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Editors' Remarks

The Problem with Buckyballs

No one on earth had ever seen,
Or even dreamt it could have been,
That carbon atoms, by themselves,
Could form these tiny, hollow shells.

But that's exactly what they do,
And I'm not talking just a few,
But scores will form the spheric wall
That's now been christened "buckyball."

(Now that is its informal name;
Its real one, though it means the same,
Is longer than you've ever seen:
It's called "buckminsterfullerene.")

Now if you thought, you are correct:
Its name came from that architect
Whose modern style and graceful curves
Inspire the honor he deserves.

But, getting back to chemistry,
These carbons all combine, you see,
And form these geodesic domes--
The same shape some folks use for homes.

Or think about a soccer ball:
You've seen its surface patches fall
Into a couple simple forms:
With five or six sides; that's the norm.

And all these carbons seem to know
Exactly where they are to go
To form these spheres of great renown,
Whose name is known in every town.

The biggest problem with these things
Is not the wonder each one brings;
The *biggest* problem's simply that
We've not yet made a buckybat!

David Arns, 1996

This 12th volume No.2 deals with various questions of **computer technologies, computer modelling, logistics, education technologies and solid state physics** problems, which are really topical for this day. We also continue our activities in the field of **solid state physics** problems. In this issue we present original innovative papers from Israel, Italy, Lithuania and Latvia. The variety of the considered problems is a strategy of our journal. We hope that our readers will find interesting ideas and recent information.

Our journal policy is directed on the fundamental and applied sciences researches, which is the basement of a full-scale modelling in practice.

This edition is the continuation of our publishing activities. We hope the journal will be interesting for research community, and we are open for collaboration both in research and publishing.

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MULTISERVER AND MULTICHANNEL REAL-TIME SYSTEMS WITH SEPARATE QUEUES AND PRE-EMPTIVE PRIORITIES

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We consider a real-time data acquisition and processing multiserver system with identical servers (such as machine controllers, unmanned air vehicles, medical monitoring devices, overhearing devices, etc.) which can be maintained/programmed for different kinds of activities (e.g. passive or active). This system provides a service for real-time tasks arriving via several channels (such as assembly lines, surveillance regions, communication channels, etc.) and involves maintenance. We focus on the worst case analysis of the system working under maximum load with pre-emptive priorities assigned for servers of different activity type.

We consider two models (with ample and limited maintenance facilities respectively) with separate queue to each channel. We show how to compute steady state probabilities and various performance measures, when both operation and maintenance times are exponentially distributed.

Keywords: *availability, performance, pre-emptive priority, real-time system*

1. Introduction

Real-time systems (RTS) are widely used for the monitoring and control of physical processes. These systems are imbedded in most modern technological structures, such as aircraft and space stations, self-guided missiles, production control systems, radars, reconnaissance, robotic and telecommunications systems, etc.

In RTS, jobs have timing constraints that must be satisfied for correct operation – an action performed out of time limits (too late or too early) may be useless, and sometimes harmful – even if such an action or computation is functionally correct. Generally, RTS are associated with such applications, in which human lives or expensive equipment may be at stake.

The data arriving to RTS is mostly incomplete or uncertain and the output may also be uncertain. Thus, many of RTS include stochastic as well as dynamic components.

Many scientific communities are treating various RTS problems, and there exists a rich literature covering this area. We will site only a small portion of it.

Liu and Layland in their classic work [23] presented analytic combinatorial analysis for multiprogram scheduling on a single processor in a hard real-time environment. An interesting modification for dynamic priority algorithm proposed by Litoiu and Tadei [22] deals with RTS allowing fuzzy due dates.

Dhall and Liu [2] handled the problem of specifying an order in which the requests made by a set of periodic real-time tasks are to be executed by a multiprocessor computing system, with the goal of meeting all the deadlines with a minimum number of processors.

A number of authors treated the real-time Flexible Manufacturing Systems (FMS). Tawegoum *et al* [29] introduced management functions in real-time monitoring of FMS. Chakravarty and Balakrishnan [1] provided the procedure for the real-time revision of production and inventory schedules in a capacitated FMS.

Various metaheuristic methods, such as Simulated Annealing [11], Tabu Search [6], and Greedy Randomized Adaptive Search Procedure ([3] and [4]) were developed during the last three decades. Good surveys on applications of Artificial Intelligence to RTS can be found in [5, [26] and [21]). A comprehensive survey on real-time decision problems in OR perspective is given in (Seguin et al. [24]).

We will focus on RTS with a zero deadline for the beginning of job processing. In these systems, jobs are executed immediately upon arrival, conditional on system availability. That part of the job which is not executed immediately is lost forever, and queueing of jobs in such systems is not allowed.

The following works treat this kind of RTS. Kreimer and Mehrez ([18] and [19]) proved that the non-mix policy of never relieving an operative server maximizes the availability of a multiserver single-channel RTS involving preventive maintenance and working in general regime with any arrival pattern under consideration and constant service and maintenance times. Kreimer and Mehrez [20] and Kreimer [13] treated muliserver and multichannel (identical servers and channels) RTS (with unrestricted and restricted number of maintenance facilities respectively), working under maximum load regime as finite source queues ([7]). Kreimer [12] and [14] applied the two-dimensional birth-and-death processes in worst case analysis of a multiserver RTS (with ample and limited maintenance facilities respectively) with two different channels, when both service and maintenance times are exponentially distributed. Ianovsky and Kreimer [9] obtained optimal assignment probabilities to maximize availability of RTS with ample maintenance facilities presented in [12], for large number of servers. Kreimer [16] extended the results of [12] for arbitrary number of different channels operating under a maximum load regime. Kreimer [15] and Ianovsky and Kreimer [10] considered multiserver and multichannel RTS working in general regime.

The work presented here is an extension of results obtained in [25] and [17] for RTS with single channel and [8] for multichannel RTS with non-preemptive priorities. It deals with multiserver RTS, providing the service to the requests of real-time jobs arriving via several channels with separate queue (working under preemptive priorities regime) to each channel. Servers are identical, but may be maintained/programmed for several kinds of activities. We provide balance equations describing two models (with ample and limited maintenance facilities respectively) operating under maximum load regime and show how to compute various performance measures, when both operation and maintenance times are exponentially distributed.

The paper is organized as follows: In Section 2, the description of the model with preemptive priorities is presented. Section 3 provides balance equations for models with ample and restricted number of maintenance teams. Section 4 is devoted to computation of various performance characteristics. In Section 5 some numerical results are presented. Finally, in Section 6 some ideas for further research are discussed.

2. The Model

The most important characteristics of RTS with a zero deadline for the beginning of job processing are summarized in [15]. We consider the following real-world problem (extension of Shimshi and Kreimer [25] , Kreimer [17] and Ianovsky [8]).

The electronic device (*channel*) contains an important component (*server*), which is subject to breakdowns. The system contains r of such identical devices/*channels*. For proper performance each device needs exactly one fixed component at *any* instant (without it the device is inactive). There is an inventory of $N > r$ such components/*servers* in the system. A component, which is out of order, needs R_i time units of maintenance. After repair a fixed component may be of u-th type (of quality, $u = 1,...,m$) and is assigned to the v-th channel with probability $p_{u,v}$, $u = 1,...,m;\ v = 1,...,r$). These probabilities can be used as control parameters. Only after the repair is completed, the quality control procedure determines the quality type of fixed component. The fixed component of u-th type assigned to v-th channel is operative for a period of time $S_{u,v}$ before requiring R_i hours of repair. $S_{u,v}$ and R_i are independent exponentially distributed random values with parameters $\mu_{u,v}$ ($u = 1,...,m;\ v = 1,...,r$) and λ respectively. It is assumed that there are K identical maintenance facilities/teams in the system. Each team can repair exactly one component at a time. The duration times R_i of repair are i.r.v. exponentially distributed with parameter λ, which does not depend on the quality type of the component (neither before nor after the repair). After repair, the component will either be on stand-by or working inside the device, it is assigned for. There is a separate queue of components/*servers* to each device/*channel*.

We assume that components/*servers* of the first kind of activity type have the highest priority, components/*servers* of the second activity type are the next priority in line, and so on. Components/*servers* of the m-th activity type have the lowest priority. Component/*server* operating in the certain device/*channel* is interrupted, if another fixed component of higher priority type is assigned to the same device after repair. When the operating component must be repaired, the fixed server with highest priority takes its place.

The system works under a maximum load (worst case) of nonstop data arrival, which is equivalent to the case of a unique job of infinite duration in each channel (a total of exactly r jobs in the whole system).

Thus, the *nonstop* operation of the device is needed. This kind of operation is typical in high performance data acquisition and control systems, such as self-guided missiles, space stations, satellites, etc.

If, during some period of time of length T, there is no fixed component to provide the proper operation of the device, we will say that the part of the job of length T is lost forever.

Our purpose is to provide balance equations for computing steady-state probabilities of this system, its availability and other performance characteristics.

3. Steady State Probabilities

We denote $\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}$ the state of the system, where $n_{u,v}$ $u = 1,\ldots,m;$ $v = 1,\ldots,r$ is a number of fixed servers of u-th activity type assigned for v-th channel (obviously, $\sum_{u=1}^{m}\sum_{v=1}^{r} n_{u,v} \le N$ and $n_{u,v} \ge 0$), and $P_{\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}}$ the corresponding steady state probability. There are $\binom{N+m\cdot r}{m\cdot r}$ states in total. We also denote $\lambda_{u,v} = \lambda p_{u,v}$, the rate of assignments of fixed servers of u-th activity type to the v-th channel.

We will consider two models: 1) with ample maintenance facilities ($K \ge N$); and 2) with shortage of maintenance facilities ($K < N$).

3.1. Model with Ample Maintenance Facilities

We assume that there are ample identical maintenance facilities $K \ge N$ available to repair (with repair times R_i being i.i.d.r.v.) all N components simultaneously, if needed. Thus, each defective component starts repair without delay.

Theorem 1. Steady state probabilities for model with ample maintenance facilities and separate queue to each channel working under preemptive priorities regime and maximum load are given by the following system of linear equations:

$$P_{\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,v},\ldots,n_{u,v},\ldots,n_{m,v} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}} \left[\left(N - \sum_{v=1}^{r}\sum_{i=1}^{m} n_{i,v} \right)\lambda + \sum_{v=1}^{r}\sum_{t=1}^{m} \min\left(n_{t,v}, \max\left(0, 1 - \delta_t \sum_{i=1}^{t-1} n_{i,v} \right)\right)\mu_{t,v} \right] =$$

$$= \sum_{v=1}^{r}\sum_{u=1}^{m} \min\left(n_{u,v}, 1\right) \cdot P_{\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,v},\ldots,n_{u,v}-1,\ldots,n_{m,v} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}} \left(N + 1 - \sum_{v=1}^{r}\sum_{i=1}^{m} n_{i,v} \right)\lambda_{u,v} + \quad (1)$$

$$+ \min\left(N - \sum_{v=1}^{r}\sum_{i=1}^{m} n_{i,v}, 1 \right) \cdot \sum_{v=1}^{r}\sum_{u=1}^{m} P_{\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,v},\ldots,n_{u,v}+1,\ldots,n_{m,v} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}} \cdot \min\left(n_{u,v} + 1, \max\left(0, 1 - \delta_u \sum_{i=1}^{u-1} n_{i,v} \right)\right)\mu_{u,v}$$

$$\sum_{v=1}^{r}\sum_{n_{1,1}=0}^{N}\sum_{n_{2,1}=0}^{N-n_{1,1}}\cdots\sum_{n_{m,v}=0}^{N-\sum_{i=1}^{m-1}n_{i,v}} P_{\begin{pmatrix} n_{1,1},\cdots,n_{m,1}\\ \vdots \\ n_{1,v},\cdots,n_{m,v}\\ \vdots \\ n_{1,r},\cdots,n_{m,r}\end{pmatrix}} = 1, \tag{2}$$

where $\lambda=\sum_{v=1}^{r}\sum_{u=1}^{m}\lambda_{u,v}$; $\delta_t = 1-\delta_{t1}$; $\delta_{t1}=\begin{Bmatrix}0, t\neq 1\\ 1, t=1\end{Bmatrix}$; $\delta_u = 1-\delta_{u1}$; $\delta_{u1}=\begin{Bmatrix}0, u\neq 1\\ 1, u=1\end{Bmatrix}$.

Proof:

eDenot $P_0 = P_{\begin{pmatrix} n_{1,1}=0,\dots,n_{j,1}=0\dots,n_{m,1}=0\\ \vdots \\ n_{1,r}=0,\dots,n_{j,r}=0,\dots,n_{m,r}=0\end{pmatrix}}$, then we have

$$P_0 N\lambda = \sum_{v=1}^{r}\sum_{u=1}^{m} P_{\begin{pmatrix} n_{1,1}=0,\cdots,n_{u,1}=0,\cdots,n_{m,1}=0\\ \vdots \\ n_{1,v}=0,\cdots,n_{u,v}=1,\cdots,n_{m,v}=0\\ \vdots \\ n_{1,r}=0,\cdots,n_{u,r}=0,\cdots,n_{m,r}=0\end{pmatrix}}\mu_{u,v} \tag{3}$$

for the state $n_{u,v}= 0$, $u = 1,\dots,m$; $v = 1,\dots,r$ with no fixed servers in the system.

$$P_{\begin{pmatrix} n_{1,1}=0,\cdots,n_{u,1}=0,\cdots,n_{m,1}=0\\ \vdots \\ n_{1,v}=0,\cdots,n_{u,v}=N,\cdots,n_{m,v}=0\\ \vdots \\ n_{1,r}=0,\cdots,n_{u,r}=0,\cdots,n_{m,r}=0\end{pmatrix}}\mu_{u,v} = P_{\begin{pmatrix} n_{1,1}=0,\cdots,n_{u,1}=0,\cdots,n_{m,1}=0\\ \vdots \\ n_{1,v}=0,\cdots,n_{u,v}=N-1,\cdots,n_{m,v}=0\\ \vdots \\ n_{1,r}=0,\cdots,n_{u,r}=0,\cdots,n_{m,r}=0\end{pmatrix}}\lambda_{u,v} \tag{4}$$

for the vertices states, where all N servers are fixed of type u and assigned to v-th channel $n_{u,v}=N; \sum_{\substack{i=1\\ i\neq v}}^{r}\sum_{u=1}^{m} n_{u,i}=0; u=1,\dots,m; v=1,\dots,r$,

$$P_{\begin{pmatrix} n_{1,1},\dots,n_{i_1,1},\dots,n_{i_u,1},\dots,n_{i_k,1},\dots,n_{m,1}\\ \vdots \\ n_{1,j_v},\dots,n_{i_1,j_v},\dots,n_{i_u,j_v},\dots,n_{i_k,j_v},\dots,n_{m,j_v}\\ \vdots \\ n_{1,r},\dots,n_{i_1,r},\dots,n_{i_u,r},\dots,n_{i_k,r},\dots,n_{m,r}\end{pmatrix}}\left[\sum_{v=1}^{c}\mu_{i_1,j_v} + \left(N-\sum_{v=1}^{r}\sum_{u=1}^{k} n_{i_{u,v}}\right)\lambda\right] =$$

$$= \sum_{v=1}^{c}\sum_{g=1}^{k}\left(N+1-\sum_{v=1}^{r}\sum_{u=1}^{k} n_{i_{u,v}}\right) P_{\begin{pmatrix} n_{1,1},\dots,n_{i_{1,1}},\dots,n_{i_{g,1}},\dots,n_{i_{k,1}},\dots,n_{m,1}\\ \vdots \\ n_{1,j_v},\dots,n_{i_1,j_v},\dots,n_{i_g,j_v}-1,\dots,n_{i_k,j_v},\dots,n_{m,j_v}\\ \vdots \\ n_{1,r},\dots,n_{i_{1,r}},\dots,n_{i_{g,r}},\dots,n_{i_{k,r}},\dots,n_{m,r}\end{pmatrix}}\lambda_{i_g,j_v} + \tag{5}$$

$$+\sum_{v=1}^{c}\mu_{i_1,j_v} P_{\begin{pmatrix} n_{1,1},\dots,n_{i_{1,1}},\dots,n_{i_{u,1}},\dots,n_{i_{k,1}},\dots,n_{m,1}\\ \vdots \\ n_{1,j_v},\dots,n_{i_1,j_v}+1,\dots,n_{i_u,j_v},\dots,n_{i_k,j_v},\dots,n_{m,j_v}\\ \vdots \\ n_{1,r},\dots,n_{i_{1,r}},\dots,n_{i_{u,r}},\dots,n_{i_{k,r}},\dots,n_{m,r}\end{pmatrix}} + \sum_{v=1}^{r}\sum_{u=1}^{\delta_v} P_{\begin{pmatrix} n_{1,1},\dots,n_{u,1},\dots,n_{i_{1,1}},\dots,n_{i_k,1},\dots,n_{m,1}\\ \vdots \\ n_{1,v},\dots,n_{u,v}=1,\dots,n_{i_{1,v}},\dots,n_{i_{k,v}},\dots,n_{m,v}\\ \vdots \\ n_{1,r},\dots,n_{u,r},\dots,n_{i_{1,r}},\dots,n_{i_{k,r}},\dots,n_{m,r}\end{pmatrix}}\cdot\mu_{u,v}$$

for the internal states

$$0 < n_{i_{1,j_1}}, n_{i_{2,j_2}}, ..., n_{i_{k,j_c}} < N; \sum_{v=1}^{c}\sum_{u=1}^{k} n_{i_{u,v}} < N; n_{i_{g,j_d}} = 0, g = k+1,...,m; d = c+1,...,r; i_{1,v} < i_{2,v} < ... < i_{k,v};$$

$$1 \le k \le m; v = 1,...,r; \delta_v = \begin{cases} m, \sum_{i=1}^{m} n_{i,v} = 0 \\ i_1 - 1, \sum_{i=1}^{m} n_{i,v} > 0 \end{cases}$$

$$P_{\begin{pmatrix} n_{1,1},...,n_{i_1,1},...,n_{i_u,1},...,n_{i_k,1},...,n_{m,1} \\ \vdots \\ n_{1,j_v},...,n_{i_1,j_v},...,n_{i_u,j_v},...,n_{i_k,j_v},...,n_{m,j_v} \\ \vdots \\ n_{1,r},...,n_{i_1,r},...,n_{i_u,r},...,n_{i_k,r},...,n_{m,r} \end{pmatrix}} \left(\sum_{v=1}^{c} \mu_{i_1,j_v}\right) = \sum_{v=1}^{c}\sum_{g=1}^{k} P_{\begin{pmatrix} n_{1,1},...,n_{i_1,1},...,n_{i_g,1},...,n_{i_k,1},...,n_{m,1} \\ \vdots \\ n_{1,j_v},...,n_{i_1,j_v},...,n_{i_g,j_v}-1,...,n_{i_k,j_v},...,n_{m,j_v} \\ \vdots \\ n_{1,r},...,n_{i_1,r},...,n_{i_g,r},...,n_{i_k,r},...,n_{m,r} \end{pmatrix}} \lambda_{i_g,j_v} \quad (6)$$

for "diagonal" states

$$0 < n_{i_{1,j_1}}, n_{i_{2,j_2}}, ..., n_{i_{k,j_c}} < N; \sum_{v=1}^{c}\sum_{u=1}^{k} n_{i_{u,v}} = N; n_{i_{g,j_d}} = 0, g = k+1,...,m;$$

$$d = c+1,...,r; i_{1,v} < i_{2,v} < ... < i_{k,v}; 1 \le k \le m; v = 1,...,r.$$

Q.E.D.

