of mechanical voice and its complicated menu system. Whereas banks first get in touch with the consumers by phone, letter or email.

As for the satisfaction with commercial banks, youth satisfaction is high and they get services suitable for their requirements. They did not have negative experiences and thus have no basis for comparison. Satisfaction of older people is relatively lower, but they can still be considered satisfied. (More people expressed their satisfaction and compared Hungarian conditions to positive foreign examples: low interest rates on deposit, high interest rate on loans, expensive services.)

Results of the in-depth interviews

During in-depth interviews, we got to know that respondents are exactly aware of the most important actors of their market (competitors, customers, suppliers). Thus, they could be properly segmented. All the banks were considered competitors, but they added that competitors are different in different fields (population, big companies, credit cards, commodity credit, estate loans). A base for segmentation can be size on the basis of what difference can be made among large banks, small banks or owner groups. According to that, we can talk about Hungarian and foreign stake. As for customers we have to make distinction between client segment on the basis of European Union recommendation: population (Hungarian and foreign), micro-enterprises, SMEs, large companies, institutions, financial and non-financial clients, state, Hungarian National Bank. Most important are suppliers of commercial banks: external counsellor, software suppliers, property managers, HR counsellors, renovations and services in connection with maintenance, factor, leasing and collection companies. On one hand, strategic associations of financial sectors are a bank alliance. Further to this point, alliances are made between banks - insurance companies; banks - pension funds and banks - broker companies.

It also turned out from the experts' answers that they know their processes well. It does not matter whether it is a value creation or directly involves consumers.. Supportive, indirect consumer involvement and supportive processes are also of no consequence. They know their phases, sub-activities, can identify directors and collaborators of the processes. Value creator processes for banks: providing loan, collecting deposit for banks, estate handling, investment management, special investment services, insurances, and financial transaction services. The purposes of value creating process are "money reinvestment", meeting financial requirements of the customers. Phases are: obtaining more clients, establishing relationship, surveying demands, making offers, contracts, approval and money flow. Directing processes: account manager (counsellor, referent, administrator), from wider aspect project sponsor or CEO. Collaborators of value creator processes are the experts of co-departments. Besides these processes, there are also a lot of back-office processes the consumers cannot meet directly.

A majority of commercial banks have very precise process description (rules) that are destined to resolve further problems appearing in their processes. These problems appear continuously, but they are not enormous. Quantity aspect is in the background of the problems facing quality aspect (overburdened staff).

Interviewees could all determine which factors their customers judge regarding the level of their service processes on predictability, quickness, access, simplicity, confidence, personal relationship, directness, conformability, prices, expertise, communication, kindness, and flexibility.

As for the types of processes modular processes are mostly present in the practice of commercial banks which can be separated into smaller, shorter linear processes. Project processes also often occur, but they make up more regarding value than quantity. Almost no one can esteem how much impact the three process types have in the life of the company. However, experts that were asked emphasized that clients do not perceive which process type they meet.

Another big topic of the interviews with the experts was the measurement and assessment of the process effectiveness. Commercial banks apply such methods. They are obliged to because of the regulation (reports, indices). In general, we can state that evaluation of process effectiveness operations. There is no problem with the usage of financial measurement tools. There are efficiency reserves, but they are caused by soft factors that are hard to eliminate. There are BPR projects, yet the attitude of the companies is reactive to the factors. Consumer satisfaction is examined by telephone questioning. Furthermore, there are also time norms that are not good for the verification of anything according to certain experts' opinion. For the measurement, evaluation of efficiency certain information coming from banking IT systems serve as a basis.

According to our respondents, there are more factors that influence the efficiency of the processes at the same time. They depend on the identification with the processes, their acceptance, commitment, expertise and personal competence. Of these human factors, personal relationship is the most important. Based on these issues, a relationship that seemed a paradox could be explored. We could be quicker, but could also lose flexibility according to standardized processes,

Regarding the development possibilities we have to mention two key areas, namely our personal competence and the information technological development. As for human factor opinions were different. According to certain experts personal contact and administration is needed, communication has to be developed and also more clerks are required. On the other hand, according to others development of the applied software, integration information technological systems, that is "switching off" human factor would be a way to follow.