3.2 Model with Shortage of Maintenance Facilities

Here we assume that there are K ($K < N$) maintenance facilities in the system. Thus, a shortage of maintenance facilities is possible when there are more than K servers out of order. In that case, the defective server waits for maintenance.

Theorem 2. Steady state probabilities for model with shortage of maintenance facilities and separate queue to each channel working under preemptive priorities regime and maximum load are given by the following system of linear equations:

$$P_{\begin{pmatrix} n_{1,1},...,n_{m,1} \\ \vdots \\ n_{1,v},...,n_{u,v},...,n_{m,v} \\ \vdots \\ n_{1,r},...,n_{m,r} \end{pmatrix}} \left[\min\left(K, N - \sum_{v=1}^{r}\sum_{i=1}^{m} n_{i,v}, K\right)\lambda + \sum_{v=1}^{r}\sum_{t=1}^{m} \min\left(n_{t,v}, \max\left(0, 1 - \delta_t \sum_{i=1}^{t-1} n_{i,v}\right)\right)\mu_{t,v} \right] =$$

$$= \sum_{v=1}^{r}\sum_{u=1}^{m} \min(n_{u,v}, 1) \cdot P_{\begin{pmatrix} n_{1,1},...,n_{m,1} \\ \vdots \\ n_{1,v},...,n_{u,v}-1,...,n_{m,v} \\ \vdots \\ n_{1,r},...,n_{m,r} \end{pmatrix}} \min\left(K, N + 1 - \sum_{v=1}^{r}\sum_{i=1}^{m} n_{i,v}, K\right)\lambda_{u,v} + \quad (7)$$

$$+ \min\left(N - \sum_{v=1}^{r}\sum_{i=1}^{m} n_{i,v}, 1\right) \cdot \sum_{v=1}^{r}\sum_{u=1}^{m} P_{\begin{pmatrix} n_{1,1},...,n_{m,1} \\ \vdots \\ n_{1,v},...,n_{u,v}+1,...,n_{m,v} \\ \vdots \\ n_{1,r},...,n_{m,r} \end{pmatrix}} \cdot \min\left(n_{u,v} + 1, \max\left(0, 1 - \delta_u \sum_{i=1}^{u-1} n_{i,v}\right)\right)\mu_{u,v}$$

$$\sum_{v=1}^{r}\sum_{n_{1,1}=0}^{N}\sum_{n_{2,1}=0}^{N-n_{1,1}}\cdots\sum_{n_{m,v}=0}^{N-\sum_{i=1}^{m-1}n_{i,v}} P_{\begin{pmatrix} n_{1,1},\cdots,n_{m,1} \\ \vdots \\ n_{1,v},\cdots,n_{m,v} \\ \vdots \\ n_{1,r},\cdots,n_{m,r} \end{pmatrix}} = 1 \tag{8}$$

Proof:

Keeping in mind that the total number of broken components is $N-\sum_{v=1}^{r}\sum_{u=1}^{m}n_{u,v}$, while the numbers of broken components in maintenance and waiting for it are $\min\left(K, N-\sum_{v=1}^{r}\sum_{u=1}^{m}n_{u,v}\right)$ and $\max\left(0, K-N+\sum_{v=1}^{r}\sum_{u=1}^{m}n_{u,v}\right)$ respectively, the proof is similar to that of Theorem 1.

4. Performance Characteristics

In this section we shall show how to compute some useful performance characteristics of the RTS under consideration. Each server can be in one of the following positions:

(i) busy (operating);
(ii) on stand-by;
(iii) out of order (in maintenance);
(iv) out of order (waiting for maintenance);

Each channel can be in one of two positions:

(i) in service;
(ii) out of service.

Keeping in mind that, the state of the system is given by the matrix $\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}$ and corresponding steady state probability is $P_{\begin{pmatrix} n_{1,1},\ldots,n_{m,1} \\ \vdots \\ n_{1,r},\ldots,n_{m,r} \end{pmatrix}}$, where $n_{u,v}$ $u=1,\ldots,m;$ $v=1,\ldots,r$ is a number of fixed servers of u-th activity type assigned for v-th channel we can represent the number of servers and channels in different positions in terms of $n_{u,v}$, namely:

the number of fixed components/servers of type u in the system is $N_u=\sum_{v=1}^{r}n_{u,v}$;

the number of fixed components assigned to v-th channel is $N_{(v)}=\sum_{u=1}^{m}n_{u,v}$;

the number of fixed components in the system is $\sum_{u=1}^{m}N_u=\sum_{v=1}^{r}N_v=\sum_{v=1}^{r}\sum_{u=1}^{m}n_{u,v}$;

the number of broken components is $N-\sum_{v=1}^{r}\sum_{u=1}^{m}n_{u,v}$;

the number of broken components in maintenance is $\min\left(K, N-\sum_{v=1}^{r}\sum_{u=1}^{m}n_{u,v}\right)$;

the number of broken components waiting for maintenance is $\max\left(0, K - N + \sum_{v=1}^{r}\sum_{u=1}^{m} n_{u,v}\right)$.

Now we can obtain corresponding average values, using steady state probabilities

$$L = \sum_{v=1}^{r}\sum_{n_{1,v}=0}^{N}\sum_{n_{2,v}=0}^{N-n_{1,v}}\dots\sum_{n_{m,v}=0}^{N-\sum_{j=1}^{r}\sum_{i=1}^{m-1} n_{i,j}} n_{u,v} P_{\begin{pmatrix} n_{1,1},\dots,n_{m,1} \\ \vdots \\ n_{1,v},\dots,n_{m,v} \\ \vdots \\ n_{1,r},\dots n_{m,r} \end{pmatrix}}$$

for average number of fixed servers in the system; $N - L$ for the average number of broken servers in the system; $\min(K, N - L)$ for average number of broken servers in maintenance; $\max(0, K - N + L)$ for average number of broken servers waiting for maintenance.

The number of fixed servers of u-th type active in v-th channel is $\delta_{iu,v} = \begin{cases} 1, & if\ \ i = u \\ 0, & if\ \ i \neq u \end{cases}$;

$u = \min_{n_{i,v} > 0, i=1,\dots,m} i \;\; ; v = 1,\dots,r$.

The average number of fixed servers of u-th type active in v-th channel

is $$L_{u,v} = \sum_{n_{1,v}=0}^{N}\sum_{n_{2,v}=0}^{N-n_{1,v}}\dots\sum_{n_{m,v}=0}^{N-\sum_{j=1}^{r}\sum_{i=1}^{m-1} n_{i,j}} \delta_{iu,v} P_{\begin{pmatrix} n_{1,1},\dots,n_{m,1} \\ \vdots \\ n_{1,v},\dots,n_{m,v} \\ \vdots \\ n_{1,r},\dots n_{m,r} \end{pmatrix}}.$$

The average number of busy servers (average number of served channels) is $\bar{r} = L_k = \sum_{u=1}^{m}\sum_{v=1}^{r} L_{u,v}$.

The average number of non-served channels is $r - \bar{r}$. The average number of fixed servers of type u on stand-by assigned to v-th channel is

$$Q_{u,v} = \sum_{n_{1,v}=0}^{N}\sum_{n_{2,v}=0}^{N-n_{1,v}}\dots\sum_{n_{m,v}=0}^{N-\sum_{j=1}^{r}\sum_{i=1}^{m-1} n_{i,j}} (n_{u,v} - \delta_{iu,v}) P_{\begin{pmatrix} n_{1,1},\dots,n_{m,1} \\ \vdots \\ n_{1,v},\dots,n_{m,v} \\ \vdots \\ n_{1,r},\dots n_{m,r} \end{pmatrix}}.$$

The average number of fixed servers of type u on stand-by in the system is $Q_u = \sum_{v=1}^{r} Q_{u,v}$.

The average number of fixed servers on stand-by assigned to v-th channel is $Q_v = \sum_{u=1}^{m} Q_{u,v}$.

The average number of fixed servers on stand-by in the system is $Q = \sum_{v=1}^{r} Q_v = \sum_{u=1}^{m} Q_u$.

The average rate of servers arriving from maintenance is $\lambda_{av} = \lambda(N - L)$.

The average rate of servers arriving from maintenance to v-th channel is $\lambda_{av(v)} = \lambda(N - L)\sum_{u=1}^{m} p_{u,v}$.

The average rate of servers of u-th type arriving from maintenance is $\lambda_{av(u)} = \lambda(N - L)\sum_{v=1}^{r} p_{u,v}$.

The average rate of servers of *u*-th type arriving from maintenance to *v*-th channel is $\lambda_{av(u,v)} = \lambda p_{u,v}(N-L)$.

The average system availability is $Av = \frac{1}{r} L_k = \frac{\bar{r}}{r}$.

The average system availability at channel *v* is $Av_v = \sum_{u=1}^{m} L_{u,v}$.

The average system loss is $Loss = 1 - Av$.

The average total cost of system operation per time unit is

$$TC = \sum_{v=1}^{r}\sum_{u=1}^{m} C_{u,v}L_{u,v} + D\left(r - \sum_{v=1}^{r}\sum_{u=1}^{m} L_{u,v}\right) + B(N-L) = D\cdot r - \sum_{v=1}^{r}\sum_{u=1}^{m}(D - C_{u,v})L_{u,v} + B(N-L),$$

where $C_{u,v}$, $u = 1,\dots,m;$ $v = 1,\dots,r$ is the cost of operation of the component of *u*-th type in *v*-th channel during the time unit, *D* is the penalty for non-served channel during the time unit and *B* is the cost of operation of maintenance facility during the time unit.

5. Numerical Results

In this Section, we present some numerical results for steady state probabilities obtained from equations (1)–(2) in the case: $r = 2$; $N = 3$; $\lambda = 28$; $m = 2$; $\mu_{11} = 8$, $\mu_{21} = 10$, $\mu_{12} = 6$, $\mu_{22} = 12$; $p_{11} = 0.21$, $p_{21} = 0.29$, $p_{12} = 0.14$, $p_{22} = 0.36$; $K \geq N$. Table 1 contains steady state probabilities.

Table 1. Steady state probabilities

n_{11},n_{21} n_{12},n_{22}	*P(n)*	n_{11},n_{21} n_{12},n_{22}	*P(n)*	n_{11},n_{21} n_{12},n_{22}	*P(n)*	n_{11},n_{21} n_{12},n_{22}	*P(n)*
0,0 0,0	0.008	0,0 3,0	0.003	1,0 2,0	0.003	1,1 0,1	0.045
0,0 0,1	0.027	1,0 0,0	0.009	0,1 0,2	0.044	1,1 1,0	0.021
0,0 1,0	0.005	0,1 0,0	0.028	0,1 1,1	0.038	0,2 0,1	0.046
0,0 0,2	0.058	1,0 0,1	0.024	0,1 2,0	0.007	0,2 1,0	0.024
0,0 1,1	0.029	1,0 1,0	0.005	2,0 0,0	0.009	3,0 0,0	0.007
0,0 2,0	0.004	0,1 0,1	0.051	1,1 0,0	0.039	2,1 0,0	0.034
0,0 0,3	0.048	0,1 1,0	0.017	0,2 0,0	0.060	1,2 0,0	0.084
0,0 1,2	0.087	1,0 0,2	0.030	2,0 0,1	0.012	0,3 0,0	0.048
0,0 2,1	0.027	1,0 1,1	0.016	2,0 1,0	0.005		

The following Table contains performance characteristics of the same model with given activity and penalty costs: $C_{11} = 4$, $C_{21} = 5$, $C_{12} = 6$, $C_{22} = 7$, $D = 5$, $B = 3$.

Table 2. Performance characteristics (averages)

Performance characteristic	**Value**
Nu. of fixed servers L	2.542
Nu. of fixed servers at channel 1 $N_{(1)}$	1.308
Nu. of fixed servers at channel 2 $N_{(2)}$	1.233
Nu. of fixed servers of type 1 N_1	0.748
Nu. of fixed servers of type 2 N_2	1.793
Nu. of fixed servers of type 1 at channel 1 $L_{1,1} + Q_{1,1}$	0.412
Nu. of fixed servers of type 2 at channel 1 $L_{2,1} + Q_{2,1}$	0.896
Nu. of fixed servers of type 1 at channel 2 $L_{1,2} + Q_{1,2}$	0.336
Nu. of fixed servers of type 2 at channel 2 $L_{2,2} + Q_{2,2}$	0.897
Availability at channel 1 Av_1	0.725
Availability at channel 2 Av_2	0.650
Availability of the system Av	0.688
Total cost of system operation per time unit TC	18.912

6. Future Research

In this Section, we present some ideas for further research. In our opinion, stochastic processes / queueing theory methodology (see Gross and Harris [7]) can be successfully applied to more general RTS with preemptive priorities such as:

- Multiserver and multichannel RTS working in general regime;
- Analytic approximations – product form solutions for steady state probabilities;
- RTS in which each server needs more than one kind of maintenance.

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REVIEW OF CURRENT STATE OF EUROPEAN 3PL MARKET AND ITS MAIN CHALLENGES

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This article examines basic reasons behind the use of 3 PL, i.e. the main drivers of outsourcing (Chapter 2) as well as explains the essence of 3PL service (Chapter 3). Chapter 4 deals with the analysis of current state of 3 PL market in Europe. Finally, Chapter 5 gives an overview of main challenges that European 3 PL service providers currently are facing.

Keywords: *3PL service, outsourcing, logistics service providers*

1. Introduction

The practice of outsourcing logistics operations has grown significantly over the past few years. Outsourcing is a strong trend and has been for decades now in most industries. Companies try to simplify the structure of their organizations and focus on “core business”, leaving everything out that does not belong to that central part of their operations. By doing so, the number of companies participating in production and distribution set-ups increases and thus the number of external relationships between the companies grows. Outsourcing opens the door to resources not necessarily available in one’s own organisation – world-class services, products, processes and technology – without the need to invest in infrastructure.

2. Concept of 3PL

The term ‘the third party logistics services’ has been used in a number of ways, from describing one single service, e.g. the outsourcing of transport to describing the outsourcing of a set of complex processes. For those firms that provide the third party logistics services, however, there are a number of established definitions [1, 2]. From the point of view of the buyer of these services, the third party logistics can be seen as a combination of the following elements:

- an external agency provides all or a considerable number of the logistics services;
- the shipper uses a limited number of service providers;
- long-term and close business relations between service provider and customer in place of single business transactions;
- integrated logistics functions;
- both parties try to exploit the synergic benefits the partnership offers.

Originally, 3PL means outsourcing logistics activities including transportation and warehousing to outside firms, which are not a consignor or a consignee. However, it is not common 3PL practice to outsource a single activity of logistics independently, but to outsource multiple activities from the firm's strategic point of view.

3PL (or 3PL provider) has the following features at present:

1. integrated (or multi-modal) logistics service provider;
2. contract-based service provider;
3. consulting service provider.