The generic design of the mathematical model

A mathematical model can be built on the basis of the previously given definitions and relationships. The aim of this model is to provide theoretical background to our future simulation model and on the basis of this mathematical model the required computing model can be prepared. It should be kept in mind during the modelling that perception driven processes (PDP) must be mapped to the model level. In-model changes shall be reflected to the observed world as if it would take place in real world. This requirement is illustrated in figure 4 below.

However, a general model is created at this stage for each of the above-mentioned processes. It is not worth detailing the model even deeper since the point may be lost. Quantities in the system are the expected values of the random variables. Accordingly, each quantity has a probability distribution whose definition requires empirical studies and schemes may be different for each element.

During this examination of the system, nodes along with their data transactions and possible inter-nodal fluid flows are to be given. These will be given after our future empirical observations. The aim of the model is to develop a method which can provide input fluids (fluids on entry points) are able to reach output fluids (exit points) in the required quality and quantity. This should be implemented optimally. Optimality will be achieved by using the objective function.

Based on the concepts of the model, known and unknown variables should be given. In addition, conditionality should be built based on relationships between certain elements of the framework. For the final examination of the system, the objective function is presented in this paper. So as our model consists of two main parts:

- conditionality,
- objective function.

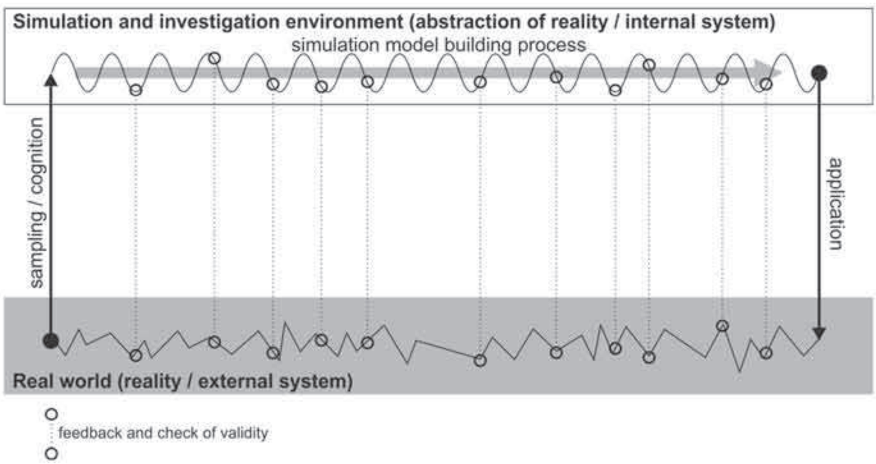

Fig. 4. Modelling requirement

Known data

Let

n_I be the number of INPUT nodes,
n_o be the number of OUTPUT nodes, and
n_k be the number of *interstitial but external* nodes.

Let

D^I be the weight of a *D* node appeared on the i^{th} input node (weight is considered in an abstracted term)
D^O be the weight of a *D* node required by i^{th} output node (weight is considered in an abstracted term)

Let

$D^I = \{D_i^I\}$ be the set of input fluids arranged by node sequence numbers
$D^O = \{D_i^O\}$ be the set of output fluids arranged by node sequence numbers.

There are some important conclusions of these assumptions. There are special nodes either on input or output side. Input nodes launch a fluid into the examined system through the particular fluid flow and they are unable to accept fluids.

Expected fluids will appear on output nodes (in appropriate quantity and quality). Here, the expectations are displayed via node related attributes. Output nodes do not emit fluids. Interstitial, but external nodes are those that are actually users intervening in the system to complete the entire process. They can emit and accept fluids.

The set of these three kinds of nodes is equal to the previously defined set of inter-users. Inter-users can be considered as the same nodes as the internal elements (nodes) of the system. Thus they can be featured by same functions, properties, transformations.

These remarks led us to conclude that a dual system is obtained. The primal system is the examined one while the dual is the independent (possibly dependent) one with external nodes.

It might be considered during our investigation as a joint connection of two of the same fluid flow system.

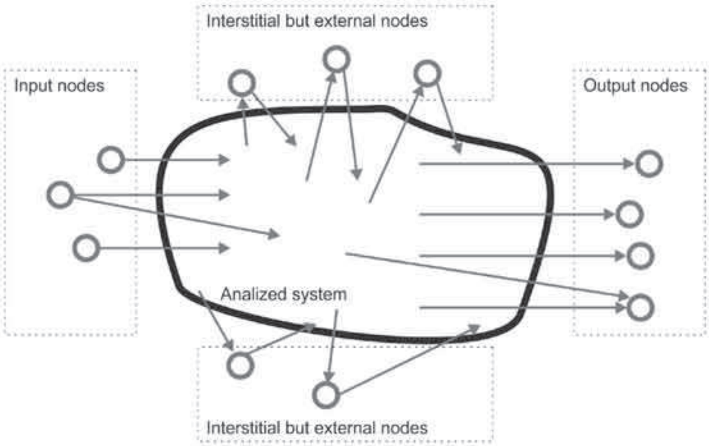

Fig. 5.: Representation of nodal flow model

However, all input-output, interstitial and external nodes can be considered as the same client. In our model, they are considered to be separate nodes for simplicity. This simplification does not violate the principles raised in the previous paragraph.

Determination of model inputs

Our system is basically built of nodes and fluid flows.

Let

n be the total number of nodes of the system

n_b be the number of interstitial but external nodes of the system

Every node is represented by an $i \in \{1, \dots, n\}$ value. $n = n_i + n_k + n_o + n_b$

If $i \in \{1, \dots, n_i\}$ then input node,

If $i \in \{n_i + 1, \dots, n_i + n_k\}$ then interstitial but external node,

If $i \in \{n_i + 1, \dots, n_i + n_k\}$ then output node ,

If $i \in \{n_i + n_k + n_o + 1, \dots, n\}$ then node in the system is considered.

m be the number of possible fluids. Every fluid is represented by a $d \in \{1, \dots, m\}$ value.

Every node is assumed to be an agent (or a computational object). Each node is structured as a set of attributes and transactions. The structure of i^{th} node consists of data and transactions.

Data

Let

$p_{max_i}(d)$ be the maximal capacity of i^{th} node in relation to fluid d. If this value is 0, then d fluid cannot flow through this node.
$h_i(d)$ be i^{th} node the compulsory node of fluid d.
$H_i(d)$ be the entropy of i^{th} node based on eq. (12).

According to these conditions – if necessary – minimal capacity may also be defined. Accordingly, inter-user entropy can be calculated based on eq. (17).

Transactions

Let

$q_i(k, j, d)$ be the measure of a unit of the transformation of d fluid to j^{th} node received from k^{th} node,
$t_i(k, j, d)$ be the time of transmission of d fluid to j^{th} node on i^{th} node (per unit)
$d_i(k, j, d)$ be the transformation of d fluid received from k^{th} node to j^{th} node (meaning that d fluid received from i^{th} node transforms into what fluid). Its quantity is determined by q_i.
$s_i(k, j, d)$ be the subject of the flow of d fluid received from k^{th} node to j^{th} node. This is an empirically determinable function, however it is also applicable.
$r_i(k, j, l, d)$ be the redirection of d fluid (received from k^{th} node and flowing to j^{th} node) when a problem occurs to l node.

Fluid merging can be specified with the application of d_i, t_i, q_i functions of two of the same fluids, thus it does not require any further definitions. Fluid splitting can be specified similarly with the given functions. As for example at $q_i(k, j, d)$ function fluid can be easily split by giving two different j.

Fluid flow model

Let (i,j) ordered pair denote the direction of the fluid flow, where i shall be the sign of the initial node of d fluid and j be the sign of the target node. In this sense every fluid flow can be represented by a separate ordered pair.
Let us assign to every (i,j) ordered pair an:

$\mathbf{E}_{n_d}(i, j)$ matrix (entropy matrix block)
$\mathbf{E}_{q_d}(i, j)$ matrix, which shows the weight of a given d fluid flowing from i^{th} node to j^{th} node

$\mathbf{E}_{v_d}(i,j)$ matrix, which shows the value of a given d fluid flowing from i^{th} node to j^{th} node

It is advisable to introduce an:

$\mathbf{E}_d(i,j)$ bivariate matrix, which has a value 1 if d fluid flows from i to j, and 0 if there is no flow.