First, a 3PL provider is regarded as an integrated logistics service provider. IT-related activities for controlling goods flow such as order processing, and inventory management, among others are also included in the function of the 3PL provider. However, the 3PL provider need not provide all the services solely. The 3PL provider can outsource some activities to sub-contractors.

A 3PL provider can be classified into the asset-based and the non-asset-based. The asset-based 3PL provider owns some assets, particularly transport-related assets such as trucks, warehouses, etc., while the non-asset-based 3PL provider does not own such assets, and usually relies on sub-contractors’ assets. Examples of non-asset 3PL providers include forwarders, brokers, marketing companies, and information system management companies.

Second, the service of 3PL is contract-based. Recently, a contract was written about the way to share responsibilities assuming various situations in detail. Such strict contract would make reliable relationship between the parties, and strengthen the alliance.

The third, offering consulting-services to the firms is an important feature of the 3PL. The 3PL provider can make various advises to answer customers' requirements concerned with marketing strategy, information system configuration, cooperative transportation, etc.

Currently Logistics Service Providers offer a number of services in addition to transportation. These are cross-docking services in terminals, and storage or integrated logistics value-added services in warehouses and distribution centres. Table 1 shows common physical and administrative services provided by LSPs.

Table 1. The type of physical and administrative services provided by Logistics Service Providers

	Basic	Intermediate	Advanced
Physical services	storage good reception picking according to order and packing (pick & pack) re-packing and labelling return of goods delivery from storage	consolidation & deconsolidation preparation for freezing, thawing, sawing prepare for delivery and pack set building, sequencing, product resorting and labelling cross-docking	assembly of components operate vendor management inventories in stores or stock-keeping facilities recycling with waste handling and reconditioning unpacking and quality control
Adm. services	tendering and contracting other LSP tendering and contracting carriers insurance services stocktaking	payment services order administration and customer service claims handling export clearance and import clearance Track & Trace information forwarding services financial services provide one-stop logistics service purchase	forecasting and inventory management administration of minimum and protective inventories purchase and call-offs delivery planning and management and follow up exception management design of individual logistics set-ups implementation of logistics set-ups operation of customers' logistics set-up responsible for the customers' logistics operations

3. Reasons Behind the Origin of 3PL

Continually pressured to improve the efficiency and reliability of their transportation and logistics operations without sending their overheads through the roof, shippers are realising the potential economic advantage of outsourcing their logistics activities.

In the early stages of logistics outsourcing, transport and warehousing activities came into focus. The effects of passing over the transport operation to the third party are obvious for those with moderate volumes of goods and widespread distribution areas, regions or countries. The outsourcing tendency has accelerated in recent years and more companies are now contracting their activities to external parties.

The principle reasons why companies use the third party services are a need to focus on core activities, to cut costs, and at the same time provide their customers with better standards of service. Outsourcing gives companies the opportunity to concentrate their resources, spread their risks and focus on matters which are vitally important for their survival and future growth [3].

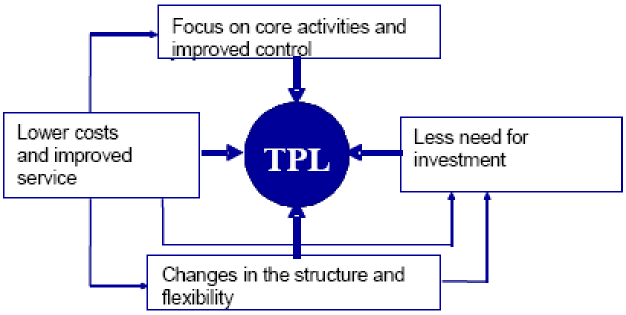

Figure 1. The third party logistics drivers

Lower logistics costs and improved services are the commonest reasons for using the third party logistics services. When successful, outsourcing logistics activities and operations has meant savings of 10% – 30% on costs. Furthermore, going by indicators that measure standards of service, outsourcing has been responsible for improvements in this area. Most savings on costs are normally achieved in those relating to capital tied up in stock and storage/warehousing costs [4].

The basic assumption is that the provider of logistics services can exploit the economies of scale involved in providing the same service to more than one customer. One has grown accustomed to the notion that improved efficiency is a precondition of long-term financial benefit and better standards of service. Better efficiency can, for example, be achieved by improving the expertise of existing staff or by recruiting new skilled personnel.

4. Current State of European 3PL Market[1]

In total, 42% of the enterprises in Europe currently outsource their logistics operations to 3PLs.

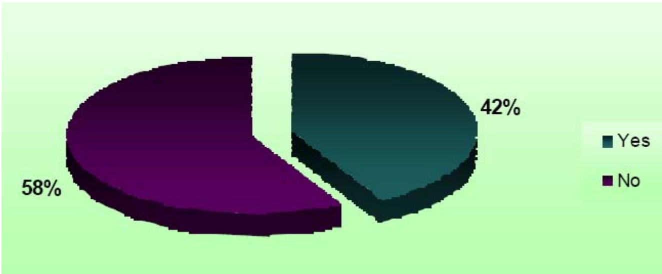

Figure 2. Share of outsourcing logistics operations

Taking into account that an increasing number of shippers are shifting to a non-asset based business model, one would expect that transport would top the list of logistics functions that are outsourced. Almost two thirds of the companies say they are outsourcing their transportation activities. Less than 10% of the respondents outsource their inventory management, while more than the third happily hand over their warehousing operations to 3PLs.

A quarter of the companies outsource their information systems. However, fleet management is only outsourced by 13% of the European enterprises.

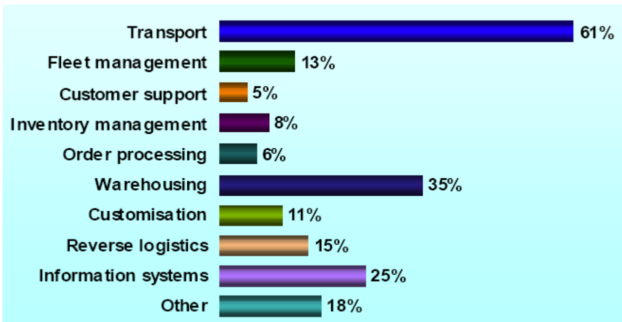

Figure 3. Outsourcing logistics operations

Some interesting findings are in respect with the level of satisfaction expressed by the users of 3PL services. Once the decision has been taken to outsource to a 3PL, satisfaction levels are generally good. A total of 79% of the companies selected ‘good’ (62%), ‘higher than expected’ (13%) or ‘outstanding’ (4%). In comparison, only 21% were somewhat less enthusiastic about the performance of their 3PLs. 74% of the companies said that outsourcing inventory management and coordination of warehousing and manufacturing answers their logistics issues, which ties in with the 73% who face frequent and dramatic shifts in customer demand.

[1] Based on the findings of the eyefortransport report „Outsourcing Logistics Europe 2006“

Just over three quarters of the companies believe that outsourcing logistics activities is the answer when it comes to expanding distribution systems without major capital expenses in labour, assets and technology.

On average, three quarters of the companies said that outsourcing logistics to a 3PL solves the problems caused by suppliers and carriers who fail to coordinate shipments and deliveries, and late shipments that result in the loss of money and customers.

Since the majority of the companies currently using 3PLs are getting 'good' to 'outstanding' service (79%), it is not surprising that they would 'possibly' (52%) or 'very likely' (32%) increase their reliance on 3PLs.

5. Main Challenges to European 3PL Service Providers[2]

Maintaining profits under price pressures from customers is still seen as the biggest challenge to European 3PLs. A total of 79% of 3PL service providers said it was a 'big challenge' or a 'very big challenge'. Relationship with customers is perceived as a big or very big challenge by 78% of 3PLs. This factor, in combination with the price pressures from customers, points to the considerable sensitivity of 3PLs to the markets they serve. Globalisation of the 3PL market and delivering services in new geographic regions was rated a big or very big challenge by 68% of 3PL companies. Consistently delivering the latest cutting edge technology to customers has considered a big or very big challenge by 59%. Completing the 'top five' challenges as perceived in 2006 was competing with giant global 3PLs, considered a serious challenge by 52%.

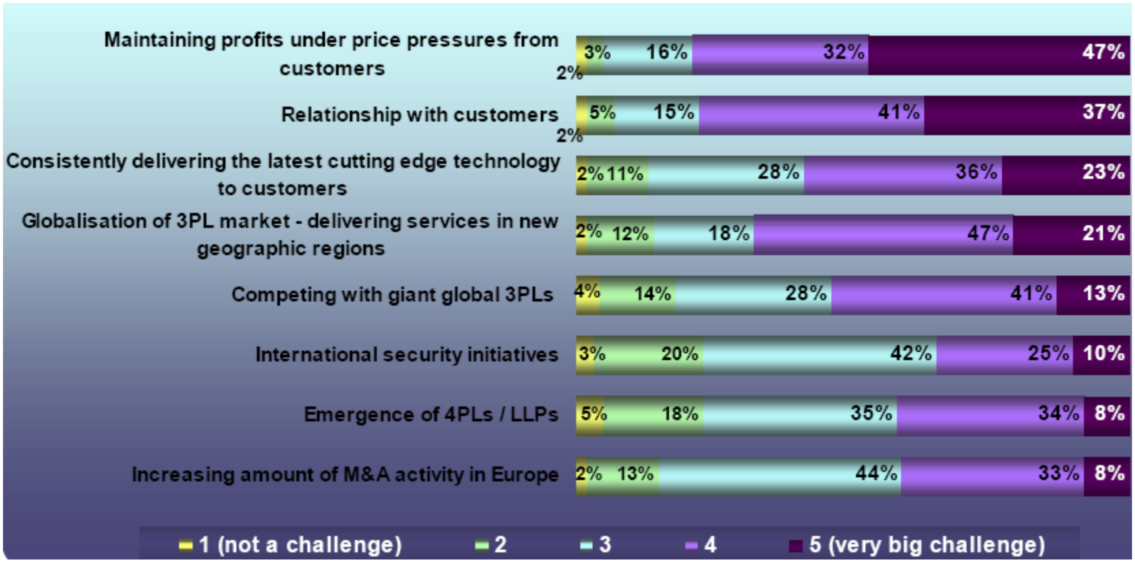

Figure 4. Main challenges for European 3PLs

Conclusions

- The practice of outsourcing logistics operations has grown significantly over the past few years. Continually pressured to improve the efficiency and reliability of their transportation and logistics operations without sending their overheads through the roof, shippers are realising the potential economic advantage of outsourcing their logistics activities.
- European industry is currently experiencing a degree of transition, and increasing numbers of shippers are considering the merits of outsourcing one or more of their logistics operations. According to the results of survey intended to investigate European 3PL market, in total, 42 % of the companies currently outsource their logistics operations to 3PLs.

[2] Based on the findings of the eyefortransport report „The European 3PL Market"

- The survey confirms that almost two-thirds of the enterprises outsource their transportation activities. Less than 10% of the companies outsource their inventory management, while more than the third happily hand over their warehousing operations to 3PLs; a quarter of the companies outsource their information systems. However, fleet management is only outsourced by 13% of the companies.
- Competition among 3PLs has become intense. Therefore the main challenges for current 3PL services providers seem to be as follows: maintaining profits under price pressures from customers; relationship with customers (this factor, in combination with the price pressures from customers, points to the considerable sensitivity of 3PLs to the markets they serve); globalisation of the 3PL market and delivering services in new geographical regions; consistently delivering the latest cutting edge technology to customers; competing with giant global 3PLs; emergence of 4PLs/LLPs.
- A total of 79% of the companies selected "good" (62%), "higher than expected" (13%) or "outstanding" (4%). In comparison, only 21% were somewhat less enthusiastic about the performance of their 3PLs.

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RESEARCH ON INFORMATION SYSTEMS DEVELOPMENT IN LITHUANIAN RAILWAYS

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As a modest-size country having limited natural resources and market, Lithuania should be very interested in becoming much more open to the world and playing traditional role of mediator between the East and the West. Among the most important conditions for the openness is a wide range of interrelated links between the maritime, road, railway and air transport with the foreign countries, as well as the relevant national transport infrastructure and the development and application of Information Systems (IS).

Keywords: *railway, information system (IS), IS selection, management, model of systems*

1. Introduction

As in most countries of the East and Middle Europe, Lithuanian railway transport sector is lagging behind in technical, economic and organisational aspects comparing with the advanced and efficiently interacting railway transport systems of the West and North Europe. Therefore radical changes are necessary in Lithuanian railways for the successful integration into the European railway transport system, particularly from the point of view of approximation of infrastructure to the standards of EU member states, and creation and implementation of integrated IS.

2. Evaluation of IS Selection and Implementation in Lithuanian Railways

In the course of IS development the cooperation of IS and functional staff becomes particularly complicated. In the integrated case the requirements for systems and their functionality are created by functional units responsible for the reaching of business goals – IS is an instrument for improvement of delivery of services and reaching the aims. In a defined way provider is selected in the enterprise and the system starts to be implemented. In this period appears the enterprise's IS division staff, which has to take care of the system's integrity, its availability for operation and further maintenance and development. After implementation of the system it is transferred to IS subdivision for taking care of maintenance. Often proposals for further IS development are provided by IS subdivisions, which are also taking care of the stability and development of the system, as well as of the maintenance and administration of users, and communication with providers.

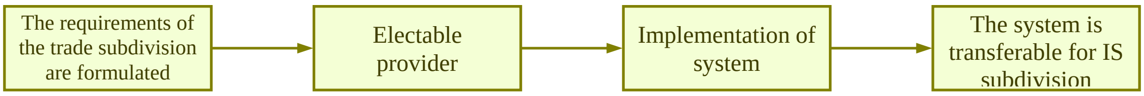


Figure 1. IS selection and implementation

Best practices of IS management occur in every company, however it is also purposeful to use best global practices that have proved successful and that are constantly improved. One of such practices is so called „ITIL", which in the period of system's existence comprises the following processes:

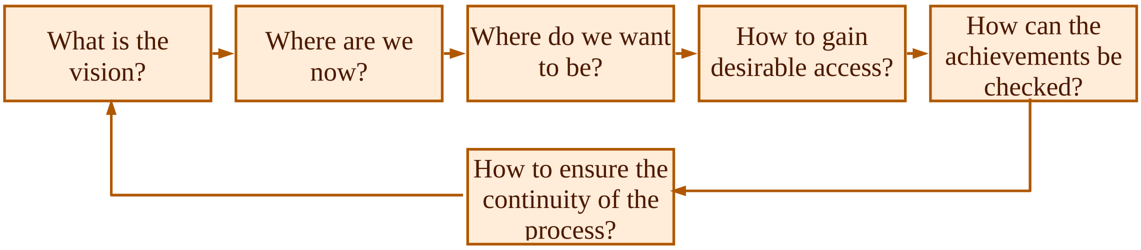
On tactical level:

1. Management of services standards;
2. Management of accessibility;
3. Management of resources volumes;
4. Management of succession;
5. Management of finances.

On operational level:

1. Management of configurations;
2. Management of prompts registration service;
3. Management of incidents and problems;
4. Management of modifications;
5. Management of versions.

Above-mentioned processes are not all required and not for all enterprises necessary – however each of them can also be used for the management of a concrete system. The following scheme is required for the attainment of desirable state of the system:



This process includes several above-indicated stages – identification of vision, short description of existing situation, definition of directions, action plan and creation of system for checking of condition.

3. Development of Information Systems

User's workplace

For the successful creation of Information Systems the following factors are particularly important: user‘s workplace, ergonomics of Information System, operational convenience of the system, amount of errors and other aspects of the workplace. User's workplace often needs to meet the requirement for possibilities to reflect a large amount of information. Therefore modern systems are usually created in the Windows environment by application of graphic means for reflection of data and actions. For this reason persons working in subdivisions of management of different business sectors (such as: flight control, network monitoring for internet service provider, assistance service operation) often use even several monitors reflecting different information necessary for decision-making. In the general case the user's computer has to ensure the 1024 X 768 differential capacity (this requires min 17" size of the screen), to picture information by the user-friendly frequency (min 90 Hz) with the widest range of colours. Application of typical solutions for data picturing and attraction of attention (fount sizes, colours, information bunching, management means) enables a significant enhancement of efficiency, speed and comfort ability for the user.

User's interface

There are various user‘s interface creation methods reflecting actual needs of the customer.

System of messages. This system is based on messages exchanged by the system users.

Process system. This system is like the message system but its essential difference is that the system itself formulates the tasks according to its coded process chain, provides information for the participant in the context of the general process.

Issues of ergonomics

Means of ergonomics, which are however often limited by the possibilities of Windows operational system, can also improve the quality of the system and convenience for the user, thus having a direct influence on the popularity of the system, comfort of work and reasonable maintenance costs.

4. Model of Systems' Interface is in the Process of Development

The above-mentioned systems have to comprise the largest proportion of services delivery functions.

In the delivery of goods' transportation services each action (transaction) has to be registered in one of the systems. Thus a system stabilised in time is created for identification of any service, place, amount, location and other parameters. Below the stages of general scheme that have to be performed out in one of the systems and depending on needs are presented.

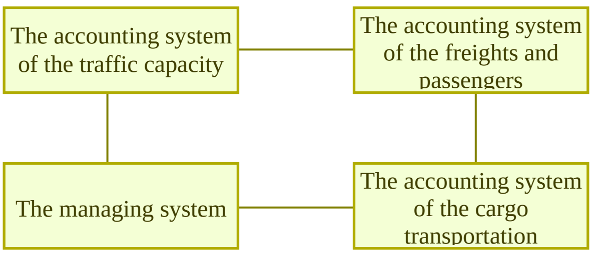


Figure 2. Model of systems being created

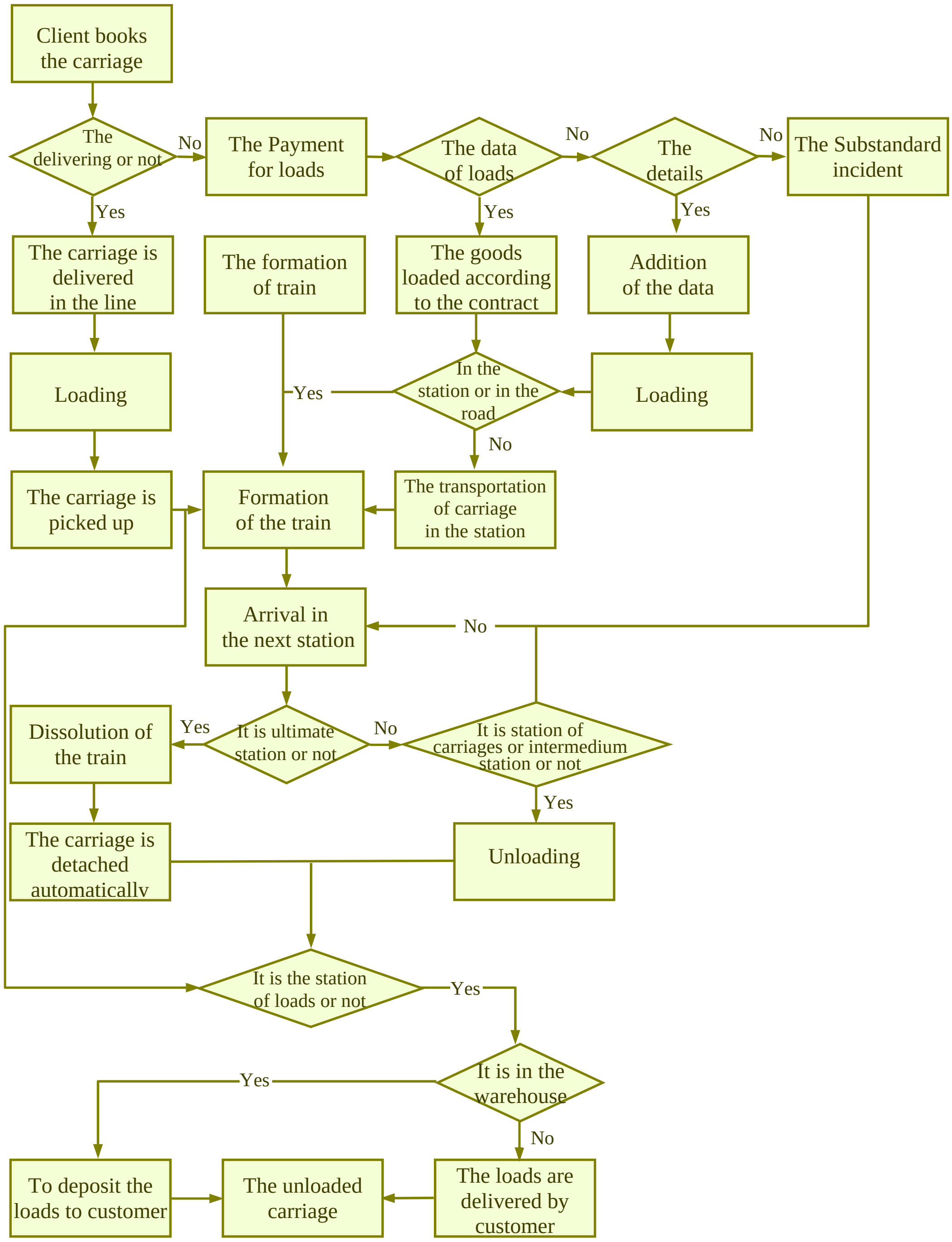


Figure 3. Stages of integrated scheme of process

Conclusions

- In the IS development the cooperation of IS and functional staff becomes particularly complicated.
- In the delivery of freight transportation services every transaction has to be registered in one of the systems.
- Presented stages of the integrated scheme of the process should be carried out from the system and depending on the requirements.

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FLUCTUATIONS AND CONTROL IN MANAGEMENT

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Goldratt's Game for the simulation purpose in the management course was presented in two different visual forms (Vensim and Excel). The first model is clearly controllable and attractive for classroom. The second one is carefully investigated under the several control rules.

Keywords: *simulation, fluctuations, control, chain*

1. Fluctuations and Control in Management

The role of fluctuations and its counterintuitive character may be understood by simulation in the appropriate way some supply chain (Goldratt's matchsticks game [1], Beer distribution game [2]). The first model has been created in Vensim (Ventana. Systems. Inc.) simulation environment (see. Fig. 1) and clearly shows the nature and role of fluctuations in the simplest matchsticks case. By changing a separate dice rules one can model drum – buffer-rope effects. The picture becomes more complicated if another feedback is included.

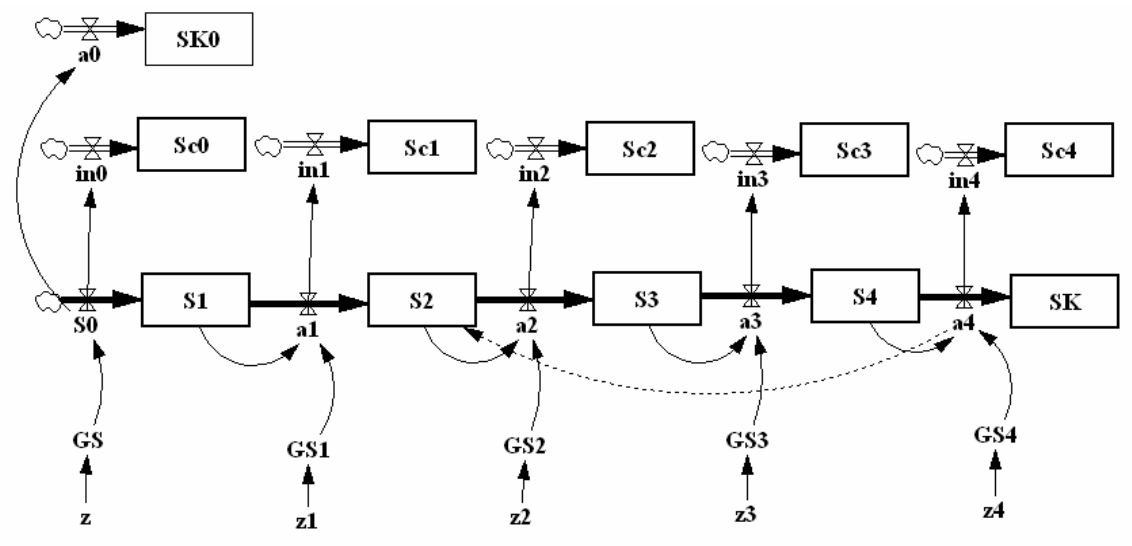

Figure 1. Vensim model

In the second model we introduce a control into the impact and interaction of statistical fluctuations and dependent events on the stylised process flow, which consists of 3 separate, defect-free operations with queues (inventory buffers) between them. We use the model described by Johnson [3]. The aim of the article would be comparing statistical characteristics of the system, described by Johnson (2002) to those of system after applying control variable. Both systems are modelled by imitation modelling each consisting of three operations with number of runs 180 with the time steps up to 32000 for each of the systems. For the second system there is a minor control applied $Uk(t) = U = \text{const} = 1$ with a fixed constant threshold $Pk = P = \text{const} = 30$ for all the operations of the system at any moment in time $1 <= t <= 350$.

2. Properties of Initial Model

The initial model has the following block structure (Figure 2):

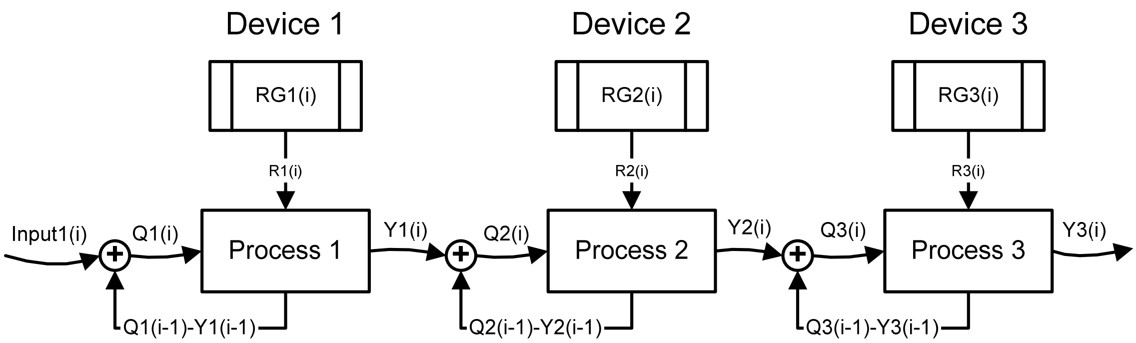

Figure 2. The block diagram of initial model before introduction of control

This model can be used to illustrate many concepts in production management. We use it to reinforce the notation that reduction of variation in processes is more efficient and economical than increasing inventory or work-in-progress in this case. The model simulates a production line with 3 work stations. The product must pass through each of the 3 work stations in order from 1 to 3. We can use pennies to simulate the process. The potential amount of work completed at each station in a given time period is a uniform distribution of 1, 2, 3, 4, 5, and 6. This random potential work is determined each period by the tossing of a die. The actual work forwarded to the next station can be represented by equation (1) below.

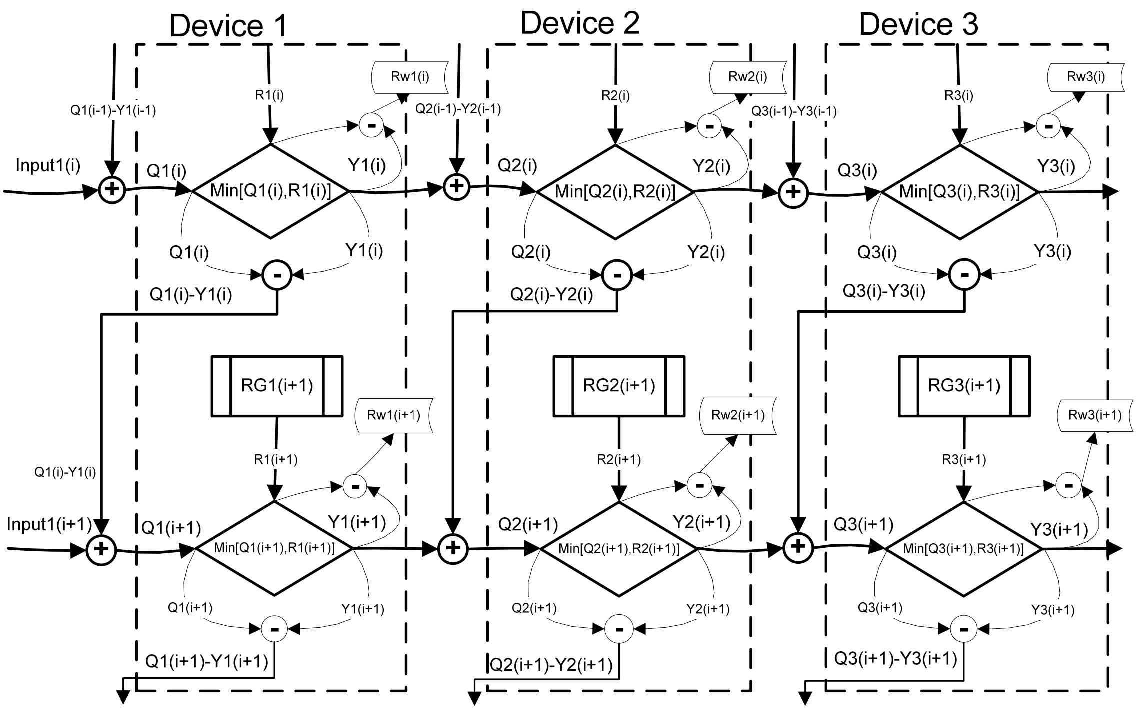

Figure 3. The model structure detalization

The model might be formalized as the following equations:

$$Q_k(i) = Q_k(i-1) - Y_k(i-1) + Y_{k-1}(i),\ Y_k(i) = \min[Q_k(i), R_k(i)],\ R_k(i) = RG_k(i), \quad (1)$$

where $\boldsymbol{Q_k(i)}$ **–** represents the input of k^{th} operation block (k^{th}device), $\boldsymbol{Y_k(i)}$ **–** represents the output of k^{th} operation block (k^{th} device), $\boldsymbol{Y_0(i)}$ – is the independent input of the system ($\boldsymbol{Y_0(i)}$ generates at every step a uniform distributed integer numbers between 1 and 6), $\boldsymbol{R_k(i)}$ – is the output of random generator $\boldsymbol{RG_k(i)}$ which produces an independent uniform distributed integer numbers between 1 and 6, i.e. $\boldsymbol{1 <= RG_k(i) <= 6}$.

The value $\boldsymbol{RG_k(i)}$ is the number of resource units available for use at time $\boldsymbol{i}$ for completing a k^{th} operation according to the equations (1). $\boldsymbol{Q_{Kmax}(i)}$ – represents the output of the system (number of units produced) during time cycle $\boldsymbol{i}$, $\boldsymbol{k}$ **–** is the ordinal number of the operation, $\boldsymbol{1 <= k <= Kmax}$, where $\boldsymbol{Kmax}$ – is the maximum number of the operations inside the system, $\boldsymbol{i}$ – represents the operation step. It is a single time period, $\boldsymbol{1 <= i <= T}$, where $\boldsymbol{T}$ is the maximum time step of observations. $\boldsymbol{Q_k(0) = 0, 1 <= k <= Kmax.}$ It is assumed that prior to start the system is at null values, i.e. there are no shortages or excess of uncompleted production in progress.

In papers [1–3] the model has been investigated only on some dozens of time intervals and with insufficiently explicitly. To estimate influence of control on behaviour of system (1), the detailed and multifold study of model dynamics is required.

For the model on Figure 2 consisting of 3 devices, step by step monitoring all variables entering the equation of model was carried out. In statistical experiments it was revealed, that realizations of queues $\boldsymbol{Q_k(i)}$, $1 <= k <= 3$ at model have no trend of stabilization, even on rather long intervals of time up to 50'000 steps. Figure 4 portrays modification of values of queues $Q_1(t)$, $Q_2(t)$, $Q_3(t)$ on an interval in length of 350 steps for 10 realizations.

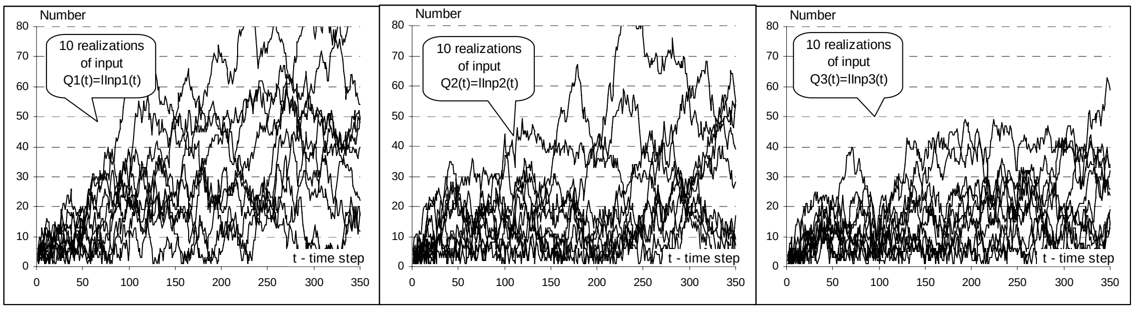

Figure 4. Visualization of 10 realizations for input $Q_1(t)$ (the left-hand side graph), for input $Q_2(t)$ (the middle graph) and for entrance $Q_3(t)$ (the right graph). The trend to increase of amplitudes of queues on entrances of model also is accompanied by increased variance

For deriving statistical conclusions there have been performed 180 independent runs of the model. All the varying values of the model have been measured and brought in a database on each time step. Thus, for each moment there have been available 180 independent measurements of each of parameters. Figure 5 illustrates the change of average values of inputs $Q_1(t) – Q_3(t)$ on an interval in length of 350 steps (averaged 180 runs of the model).