The fluid process model

Based on above definitions of fluid, they can even flow in batches. Then

$b(k,j,l,d)$ is the batch of d fluids flowing from i^{th} node to j^{th} node (where d vector contains the serial numbers of the fluids that are included in the batch). Batch flows can be also described by the given above and easily generalized functions.

Unknown data

Let

x_{ijd} be the weight of d fluid flowing from i^{th} node and arriving to j^{th} node.

y_{ijd} be the weight of d fluid flowing from i^{th} node and departing to j^{th} node.

Conditions

Not any d fluid can be transformed or flown through a given node than the maximum capacity of that node:

$$\sum_{d\ fluid\ entering\ to\ i\in j} x_{ijd} \leq p_{max_j}(d)$$

The sum of the continuation without any formal change of an entering d fluid and other fluids transforming to d must be equal to the sum of leaving d fluids from a node.

$$\sum_{d\ fluid\ entering\ to\ k\in j} x_{kjd}q_j(k,j,d) + \sum_{f_i(k,j,f')=f} x_{kjf'}q_j\big(k,j,d_i(k,j,d')\big)_i = \sum_{d\ fluidum\ flowing\ from\ i\in j} y_{ijd}$$

The objective function

Our objective in this system is to produce expected fluids on outputs flowing from inputs in required quality and weight. All of this is done by the minimization of the system's internal entropy, lead time and cost. Accordingly, the structure of the objective function is as follows:

$$c(D^I, D^O, P) = \lambda_1 K(D^I, D^O) + \lambda_2 T(D^I, D^O) + \lambda_3 H(D^I, D^O) \rightarrow min.$$

where

$K(D^I, D^O)$ is the cost of INPUT and OUTPUT fluid flows according to the system,

$T(D^I, D^O)$ is the lead time of INPUT and OUTPUT fluid flows according to the system,

$H(D^I, D^O)$ is the process entropy of INPUT and OUTPUT fluid flows.

The fulfilment of output requests is limited by the conditions, so it may occur that there is no possible solution to the problem. The λ_i's of the objective function are normalized scalars allowing us weighting of each component according to their importance during the investigations. If a certain $\lambda_i = 0$, then the aspect is not included in the examination.

Our investigations basically deal with the third component. The primary $\lambda_1 = \lambda_2 = 0$, and $\lambda_3 = 1$ assumed. Accordingly a P process with D^I, D^O input and output parameters in accordance with the previous chapter can be considered as follows:

$$H(D^I, D^O) = -\log_2 \min\{P_{Oc}(d) | d \in O(P)\}$$

Structure of the system

The system consists of nodes and fluid flows interpreted among them (batch of fluid flows can be considered as fluid processes). It can be described as a controlled graph containing circular paths wherein edges have no values, but rather functions. The objective is the circulation of the fluid from certain inputs to given outputs. This is done while minimizing the given objective function in such a manner that the fluid must pass over compulsory nodes.

These nodes can also be considered as special Mealy-automatons. In contrast to the classical Mealy automaton theory herein stated changes are not necessarily performed one after the other. However, parallel activities may occur. An important condition is that the criterion of discrete time scale is met.

Time, though, is allocated to status changes [see $t_i(k,j,d)$ function] that affect the launch of a following process and also the whole lead time.

Mealy automaton approach for fluid flows

The previously shown concept of logistification predicts a very difficult and complicated mathematical in IT task for process engineers. The solution must be exact. Even a single improperly modelled and implemented nodal transformation may generate an entropy growth flow causing the *entropy domino effect* (EDE). At this stage of our investigation, it can be theoretically foreseen that some obvious heuristic modelling tools (such as harmony search and genetic algorithms) should be abandoned. A certain implementation should be the application of Mealy automatons which could be easily incorporated into the simulations.

For this it must be assumed that the observed time interval can be divided into discrete time slots and each scale shall be considered as discrete exact moment.

The number of nodes is finite and the number of transformations in those discrete time slots is also finite. In the case of fluid flows, this means that such a time-slice (slot) allocation can be definitely formed in a natural fluid flow. An appropriate number of nodal transformations can be ordered and time structures can be assigned to these transformations.

Another very important characteristic of Mealy automatons is that they always respond to an input signal with an output signal (except condition state changes). In the case of fluid flows, this means that the automaton will produce output fluids through nodal transformations as a response for one or more input fluids. As the Mealy automaton possesses appropriate generalisation therefore nodes (with their transformations) can be easily considered as a single Mealy automaton.