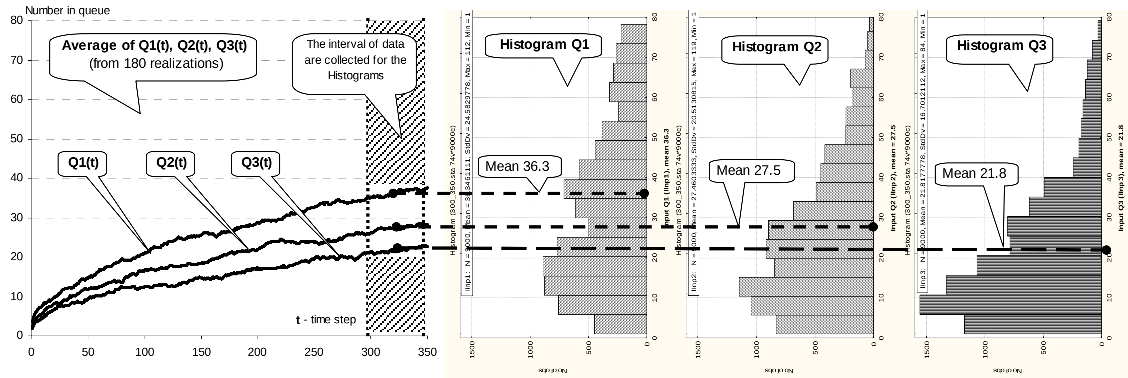

Figure 5. The changing in average values of outputs $Q_1(t) – Q_3(t)$ on an interval of 350 steps (averaged 180 runs of the model). The amount of objects in queue is depicted on the vertical axis. Histograms of corresponding inputs are arranged in the right side of the figure. Data for histograms are collected on an interval of time from 300 up to 350 steps for 180 realizations, i.e. each of histograms represents a set of 50*180 = 9000 observations

There follows one important observation from the presented graphs: before each operation the amount of unprocessed objects is constantly growing. The sum of inputs $Q_1(t)$ $+Q_2(t)$ $+Q_3(t)$ makes the total number of the objects which have been accumulated by the system at present time "*t*".

In a running model not all resources are used rationally. From the second equation of system (1) it follows that at $\boldsymbol{R_k(i) > Q_k(i)}$, a part of resources which we shall designate as $\boldsymbol{R_{kw}(i) = R_k(i) - Q_k(i)}$, is not used on a step **"*i*"** and consequently is irrevocably lost.

It is obvious, that with increasing queues $\boldsymbol{Q_1}$ (*t*), $\boldsymbol{Q_2}$ (*t*), $\boldsymbol{Q_3}$ (t) the losses of resources should decrease, as probability of occurrence of queues with number of objects in each of them decreases (which is below 6). Since the use of resources is limited on each time step by an inequality $\boldsymbol{1 <= R_k(i) <= 6}$ at length of queue $\boldsymbol{Qi(t) > 6}$ the model should function more effectively as all of the resources should be used.

Let's consider, how the accumulated sum of losses of resources eventually varies (see Figure 6).

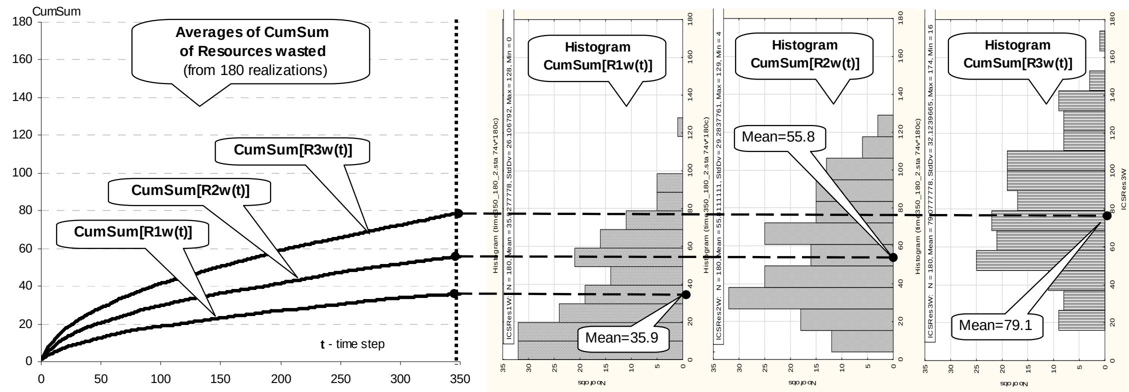

Figure 6. Change of average accumulated sums of resource losses over time (the left graph) and histograms of wasted resources accumulated sums at time = 350 (180 observations)

From graphs on Figure 6 there can be seen constant increase of average cumsum the lost resources is visible. Eventually the tendency of increase of resource losses at the subsequent stages of processing in relation to the previous operations is kept. Histograms of distribution of resource losses presented in section $t = 350$ show very wide and asymmetrical spread of values. The model shows unexpected behaviour as with increase of average size of queues (Figure 5) average losses of resources (Figure 6) also increase. As in reality losses of resources grow at increment of average sizes of queues it can mean growth in fluctuations of number of objects in queues.

The observed effect will remain, if the probability of occurrence of small queues (till 5 details) does not aspire to zero with growth of time. Increase expenditures by storage of not completed production $Q_1(t)$ $+Q_2(t)$ $+Q_3(t)$, and expenditures grow on payment of increasing losses of resources $\boldsymbol{R_{kw}(i)}$**,** $1 <= k <= 3$ from the point of view of economy**.** It is obvious that the behaviour of model described by a set of equations (1) is non-rational for modelling productions. The possibility appears to make correcting control with the purpose of possibilities of the best use on resource management. If immediate interference in "process of manufacture" is not possible to use of additional resources can begin one of possibilities change on behaviour of the system.

3. System with Control of Additional Resources

So, there is a problem how "to improve" functioning model by means of introduction of additional resources in such a way, to increase profit (or other criterion), not rendering influence on statistical properties of initial generators of resources. On the Figure 7 the block diagram of admissible updating of system is presented. We investigate influence of "weak" management which can be characterized as enough in the big size of a threshold $\boldsymbol{P_k} >> 6$ in comparison with a dispersion of a source of the basic resource, and as when it is supposed to use external sources of resources ***UGk* (*i*)** which on each step can add no more than on one unit ***Uk* (*i*) = 0 or 1** for each of **"*k*"** resources **1 <= *k* <= 3.**

The formal objective is to inset into the system (1) additional number of resource units in accordance to several rules, which we later refer to as *control variables.* The control ***Uk*(*i*)** is given separately for each process through a feedback mechanism. The value of control variable ***Uk*(*i*)** for $\boldsymbol{k^{th}}$ operation is determined by the threshold parameter $\boldsymbol{P_k}$ which in the context of the present article is considered constant for all the operations. If the queue length $\boldsymbol{Q_k(i)}$ on intake of a $\boldsymbol{k^{th}}$ operation at a time ***i*** exceeds the value of P_k then the resource of k^{th} operation is added a predetermined non-random resource $U_k(i) > 0$ in the general case. Thus, k^{th} operation on i^{th} step will be completed with an increased resource $R_k(i) = RG_k(i) + U_k(i)$.

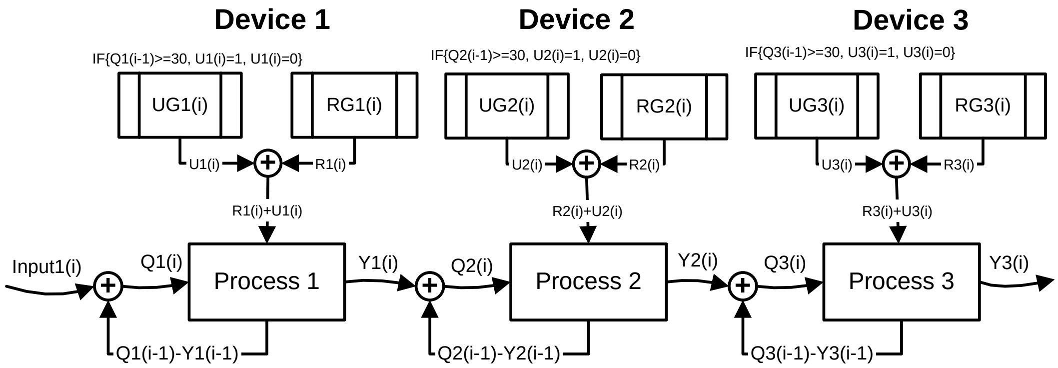

Figure 7. The block diagram of model with control of additional resources

The system with control variable will take the following form:

$$Q_k(i) = Q_k(i-1) - Y_k(i-1) + Y_{k-1}(i),\ Y_k(i) = \min\,[Q_k(i), R_k(i)],\ R_k(i) = RG_k(i) + U_k(i),$$

$$U_k(i) = if\ [Q_k(i-1) - Y_k(i-1)] > P_k,\ then\ U_k,\ else\ \mathbf{0}. \quad (2)$$

To the equations (2) there corresponds the block diagram on Figure 8.

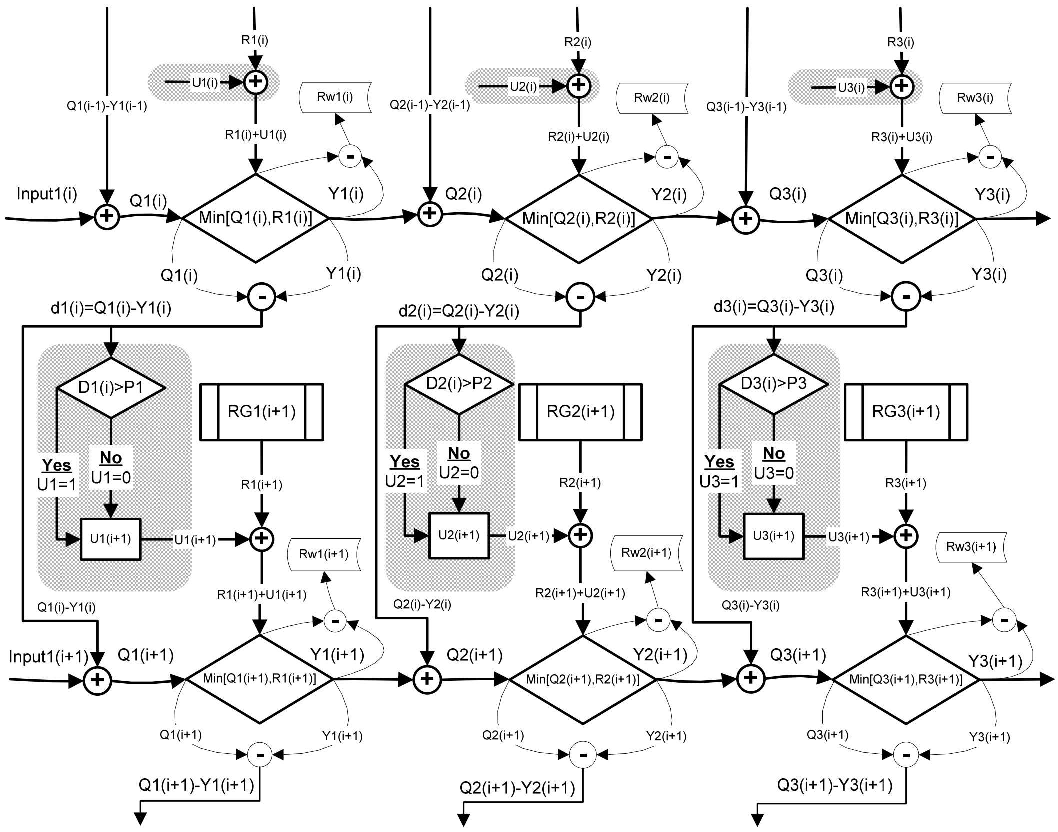

Figure 8. The block diagram of system with discrete management of additional resources according to the equations (2). Monitoring is carried out on value of threshold ***Pk*** for length of queue ***Qk*** **(*i*)**.

Let us consider, as the system will be functioning at threshold ***Pk*** = 30 which has been chosen heuristically

We would like to discover by means of a simulation modelling as in system with the control described above to receive properties the best, than in initial system.
Let us consider, as dynamics of queues will vary at threshold ***Pk*** = 30, ***Uk*** **(*i*)** can accept values or **0 or 1,** for each of **"*k*"** resources **1 <= *k* < =3**

$U_k(i) = if\ [Q_k(i-1) - Y_k(i-1)] > 30,\ then\ 1,\ else\ 0.$

On the Figure 9 average values of queues and histograms correspondingly them in an interval of time from 300 up to 350 time steps are represented at 180 realizations of model with control.

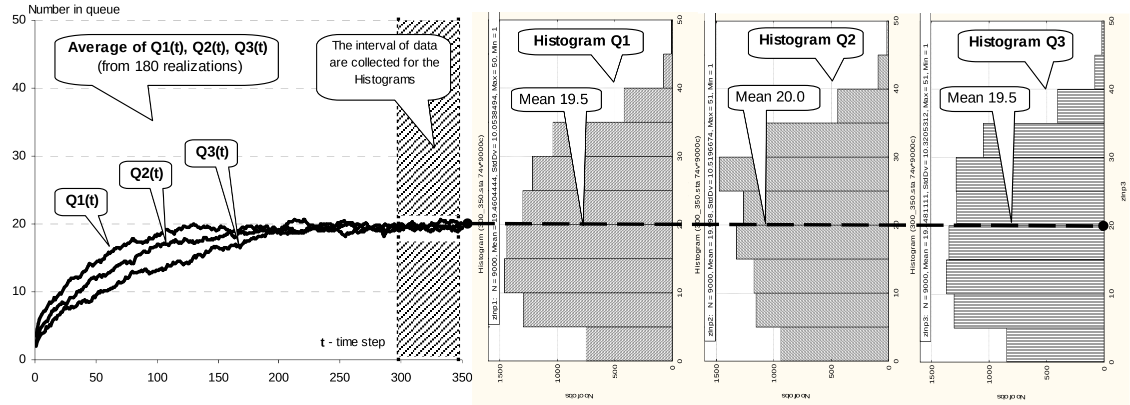

Figure 9. Dynamics of average values of queues (graphs at the left) and corresponding histograms (graphs on the right) in an interval of time from 300 up to 350 time steps at 180 realizations of model with control

Dynamics of queues in model with control essentially differs from dynamics of queues in initial model. Let us note convergence of all average lengths of queues to one value $Q(t) = 20$. As all thresholds are equal to one number $P1 = P2 = P3 = 30$ the average lengths of queues come to the same value. We shall note also very big similarity of all histograms of queues $Qk(t)$.

For system 2 the equation of balance for products is true:

$$\sum_{t=1}^{t} Q_0(t) - \sum_{t=1}^{t} Y_3(t) = \sum_{t=1}^{t} Q_1(t) + \sum_{t=1}^{t} Q_2(t) + \sum_{t=1}^{t} Q_3(t)\,. \qquad (3)$$

The difference between number of products **CumSum of Y_0** which have arrived on the system input and number of products **CumSum of $Y_3(t)$** which have gone out system, shows common number of the products which have remained inside of system. **$Y_0(i)$ –** is the independent input of the system.

For system with control the number of products inside of system approximately equally **60**, thus the number of not completed products is in equally allocated between operations approximately on **20** units.

Also holds the following equation of balance for resources

$$\begin{aligned}
&\sum_{t=1}^{t} R_1(t) + \sum_{t=1}^{t} R_2(t) + \sum_{t=1}^{t} R_3(t) = \\
&= \sum_{t=1}^{t} R_{1used}(t) + \sum_{t=1}^{t} R_{2used}(t) + \sum_{t=1}^{t} R_{3used}(t) + \sum_{t=1}^{t} R_{1w}(t) + \sum_{t=1}^{t} R_{2w}(t) + \sum_{t=1}^{t} R_{3w}(t) = \qquad (4)\\
&= \sum_{t=1}^{t} Q_2(t) + \sum_{t=1}^{t} Q_3(t) + \sum_{t=1}^{t} Y_3(t) + \left\{ \sum_{t=1}^{t} R_{1w}(t) + \sum_{t=1}^{t} R_{2w}(t) + \sum_{t=1}^{t} R_{3w}(t) \right\}.
\end{aligned}$$

The sum in parenthesis in expression (4) represents all the resources lost by system at moment "*t*". Let us see how the cumulative sum of the lost resources varies at increasing of functioning time of the system (Figure 10).Constant increase of average CumSum the lost resources is visible from graphs on Figure 10. Common character of change of processes is the same, as well as for model without control. We shall note distinctions in a velocity of increase of losses of resources for model with control.

For example, average growth rate of losses of resources at last stage of handling "CumSum[R3w(t)]" for model with control (mean = 66, Figure 10) noticeably below, than for model without control (mean = 79.1, Figure 6).