In this subchapter a Mealy automaton based network will be given that describes the previously presented system of nodes and fluid flows.

Definition 10: **A Mealy automaton** is a tube $A = < Q, X, Y, \delta, q_0 >$, where Q is a finite set of states, X, Y are input alphabet and output alphabet, particularly, $q_0 \in Q$ is the initial state, and $\delta: Q \times X \to Q \times Y$ is the transition-output mapping.

The transition-output mapping in fact is a couple: $\delta = (\sigma, \rho)$, where

$$\sigma: Q \times X \to Q, \rho: Q \times X \to Y$$

and

$$\delta(q,x) = \big(\sigma(q,x), \rho(q,x)\big)$$

Let $X^\varepsilon = X \cup \{\varepsilon\}$. The transition-output mapping can be extended into $\delta: Q \times X^\varepsilon \to Q \times Y^\varepsilon$ as follows:

i. $\sigma(q,\varepsilon) = q, \rho(q,\varepsilon) = \varepsilon,$

ii. $\sigma(q,wx) = \sigma(\sigma(q,w),x),\ \rho(q,wx) = \rho(q,w)\rho(\sigma(q,w),x))$

Definition 11: **A network of Mealy automaton** is a set $\{\mathcal{B}, \mathcal{R}, \wp\}$, where $\mathcal{B} = \{A_i | i \in I\}$ is the set of automata, where $A_i = < Q_i, X_i, Y_i, \delta_i, q_0^i >$, $\mathcal{R} \subseteq \mathcal{B} \times \mathcal{B}$ is a relation between the automata, and $\wp$ is the set of mappings $\pi_i: \bar{X}_i \to X_i$, where if we denote by $X_i^\varepsilon = X_i \cup \{\varepsilon\}$, ε is empty symbol, $I_i = \{j | (A_j, A_i) \in \mathcal{R}\}$, then $\bar{X}_i = X_i^\varepsilon \times Y_{i_1}^\varepsilon \times Y_{i_2}^\varepsilon \times ... \times Y_{i_n}^\varepsilon$, $i_{k_i} \in I_i$.
$\bar{X}_i$ is in fact the set of extended inputs of the automaton A_i.

A network of automata can be considered as an automaton that is defined as follows:

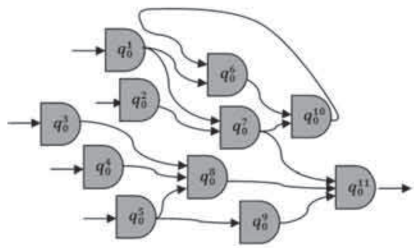

Fig. 6.: A network of automata.

Definition 12: Let $\aleph = \{\mathcal{B}, \mathcal{R}, \wp\}$ be a network of automata where $\mathcal{B} = \{A_i | i \in I\}$, $A_i = < Q_i, X_i, Y_i, \delta_i, q_0^i >$, $\mathcal{R} \subseteq \mathcal{B} \times \mathcal{B}$, and $\wp$ is the set of mappings: $\pi_i: \bar{X}_i \to X_i$. Then:

- The set of network states ($\aleph$-state) is $Q = Q_1 \times Q_2 \times ... \times Q_n$
- The set of network inputs ($\aleph$-inputs) is $X = X_1 \times X_2 \times ... \times X_n$
- The set of network outputs ($\aleph$-outputs) is $Y = Y_1 \times Y_2 \times ... \times Y_n$

Let's denote $X^\varepsilon = X_1^\varepsilon \times X_2^\varepsilon \times ... \times X_n^\varepsilon$ and $X^* = \bigcup_{k=1}^{\infty} (X^\varepsilon)^k$.
Let's denote also $p_i: (X^\varepsilon, Y^\varepsilon) \to \bar{X}_i$, where

$$p_i\big((x^1, x^2, ..., x^n), (y^1, y^2, ..., y^n)\big) = \big(x^i, y^{i_1}, y^{i_2}, ..., y^{i_{k_i}}\big) \in \bar{X}_i,\ i_j \in I_i.$$

The **network transition mapping** $\delta_\aleph = (\sigma_\aleph, \rho_\aleph): Q \times X \times Y \to Q \times Y$ is defined as follows: For $x = (x^1, x^2, ..., x^n) \in X^\varepsilon$, $y = (y^1, y^2, ..., y^n) \in Y^\varepsilon$ let
and

$$\rho_{\aleph}((q^1, q^2, \ldots, q^n), x, y) = (\rho_1(q^1, \pi_1(p_1(x, y))), \rho_2(q^2, \pi_2(p_2(x, y))), \ldots, \rho_n(q^n, \pi_n(p_n(x, y))))$$

The network transition mapping $\delta_{\aleph}$ can be extended into $\delta^*_{\aleph} = (\sigma^*_{\aleph}, \rho^*_{\aleph}): Q \times X^* \rightarrow Q \times Y$ as follows: For $q = (q^1, q^2, \ldots, q^n) \in Q, w = w_1 w_2 \ldots w_k \in X^*, w_j = (x_j^1, x_j^2, \ldots, x_j^n) \in X^{\varepsilon}$, then

(1) $\sigma^*_{\aleph}(q, w) = q_0 q_1 q_2 \ldots q_k \ldots$

(2) $\rho^*_{\aleph}(q, w) = y_1 y_2 \ldots y_k \ldots$

where

$$q_0 = q, y_0 = (\varepsilon, \varepsilon, \ldots, \varepsilon)$$
$$q_{i+1} = \sigma_{\aleph}(q_i, w_{i+1}, y_i)$$
$$y_{i+1} = \rho_{\aleph}(q_i, w_{i+1}, y_i)$$

The sequences (1) and (2) show the movement of the network ℵ at the input w starting from the state q.

By definitions one can see that the network of automata is not only a set of independent automata. The working procedure of a network of automata is determined by the operation of each automaton in the network as well as the interactions between the automata.

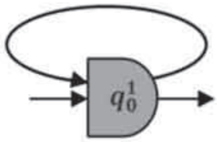

Fig. 7.: The network of a single automaton

A network of automata may operate infinitely in loops and will not halt. The set of sequences (1) and (2) characterize the feature of the network of automata.

Results and conclusions

To determine and model the operation of a process based system the first and most important task should be the conceptualization of the terms of the related discipline. In our research there have been many undefined and misunderstood terms and comprehension problems have occurred. In order to prepare the modelling phase of our research and to lay the foundations of logistification, this conceptualization is inevitable. Accordingly, the fluid flow based technical and mathematical model of a process system is prepared. A simulation built on this can be carried out to examine and reorganize an arbitrary process system from a flow perspective.

A model for nodal process and user entropy is given in this paper. A full mathematical approach is also given on a service process-reengineering concept. This is combined with the development of classical Mealy automaton theory that now fits even for service processes.

Limitations and future research

Although many efforts were made to build a generally useable model for service process re-engineering, this paper presents only the first steps of conceptualization and mathematical framework building process. However, it still has some limitations. The model can only handle predefined node attributes. Thus, as node features arise (and even fluids) they can be incorporated into the system by an iterative fine-tuning of the model.

Transaction that appear in the model as a function must be well defined. Those parts, which may only be observed with significant subjectivity, cannot be taken into account at this stage. All items will be a numeric value, so the mapping of subjects may differ from reality. In its current form, the model cannot be dynamically modified during a simulation.

The introduction of Mealy automation into our model also elicits further questions. The individual automaton can be considered as the "nodes" in other fluid flow researches. Therefore, the network of automata can be considered as a model of the fluid flow with finite number of nodes. This model may be the object for more thorough studies of behaviour of the network, as well as the role of nodes in the whole model. As one can pick out, some states of the automaton are the "goal" states, or as "damned" (or "jammed") states. The operations of the networks to get the "goal" states, or to avoid the "jammed" states may be an interesting problem. However, the analytical problems of the fluid flows may be solved based on the model. Information-theoretical problems of the fluid flows may be solved based on the model as the performance of the network and its components may be therein determined

Further investigations should be performed in the areas of users' perceptions which are very important issues for either a production or service oriented business organization. In many cases, the demands of the system's outputs may be determined by the customers' perceptions. By the coordination of this two investigation areas such a simulation model can be developed. This could help in the amelioration of dysfunctional process systems.

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