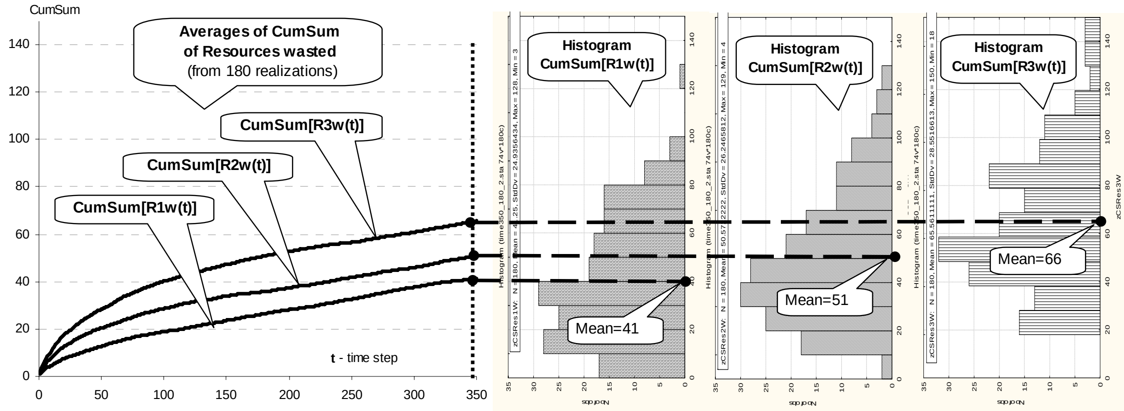

Figure 10. Dependence of average cumulated sums losses of resources from time (the left graph) and histogram of resources wasted at time = 350 (180 observations) for model with control

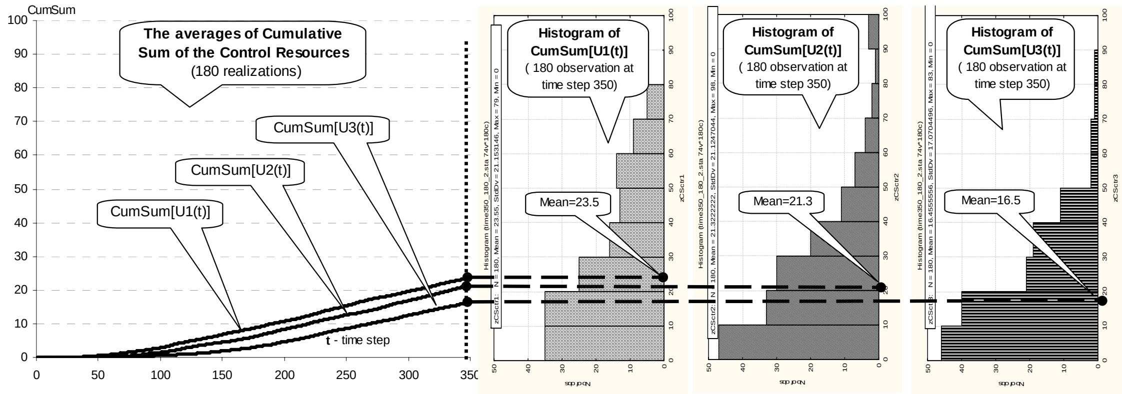

Figure 11. The graph of use of controllable resources. A change of averages cumulated sums (at the left). Histograms of controllable resources cumulated sums at time = 350 (180 observations) for model with control (at the right)

4. The Comparative Analysis of Models

Both models show rather significant dispersion for all observable characteristics. In order for it to be possible to determine more precisely distinctions in behaviour of models, the combined system schematically presented on Figure 12 has been created. We compared the two models under identical common inputs and identical common recourses flows. The aim of such modelling is quantitative estimation of effect control of system behaviour efficiency.

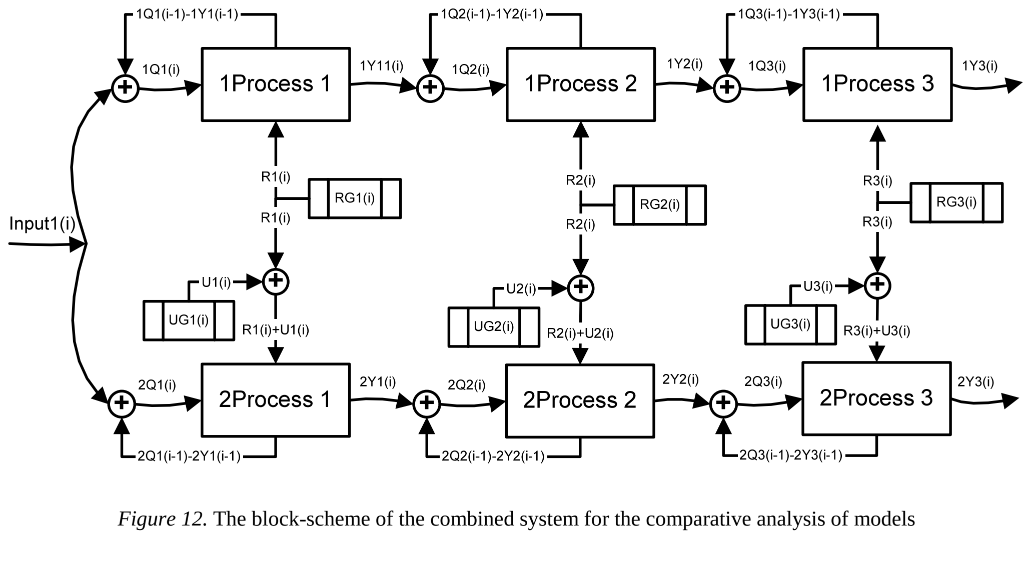

Figure 12. The block-scheme of the combined system for the comparative analysis of models

The combined model allows using identical inputs and generators of all resources for both submodels; therefore distinctions will be shown only due to management. At separate studying models substantial growth of number of experiments would be required to reduce influence of a selective statistical error of supervision. We shall notice, that performance of conditions $UGk\ (t) = 0$ or Pk = [big enough number], allow to supervise identity of functioning both submodels.

By means of control the additional resources are introduced into model, which in a considered case with 100% probability are used only for manufacture of products. It is interesting to compare an amount of incomplete products, which have been accumulated in system with control those accumulated in system without control.

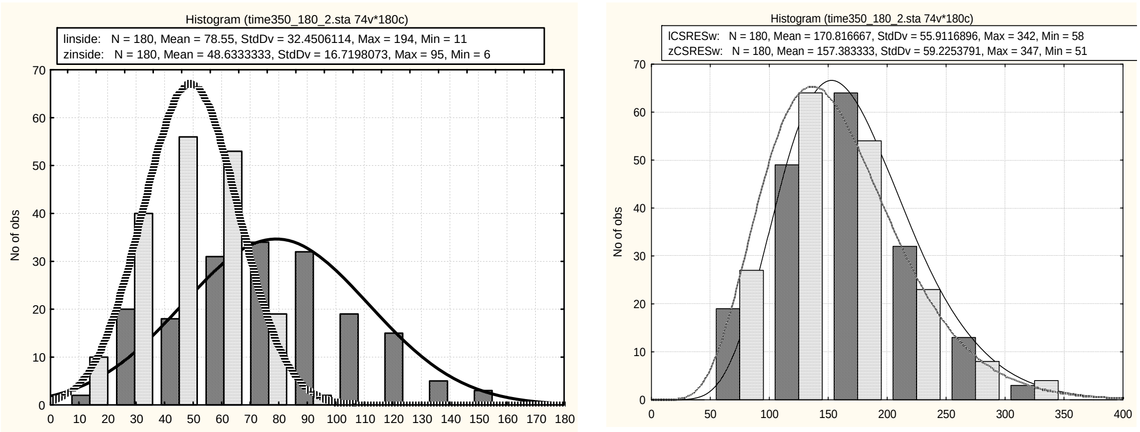

Figure 13. Histograms of unfinished objects which have been accumulated in two systems at the moment of time $t = 350$ (at the left) and histogram CumSum of lost resources by the same moment (Figure on the right). Histograms of initial system are shaded; histograms of system with control are shown as a dotted line. The histogram of not ready details in initial systems has parameters $N = 180$, Mean = 78.55, StdDv = 32.45, Max = 194, Min = 11, the histogram of not ready details in system with control $N = 180$, Mean = 48.63, StdDv = 16.71, Max = 95, Min = 6. Histogram of CumSum of the lost resources in initial system has parameters $N = 180$, Mean = 170.81, StdDv = 55.91, Max = 342, Min = 58 and histogram of cumsum of the lost resources for system with control has parameters $N = 180$, Mean = 157.38, StdDv = 59.23, Max = 347, Min = 51

Pairs of observations on the basis of which there were histograms, was tested on inequality by nonparametric Wilcoxon Signed Ranks Test. If data are continuous, the sign test or the Wilcoxon signed-rank test can be used. The sign test computes the differences between the two variables for all cases and classifies the differences as either positive, negative, or tied. If the two variables are similarly distributed, the number of positive and negative differences will not differ significantly. The Wilcoxon signed-rank test considers information about both the sign of the differences and the magnitude of the differences between pairs. Because the Wilcoxon signed-rank test incorporates more information about the data, it is more powerful than the sign test. The test calculates negative ranks = 111, positive ranks = 59, ties = 10, $Z = -5.809$, asymptotical significance (2-tailed) = 0.000, therefore the difference is significant. Paired samples correlation is equal to 0.882.

Thus, we can draw an unexpected conclusion that in system with monitoring there are less lost resources than in the initial system. Accumulation of incomplete production in both systems happens for one common reason; namely, because of shortage of utilized resources. We shall note that an average amount of all resources acting in system, it is equal to average amount raw materials, acting on an input of initial system. If the amount of objects in queue on handling for some reason becomes less, than the resources currently available, then respective unutilised resources become lost irrevocably.

The comparative analysis of the accumulated losses of resources on right graph of Figure 13 shows not strong, but explicitly notable shift of histograms which speaks about a drop of an average of losses of resources in system with control. As this distinction has appeared statistically significant in system with monitoring it is for some reason lost fewer resources though average sizes of turns for each of operations constantly increase in system without monitoring. If the turn increases, losses of resources fall. It would be logical to assume, that losses of resources will be less in that from systems, in which lengths of turns it is more. We have the outcome contradicting this logic. This rather strange outcome shows that with introduction in system of additional inspected resources we achieve also more effective use of resources than before introduction of monitoring.

The comparative analysis of statistical distributions of not ready products accumulated in systems shows an essential drop of an average store of products in system with monitoring up to 49 products after enough long functioning. The system without monitoring at the moment of time $t = 350$ had an average store of not ready production of 79 products, i.e. in one and a half time it is more. In a considered instant the system with control had in 2 times a smaller variance, than initial system. Thus the system with monitoring has more predicted behaviour, than system without monitoring that is illustrated on Figure 14.

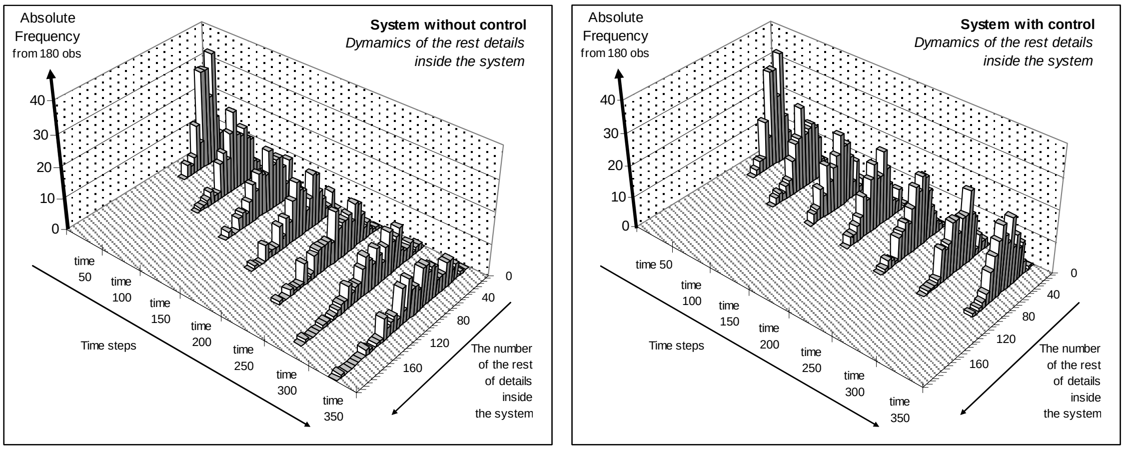

Figure 14. Mean and dispersion of the incomplete items have the tendency to increase their values accorded to time (left graph, initial system). System with control demonstrates stability of such parameters

Let us compare now outputs of two systems (Figure 15)

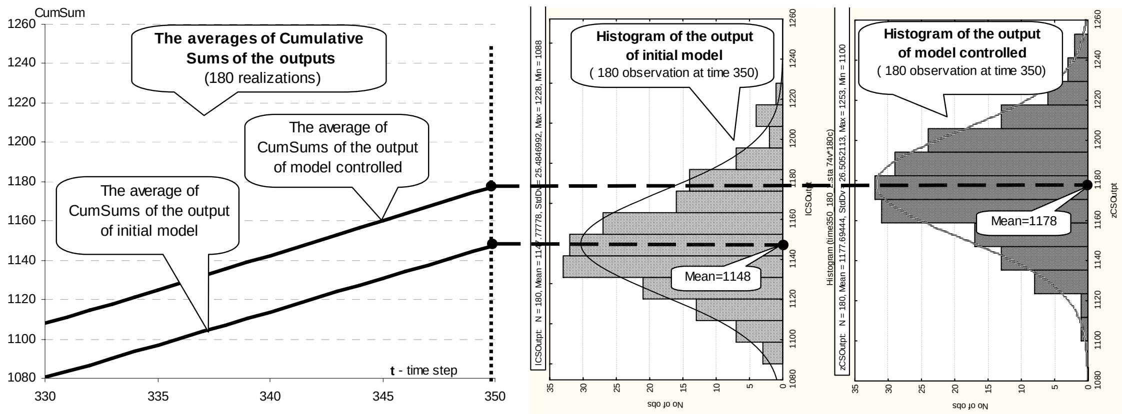

Figure 15. Outputs of systems and their statistical properties. For convenience of comparison of histograms the left schedule of dependence of accumulated output is adjusted for the time scale from $t = 330$ up to $t = 350$

As the difference between an output of initial system and the output of system with the control has statistically significant value size the system with the control is more productive. The reason is reduction of length of turns due to an expenditure of additional resources which delivery is provided with a control system, and due to decrease in losses of normal resource amount.

Let us consider the estimation of additional profit which can be received under certain conditions. As an example we shall take following sizes. We shall admit that the prices of one unit are equal to the values presented in the Table 1.

Table 1. Costs per unit

	Resource Wasted	Resource Used	Resource of control	Input	Output
Cost, $ per a unit	3	5	7	10	30

Let us notice, that the cost of *Resource of control* is taken at 40% extra of cost of usually spent unit of a resource to compensate charges on management. Besides, expenses for storage of not ready objects which essentially above at system without the control, here were not considered by us graphs of dynamics of received profit for two systems and respective histograms are illustrated on the Figure 16.

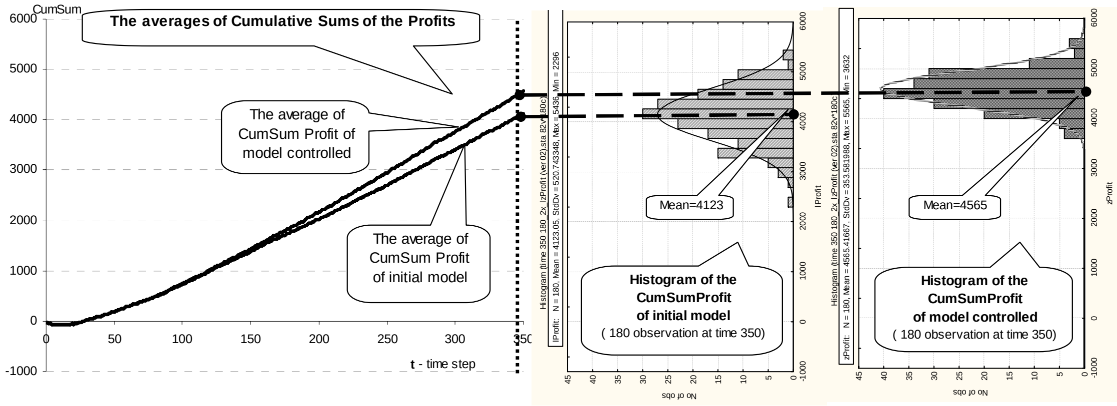

Figure 16. Dynamics of resulting profit for two systems (on the left) and corresponding histograms (on the right)

It is easy to see that the relative gain of profit for system with the control over time t = 350 has made more than 10% in comparison with initial system, and thus the dispersion of received profit has decreased twice less than a dispersion of profit for initial system.

Thus, insignificant addition of the minimal resources (not exceeding on each step of one resource unit for each operation) at moments of time when the queue length exceeds threshold value leads to cardinal change of dynamics of initial system.

Conclusions

The comparative analysis of two systems shows that introduction of the control:

- leads to stabilization of number of not ready details in system;
- reduces the lost of resources;
- increases speed of an output of finished goods;
- allows at some level of prices for raw material and resources to increase profit 10% and more.

Besides the influence on security resources of each operation probably also influences length of turn before operation. The control system can be constructed so that to accumulate products in special buffers and to start products from buffers on operation on processing when queues become small.

Let us make some remarks on opportunities of control systems. We have considered a control system with allocation of additional resources for each operation on the basis of enough simple algorithms. Use of the expanded algorithms of resource management and buffers with functions of the forecast allows arriving at the solution for optimum control, common for the given class of models. The problem appears complex enough because of presence of the big number of optimised parameters and is even more complicated by strong stochastic of model.

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RESOURCE ALLOCATION MODEL FOR CUSTOMERS WITH DIFFERENT PRIORITIES

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A resource delivery system which supplies several customers by homogenous non-renewable resources is considered. For each customer its minimal and maximal amounts of resources to be delivered, are pre-determined, as well as its preference (importance) rate. A real-time model which at any decision-making moment reallocates optimally the total available amount of resources among the customers, is presented. The values to be optimised are the resource amounts actually delivered to each customer, while the objective to be maximized is the summarized product of the delivered resource amounts and the customers' rates. A numerical example is presented.

Keywords: *resource reallocation, homogenous consumable resources, resource delivery model, customer's preference rate, precise resource reallocation algorithm.*

1. Introduction

Problems of resource reallocation in organizational systems, e.g. in Project Management, Reliability Engineering, various service systems, etc., are nowadays truly urgent. Multi-level organization systems [2] are one of the most essential components in modern technical progress and strategic management [1–2]. Such systems are usually monitored by companies with multi-level structure. At the upper level company managers transfer to lower levels various goal parameters. The latter actually determine and implement all the planning, control and scheduling procedures for the corresponding system's elements to reach their goals on time.

In order to process the elements they have to be supplied with resources. Since the total amount of the company's available resources is usually restricted, resource allocation among the system's elements has to be carried out.

It can be well-recognized from analysing various organization systems, e.g. building systems [1, 4], production systems [3, 5], that to-day proper resource reallocation techniques among the system's elements are not implemented both in on-line control or scheduling procedures. Each contractor takes all measures in order to refine his own element's parameters, independently on other company's units. Such actions, being useful for a single unit, may result in heavy financial losses for the company as a whole, since a unification of local optimums may be very far away from the global one.

The goal of our paper is to consider a resource reallocation model for a supply system with several customers of different preference (significance). The values to be optimised are the amounts of resources to be delivered to each customer, while the objective to be maximized is the summarized product of actually delivered resources to each customer and their corresponding preference rates. A numerical example is presented.

2. The Delivery System's Description

The system under consideration comprises a storehouse and several supply lines which deliver consumable resources to *n* customers C_i, $1 \le i \le n$ (production units). Each unit consumes non-renewable homogenous resources (fuel, grain, steel, cement, etc.) which are similar for all units. All customers C_i

place beforehand an order with the delivery system on resource supplement. An order comprises usually two values:

$V_{i\ \min}$ – the minimal amount of resources to be obtained – otherwise production process cannot be launched, and

$V_{i\ \max}$ – the maximal desirable amount of resources in order to reach the unit's goal as soon as possible. If the amount of resources exceeds $V_{i\ \max}$ it becomes redundant.

Assume that the system's resources are restricted, i.e., the storehouse contains less resources than the sum of the customers desirable amounts, but exceeds the sum of the minimal amounts. Thus, the amount of resources V_i to be delivered to each customer C_i must not exceed $V_{i\ \max}$ but has to be not less than $V_{i\ \min}$.

The company attributes (usually by means of experts) to each customer C_i its preference rate η_i which designates the level of the customer's importance. The company has to take all measures to deliver as much resources as possible to customers with high preference rates. Only afterwards the company supplies other production units.

The problem under consideration is to reallocate optimally the company's available resource amount among the customers. The objective is the summarized product of the delivered resource amounts and the customers' preference rates $I = \sum_i V_i \eta_i$. The optimised variables V_i^{opt}, $1 \le i \le n$, are the delivered resource amounts to each customer.

Note that in the course of planning horizon the customers' preference rates may undergo certain changes. The same goes for the company's available resource amount *V*. The first decision-making to allocate available resources has to be undertaken at $t_1 = 0$, i.e., before the units' production process starts. Later on, within the planning horizon, other decision-making moments t_s, $s = 2,3,...$, may occur. Thus, it is reasonable to substitute the terms V , V_i , $1 \le i \le n$, by V_t , V_{it} and V_{it}^{opt} .

3. Notation

Let us introduce the following terms:

C_i – the *i*-th customer, $1 \le i \le n$;

n – the number of customers;

η_i – importance rate attributed to customer C_i;

$V_{i\ \min}$ – the minimal permissible value of the resource amount to be delivered to C_i;

$V_{i\ \max}$ – the maximal possible value of the resource amount to be supplied for C_i;

V_t – the total available and non-delivered amount of resources at moment $t \ge 0$;

V_{it} – the determined amount of resources to be delivered to C_i (decision-making value to be optimised at any decision-making moment $t \ge 0$).

Assume that both relations

$$V_t \ge \sum_{i=1}^{n} V_{i\ \min} , \tag{1}$$

$$V_t \le \sum_{i=1}^{n} V_{i\ \max} , \tag{2}$$

hold. If (1) does not hold the problem under consideration has obviously no solution. In case (2) does not hold the problem obtains a trivial solution $V_{it} = V_{i\ \max}$.

4. The Problem

There is given as follows:

- decision-making moment $t \geq 0$;
- value V_t;
- values $V_{i\,\min}$ and $V_{i\,\max}$, $1 \leq i \leq n$;
- preference rates η_i, $1 \leq i \leq n$,

the problem is to determine optimal values V_{it}^{opt} to maximize the objective

$$I = \sum_{i=1}^{n} \eta_i V_{it} \tag{3}$$

subject to (1–2) and

$$\sum_{i=1}^{n} V_{it} = V_t . \tag{4}$$

Problem (1–4) is a resource reallocation optimization model which refers to a broad spectrum of production planning and control problems (see, e.g. [4–5]).

Problem (1–4) can be solved by means of linear programming [6]; in this study we present a more simple step-wise algorithm which delivers the precise solution.

5. The Algorithm

Step 1. Set $V_{it}^{*} = V_{i\,\min}$, $1 \leq i \leq n$.

Step 2. Determine the available resource reallocation volume $R_t = V_t - \sum_{i=1}^{n} V_{it}^{*}$.

Due to (1), value R_t cannot be negative.

Step 3. Reorder the sequence of values $\{\eta_i\}$ in decreasing order. Transform the sequence of ordinal numbers $\{i\}$ to a new one, $\{\psi_j\}$, $\{\psi_j\} \in \overline{1,n}$, where value η_{ψ_j} denotes the j-th value $\{\eta_i\}$ in the reordered sequence; thus, for any $\psi_1 \neq \psi_2$, $\psi_1 > \psi_2$ relation $\eta_{\psi_1} > \eta_{\psi_1}$ holds.

Step 4. Set counter $k = 1$.

Step 5. Calculate value

$$\Delta_k = \min\{R_t, V_{\psi_k \max} - V_{\psi_k \min}\}. \tag{5}$$

Step 6. Determine

$$V_{\psi_k t}^{opt} = V_{\psi_k \min} + \Delta_k . \tag{6}$$

Step 7. Update value R_t: $R_t - \Delta_k \Rightarrow R_t$.

Step 8. Check inequality $R_t > 0$. If $R_t > 0$ holds, apply the next *Step*. Otherwise go to *Step 11*.

Step 9. Counter k works, $k + 1 \Rightarrow k$.

Step 10. If $k > n$, apply the next *Step*. Otherwise go to *Step 5*.

Step 11. Determine optimal values $V_{\psi_k t}^{opt}$, $1 \le k \le n$, for all indices k which have changed their values at *Step 6*. For all other indices k their optimal values are set to their minimal values $V_{\psi_k \min}$ (see *Step 1*).

It can be well-recognized that the algorithm terminates either:

- in case when the available resource reallocation volume R_t is exhausted (see *Step 8*), or
- all indices k, e.g. customers C_{ψ_k}, $1 \le k \le n$, are examined.

Thus, the general idea of the algorithm centres on delivering to the most important customer as much resources as possible, on the basis of the up-dated remainder R_t. Afterwards the second, less important customer is examined, etc., until the algorithm terminates.

6. Optimality Investigation

Theorem. The algorithm provides an optimal solution of problem (1–4).

Proof. Assume that the algorithm under consideration does not provide an optimal solution, i.e. versus values $\{V_{it}\}$ obtained by (5–6), there exists another set of values $\{V_{it}^*\}$ (obtained by what we will henceforth call Algorithm 2) satisfying

$$I_1 = \sum_{i=1}^{n} \left(V_{it} \cdot \eta_i\right) \; < \; I_2 = \sum_{i=1}^{n} \left(V_{it}^* \cdot \eta_i\right). \tag{7}$$

Choose the first value $V_{\xi t}$ which, beginning from V_{1t} in descending order of values η_i, differs from its corresponding value $V_{\xi t}^*$. Because of

$$V_{\xi t} = V_{\xi \min} + \min\left\{R_t, V_{\xi \max} - V_{\xi \min}\right\}. \tag{8}$$

value $V_{\xi t}^*$ cannot exceed $V_{\xi t}$, since value R_t remains the same for both algorithms and $V_{\xi t}^* > V_{\xi t}$ results in either $V_{\xi t}^* > V_{\xi \max}$, or $V_{\xi t}^* > R_t$. Both relations do not hold because of (2) and since no solution of problem (1–4) can ever exceed the overall available amount of resources. Thus, $V_{\xi t} > V_{\xi t}^*$. Since both solutions $\{V_{it}\}$ and $\{V_{it}^*\}$ satisfy (4), an obvious relation

$$\sum_{j=1}^{n-\xi} \left[V_{\xi+j,t}^*\right] - \sum_{j=1}^{n-\xi} \left[V_{\xi+j,t}\right] = \Delta_\xi = V_{\xi t} - V_{\xi t}^* \tag{9}$$

holds. Since, due to the decreasing property of sequence $\{\eta_i\}$,

$$\eta_{\xi+1} \cdot \left\{\sum_{j=1}^{n-\xi} V_{\xi+j,t}^*\right\} > \sum_{j=1}^{n-\xi} \left(\eta_{j+\xi} \cdot V_{\xi+j,t}^*\right) \tag{10}$$

and

$$\eta_{\xi+1} \cdot \left\{\sum_{j=1}^{n-\xi} V_{\xi+j,t}\right\} > \sum_{j=1}^{n-\xi} \left(\eta_{j+\xi} \cdot V_{\xi+j,t}\right), \tag{11}$$

we obtain

$$\sum_{j=1}^{n-\xi} \eta_{j+\xi} \cdot V^*_{j+\xi,t} - \sum_{j=1}^{n-\xi} \left(\eta_{j+\xi} \cdot V^*_{\xi+j,t} \right) <$$

$$< \eta_{\xi+1} \cdot \left\{ \sum_{j=1}^{n-\xi} V^*_{j+\xi,t} \right\} - \eta_{\xi+1} \cdot \left\{ \sum_{j=1}^{n-\xi} V_{j+\xi,t} \right\} = \eta_{\xi+1} \cdot \Delta_{\xi} \,. \tag{12}$$

Since ξ was chosen to be the first differing number for $V_{\xi t}$ and $V^*_{\xi t}$, relation

$$\sum_{k=1}^{\xi-1} \eta_k \cdot V_{k t} = \sum_{k=1}^{\xi-1} \eta_k \cdot V^*_{k t} \tag{13}$$

holds. Summarizing the left and the right parts of equation (13), we obtain

$$\eta_{\xi} \cdot V_{\xi t} = \eta_{\xi} \cdot V^*_{\xi t} + \eta_{\xi} \cdot \Delta_{\xi} \tag{14}$$

and, thus

$$\sum_{j=1}^{n-\xi} \left(\eta_{j+\xi} \cdot V_{j+\xi,t} \right) + \eta_{\xi+1} \cdot \Delta_{\xi} > \sum_{j=1}^{n-\xi} \left(\eta_{j+\xi} \cdot V^*_{j+\xi,t} \right). \tag{15}$$

This, in turn, causes

$$\sum_{i=1}^{n} \left(\eta_i \cdot V_{i t} \right) + \eta_{\xi+1} \cdot \Delta_{\xi} - \eta_{\xi} \cdot \Delta_{\xi} > \sum_{j=1}^{n-\xi} \left(\eta_{j+\xi} \cdot V^*_{j+\xi,t} \right). \tag{16}$$

Since $\eta_{\xi+1} < \eta_{\xi}$ and $\Delta_{\xi} > 0$,

$$\sum_{i=1}^{n} \left(\eta_i \cdot V_{i t} \right) > \sum_{i=1}^{n} \left(\eta_i \cdot V^*_{i t} \right), \tag{17}$$

which contradicts our main assumption. Thus, the algorithm outlined in Section 5 provides indeed a precisely optimal solution.

7. Extension of the Algorithm

The developed algorithm for solving problem (1–4) may be extended to a real-time algorithm. Three different decision moments may occur:

1. Due to various economical or other influences, the customers' preference rates $\{\eta_i\}$ may undergo at moment t_2 certain changes. In this case values $\{\eta_i\}$ have to be substituted by new ones, and we must apply *Step 1* of the algorithm again. New optimal values $V^{opt}_{i t_2}$ will be determined, and implemented in the resource delivery process.
2. At a certain moment t_2 one of the customers is fully supplied with the amount of resources which has been determined at moment $t_1 = 0$ by means of the algorithm. Let this customer's ordinal number be γ.

Corollary. Resolving the problem of resource reallocation among the remaining customers on the basis of the up-dated information, will not result in any changes for the remaining values $V_{i\,t_2}^{opt}$, $1 \le i \le n$, $i \ne \gamma$.

Proof. Assume that we are mistaken, and relation

$$\sum_{\substack{i=1 \\ i\ne\gamma}}^{n} \eta_i \cdot V_{i\,t_1}^{opt} < \sum_{\substack{i=1 \\ i\ne\gamma}}^{n} \eta_i \cdot V_{i\,t_2}^{opt} \qquad (18)$$

holds. Here $V_{i\,t_2}^{opt}$ stand for the optimal values obtained for the remaining $n-1$ customers and the up-dated available resources $V_{t_1} - V_{\gamma\,t_1}^{opt} \Rightarrow V_{t_2}$. Adding to both parts of (18) the same additive $\eta_\gamma \cdot V_{\gamma\,t_1}^{opt}$, we obtain

$$\sum_{i=1}^{n} \eta_i \cdot V_{i\,t_1}^{opt} < \sum_{\substack{i=1 \\ i\ne\gamma}}^{n} \eta_i \cdot V_{i\,t_2}^{opt} + \eta_\gamma \cdot V_{\gamma\,t_1}^{opt}, \qquad (19)$$

where at least one value $V_{i\,t_1}^{opt}$, $i \ne \gamma$, differs from $V_{i\,t_2}^{opt}$. By setting $V_{\gamma\,t_1}^{opt} \Rightarrow V_{\gamma\,t_2}^{opt}$, we finally obtain

$$\sum_{i=1}^{n} \eta_i \cdot V_{i\,t_1}^{opt} < \sum_{i=1}^{n} \eta_i \cdot V_{i\,t_2}^{opt} , \qquad (20)$$

where all n values $V_{\gamma\,t_1}^{opt}$, as well as n values $V_{i\,t_2}^{opt}$, satisfy (2–4). Relation (20) contradicts the fact that $V_{\gamma\,t_1}^{opt}$ have been obtained by using a *precise* algorithm, and objective $I = \sum_{i=1}^{n} \eta_i V_{i\,t_1}^{opt}$ cannot be further increased on the basis of the same restrictions set. Thus, our assumption is a false one.

A conclusion can be drawn that in Case 2 there is no need to resolve problem (1–4). The only amendment required boils down to changing value V_{t_2} by excluding $V_{t_2} - V_{\gamma\,t_1}^{opt}$.

3. At decision moment t_2 new ℓ customers C_j , $n+1 \le j \le n+\ell$, are fed into the system, together with corresponding parameters $V_{j\,\min}$, $V_{j\,\max}$, η_j , as well as new additional resource amount ΔV_{t_2} to cover for the extra demand, which is replenished at the storehouse.

In Case 3 an inspection has to be undertaken to determine the resource amounts which *all the customers, beginning from* $t_1 = 0$, *have actually obtained towards moment* t_2 . For all those customers which are under way, parameters $V_{i\,\min}$ and $V_{i\,\max}$ have to be updated, and later on the updated initial data for the delivery system has to be determined. The available resource amount at moment t_2 has to be updated: $V_{t_1} + \Delta V_{t_2} - \Delta V_{t_1,t_2} \Rightarrow V_{t_2}$, where $\Delta V_{t_1,t_2}$ designates the resource amount being already delivered. Later on we apply *Step 1* of the algorithm to establish new optimal values $V_{i\,t_2}^{opt}$. The on-line algorithm terminates when all production units are fully supplied with resources.

8. Numerical Example

To demonstrate implementation of the suggested procedures, let us consider the extended on-line version of the allocation algorithm. A company delivers fuel in pipe-lines to ten different customers C_i , $i = \overline{1,10}$, with appropriate preference rates η_i . The system's initial data is presented in Table 1. Assume that all the pipe-lines are similar, i.e., provide equal delivery rates.

Table 1. The system's initial data at $t_1 = 0$

C_i	$V_{i\ \min}$	$V_{i\ \max}$	η_i
1	15	25	0.65
2	20	45	0.80
3	15	25	0.76
4	40	60	0.73
5	60	80	0.67
6	75	100	0.72
7	50	75	0.70
8	60	90	0.68
9	25	40	0.78
10	30	50	0.71

At the beginning of the fuel supply, at $t_1 = 0$, the total amount equals $V_{t_1} = 480$. By implementing the allocation algorithm at $t_1 = 0$, we obtain values V_{it}^{opt} as follows:

$V_{1t} = 15$, $V_{2t} = 45$, $V_{3t} = 25$, $V_{4t} = 60$,
$V_{5t} = 60$, $V_{6t} = 95$, $V_{7t} = 50$, $V_{8t} = 60$,
$V_{9t} = 40$, $V_{10t} = 30$,

and the fuel delivery process starts. At moment $t_2 = 3$ customer C_1 is fully supplied with fuel and leaves the system. The fuel delivery process proceeds with $V_{t_2} = 465$ until the moment $t_3 = 5$ when customer C_3 is fully supplied with fuel as well. It can be well-recognized that at moment t_3 the total resource amount equals $V_{t_3} = 440$, and the process proceeds until moment $t_4 = 6$, when three new customers C_{11}, C_{12} and C_{13} enter the system; simultaneously, the overall resource amount to be distributed is up-dated by an additional total of $\Delta V_{t_4} = 140$.

Assume that the considered company implements on-line control on the following principles (see Section 7):

1. Due to the Corollary outlined above, when at a certain moment t one or several customers finish to be supplied with fuel, for other customers still being under supply their delivery volumes are not re-calculated.
2. If at a certain moment t one or several *new* customers are fed into the delivery system, an inspection has to be undertaken, to determine the actual amount of fuel which all the remaining customers have already received to that moment. For the customers under way their appropriate parameters $V_{i\ \min}$ and $V_{i\ \max}$ are diminished by the supplied amounts of fuel (if the difference becomes negative it is set equal to zero), and optimisation problem (1–4) is resolved for the updated system data.

It can be well-recognized that in Case 2, whenever newly considered customers have higher preference rates than the remaining "older" ones, the reallocation algorithm will redistribute the available fuel amount by taking care of more important customers first. In some cases the "older" customers may even "loose" some of the supply amounts which have been previously assigned to them, for the benefit of the "new" ones.

In the considered numerical example, an inspection is therefore undertaken at $t_4 = 6$, to determine that each customer under way (this does not count for those who have already left the system) has received $V_{i t_4} = 30$ units of fuel amount. Thus, the system's management has to update the system's initial data in order to re-apply the allocation algorithm. The updated system's data at moment $t_4 = 6$ is presented in Table 2:

Table 2. The system's updated data at $t_4 = 6$

C_i	$V_{i\ \min}$	$V_{i\ \max}$	η_i
2	0	15	0.80
4	10	30	0.73
5	30	50	0.67
6	45	70	0.72
7	20	45	0.70
8	30	60	0.68
9	0	10	0.78
10	0	20	0.71
11	20	40	0.80
12	15	60	0.69
13	50	100	0.78

To enable decision-making for customers with the same preference rate, assume that the company management, when applying the reallocation algorithm at *Step 3*, acts as follows:

- when at least two customers have equal preference rates, they are re-ordered with preference given to the customer who entered the system before;
- if several competing customers entered the system simultaneously, preference is granted to those who have a smaller "tolerance gap" in terms of $V_{i\ \max} - V_{i\ \min}$;
- in case both the remainder $V_{i\ \max} - V_{i\ \min}$ stays the same, re-ordering customers is carried out by means of implementing random Monte-Carlo simulation.

The updated available amount of resources at $t_4 = 6$ may be estimated therefore as

$$V_{t_4} = 480 - 15 - 25 - 8 \times 30 + 140 = 340 .$$

Applying the resource reallocation algorithm, we finally obtain the following:

$V_{2t_4} = 15$, $V_{4t_4} = 30$, $V_{5t_4} = 30$, $V_{6t_4} = 50$,
$V_{7t_4} = 20$, $V_{8t_4} = 30$, $V_{9t_4} = 10$, $V_{10t_4} = 0$,
$V_{11t_4} = 40$, $V_{12t_4} = 15$, $V_{13t_4} = 100$.

It may be noted that customer C_{10} ceases to be supplied ($V_{10t_4} = 0$), since he already obtained his minimal permissible fuel amount according to his preference rate. The fuel delivery process proceeds until the next decision making moment, etc.

Conclusions

The following conclusions can be drawn from the study:

a) The developed delivery model for homogenous consumable resources can cover a broad spectrum of organization systems, e.g. building enterprises, various production systems, service systems, etc.
b) The developed model incorporates a resource reallocation algorithm which delivers the precise solution.
c) The developed algorithm can be incorporated in real on-line control models. The algorithm is simple in use and can be easily programmed on PC.

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COMPETENCE-BASED EDUCATION – A COMMON EUROPEAN STRATEGY

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The article gives a brief review of competence-based professional higher education today and its underlying principles. Following this overview is an appraisal of literature that illuminates the heritage of competence-based education and contains current writings that offer further understanding of the research subject matter. This section analyses and distinguishes the concepts "competence" and "competency", identifies and defines integral structure and contents of the communicative language competence, substantiates the choice of the key competences necessary for everyone, and function-orientated competences, which in their unity stipulate the successful adaptation and self-realization of a young specialist in the modern fast changing world. At the end of the article the authors offer an innovative exploitation of the Systemic approach contributing to the development of a Systemic linguo-didactic model, its theoretical grounding with definitions of key concepts. The model implies context-dependent management of the educational activities based on the analysis of semantic changes in data relations – contextual concordance of relations within an intelligent system.

Keywords: communicative language competence, Systemic approach, Systemic linguo-didactic model

1. Introduction

In the last years "competences" cause a lot of interest among practitioners of higher education and vocational training and come to the foreground of educational goal-setting. Authentically assessing competence-based education today requires a worldview that includes multiple beliefs about the purpose of education and a capacity to draw a connection between what results from these purposes and the impact those results have on the individual, the society and the world.

Nowadays education in a broad sense has been considered as the investment in the development of the society. The governments and the wide public are concerned about adequacy of quality of education and training and economic and social profitability of the means invested in education. The question of educational contents corresponding to tomorrow's demands has become a vital issue in educational reforms all over the world. Importance of flexibility, adaptability, mobility, creativity of education and life-long learning in the global, changing world is the focal point of modern national and international discussions concerning higher education and vocational training.

In the light of Bologna agreements assuming the academic and professional recognition of the state diplomas within the European space, graduation of qualified specialists, capable of life-long learning and performing professional work in conditions of multicultural environment, the problem of professionally-orientated communicative language competence development acquires a special meaning [1–4].

Competence-based professional higher education is not a tribute to fashion to introduce new words and concepts, but the objective phenomenon in higher education caused to life by social and economic, political and educational conditions. First of all, it is a reaction of professional education to the changed social and economic demands and to the innovative processes which have appeared together with the global market economy. The labour market shows the whole gamut of new requirements which are insufficiently considered or not considered completely in educational programmes for young specialists. These new requirements are not connected rigidly with any particular discipline; they are trans-disciplinary in character and are notable for their universality. To ensure young adults education which corresponds to these requirements means not as much changing the content of education as pedagogical approaches and methodologies. Such requirements some authors call 'basic skills' (Duke S., Oscarsson B., Baidenko V. I.), others treat them as sub-professional basic qualifications (Novikov A. M., Izarenkov D. I.,), or key competences (Wildt J., Rychen and Salganik, Van der Blij M. and Boon J., Zimnyaya I. A., Zeer E. F.).

Nowadays it is obvious that subject knowledge and skills do not comprise a full range of educational results necessary for the development of a socially mature person who is capable of political and economic management and full self-realization in the society. The search for the answer to the question what competences besides the abilities to read, write and count are important for the contemporary young specialist to actively participate in social life and to meet the challenges of the present and the future has become a focal point in the analysis of this scientific research where various aspects of competence-based approach to education are presented: *as a condition for successful adaptation of each person in the modern fast-changing world* (Jonnaert Ph., Barnett R., Jarvis P., Cox R., Light G., Rychen D. S., Weinert F., Koķe T., Tiļļa I., Maslo I., Shishov S. E., Zimnyaya I. A., Izarenkov D. I., etc.) *as a necessity of further reorganization of higher education based on the concept of dialogue of cultures* (Isaacs W., Senge P., Schein E. H., Bohm D., Bibler V., Leontyev A. N., Passov E. I.) *and transformations in higher education in the direction of international communications* (Nunn R., McKay, Kasper G. and Kellerman, Bachman L. and Palmer A., Light G. and Cox R., Koķe T., Baidenko V. I.).

Data of researches are especially significant from the perspective of developing future specialists' personal and creative qualities, their key and professionally-orientated competences which provide graduates with better chances for successful adaptation and self-realization in conditions of new information technologies, life-long learning and self-development (Light G., Cox R., Koķe T., Zimnyaya I. A., Shishov S. E., Baidenko V. I., etc.).

Although cognitive skills and abilities gained through traditional higher school programmes are the important results of education, still, the choice of competences can hardly be reduced only to these frameworks [5]. This is just one aspect of the difficulty to be considered. As theory and practice of hiring young specialists proves, such non-cognitive aspects as practical skills, attitudes, motivation, value preferences and ethics, which are not necessarily achieved and developed in the field of formal education, play an important role. Furthermore, such terms as competence, competency, key competences and skills, are ambiguously treated at their use.

The essential contribution to the theoretical analysis of concepts 'competence', 'competency', with reference to young specialists in conditions of a contemporary competitive market, was made by such scientists and researchers as Hymes D., Canale M and Swain M., Bremer C. and Kohl K., Schneckenberg D. and Wildt J., Rychen D. S. and Salganik L. H., Weinert F., Nunn R., Tiļļa I., Maslo I., Maslo E., Bolotov V. A., Shishov S. E., Novikov A. M., Zimnyaya I. A., Elkonin B. D., and others.

However, despite a wide use of concepts 'competence', 'competency', in scientific literature, the given notions, in opinion of many scientists (Jonnaert Ph., Nunn R., Weinert F., Schneckenberg D., Wildt J., Tiļļa I., Zimnyaya I. A, Kuzmina N. V., Baidenko V. I.), are not explicitly distinguished, therefore a question of differentiation of these terms still remains topical.

In a number of works the concept 'competency' is defined as intellectual and personal ability of an individual to practical activities, and 'competence' as a contents component of the given ability in the form of knowledge, skills and aptitudes (I .A. Zimnyaya, M. G. Evdokimova, etc.).

In I. A. Zimnyaya's opinion, 'competency always displays the actual competence' [6]. B. D. Elkonin believes that 'competency' is a degree of a person's involvement into activity [7]. S. E. Shishov considers the category of competence as a general ability based on knowledge, values, aptitudes, enabling to establish relationship between knowledge and situation, to reveal a procedure (knowledge and action), suitable for a problem.

I. Tiļļa defines competence as an individual combination of abilities and experiences stipulated by opportunities to gain these [8].

According to Weinert, in the light of terminological and conceptual disorder connected with the concepts 'competence', 'skill', 'professionalism' and so on, it is necessary to develop an explicit definition of the concept 'competence' [9].

Weinert tries to lay a bridge between a psychological-pedagogical concept, on the one hand, and a sociological concept on the other. He defines 'competence' as a 'slightly specialized system of aptitudes, abilities or skills necessary for achievement of a specific goal. It can concern both the individual abilities and the distribution of abilities within a social group or establishment [9].

The young of the 21st century should be ready to carry out various functions as students, specialists-professionals, citizens, family members and consumers, to act and be able to find their bearings inside and outside the real complex contexts and to face numerous complicated problems, showing critical thinking, systemic thinking and to make responsible decisions. Therefore Rychen D. S defines competence as an 'ability to successfully meet the complex requirements in a certain context' [3].

It seems that the theoretical uncertainty of the considered concepts depends on the English terms "competence" and "competency" which are often translated as synonymous, in a double meaning. Different interpretations in the use of the concepts are also caused by their ambiguous treatment in social, psychological, pedagogical, and linguistic aspects.

Moreover, in non-language-related higher education, there are no systemic pedagogical researches describing the content of professionally-orientated communicative language competence and conditions for its development in respect to professional, cognitive, linguistic, communicative, socio-behavioural, socio-cultural, ethical, strategic, and personality-directed components. Therefore, investigation of the concept 'competence' and the terms connected with it is central in the research of competences, their definition, selection and inclusion into the educational language programme for the students of non-language-related departments.

At the international level, the work in the field of competences began in 1990 under the aegis of the Organization of Economic Cooperation and Development – OECD with the International interdisciplinary programme DeSeCo (Definition and Selection of Competencies: theoretical and conceptual foundations) [10]. The work started with the analysis of the results of three main researches in the field of competences which have been realized in the context of OECD: the project of interdisciplinary competences (the Cross-Curricular Competencies Project), the international research of literacy of adults (IALS – International Adult Literacy Survey), and the project of the human capital (the Human Capital Project). Also some minor projects have been briefly considered: the International Programme of the Estimation of Pupils (PISA), Literacy and Skills of a Life of Adults (ALL – the Adult Literacy and Life-skills), the International Association of the Estimation of Educational Achievements (IEA – the International Association for the Evaluation of Educational Achievement), Civil Education (CivED), and the Third International Research on Mathematics and Natural Sciences (TIMSS). Some of the central themes of programme DeSeCo are beyond the listed researches. For example, the concept that education is not a result in itself but a means to be prepared for life.

In reality, in the world community there is a consent concerning the importance of such competences as social, communicative, literacy (including skills in processing information, solving problems, critical thinking, possessing native and foreign languages, systemic thinking and life-long learning competence) necessary for successful participation in social life. Besides, in some countries values have become an aspect of special attention.

The fact, that at a global level among the countries there is a lot in common, does not mean that it can automatically lead to defining the most significant key competences in all countries, and will not allow extrapolating key competences found in one particular country to all other countries. However, the most often mentioned competences or components considered by majority of countries represent a valuable list of areas of special interest.

2. The Essence of the Concept 'Competence'

DeSeCo defines competence as a 'system of internal mental structures and abilities assuming mobilization of knowledge, cognitive skills, practical skills, and also social and behavioural components such as attitudes, emotions, values and ethics, motivations for successful realization of activity in a particular context' [10].

Conceptualisation of the concept of competence accepted by DeSeCo, is entire in the sense that it has integrated and connected external demands, individual characteristics (including ethics and values) and context as essential elements of competence presentation. However, considering individual characteristics, such an important element as individual peculiarities has been overlooked. It is impossible not to take into account that a person is, first of all, a subject of social development and, what is more important, an active subject of self-development, including self-education. Internalising social experience is always deeply individual. The same social situations are differently perceived and experienced by various persons. Accordingly, social experience which has been gained from objectively identical situations will be very individual.

Higher education institution as a social institute should prepare a graduate for life. And life as a circuit of consecutive objectives and responsible choices does not imply only academic knowledge. A. A. Rean and N. V. Bordovskaya argue that development of a person as a subject of activity necessarily includes the factors which form a socially-mature person:

- development of intelligence,
- development of positive thinking, positive attitude,
- development of autonomy, responsibility,
- development of motivation leading to self-development, self-realization.

Educational results are, in fact, measurable, demonstrated by students (graduates) knowledge, skills and abilities after the accomplishment of an educational process, which can be expressed by means of competence.

It is necessary to emphasize that the terms 'competence' and 'skill' should not be treated as synonyms. Skill is defined as an ability to execute complex action and /or cognitive action with ease, accuracy and adaptability to changing conditions, while competence is defined as a complex system of abilities, encompassing cognitive skills, attitudes and other non-cognitive components. In this sense competence is considered as a holistic concept. Competence is a systemic, holistic concept and therefore cannot be reduced only to cognitive areas. Therefore the concept ‘competence’ and ‘skill’ are not synonyms [3].

Thus, taking into consideration trans-disciplinary educational perspectives, external demands, individual characteristics, peculiarities and context as an integral element of competence realization, it is possible to illustrate a unified model of structural composition and content of competence by means of function-orientated competence (Fig. 1). We focus on a functional approach since competence is viewed to ensure an individual the ability to cope with complex demands and tasks in multiple social contexts and situational practices.

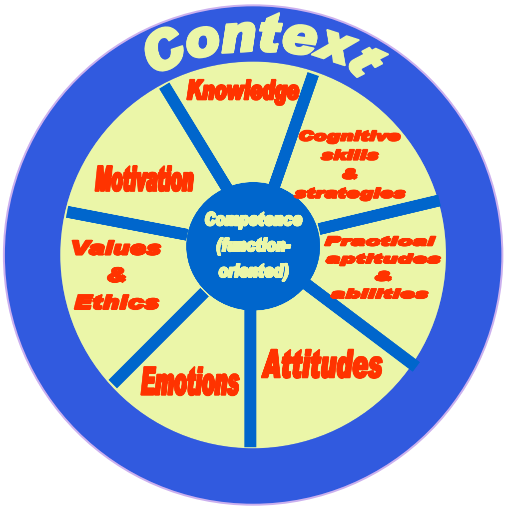

Figure 1. Functional orientation and structurally-componential content of competence

As we see from the model, functional orientation of competence and context or social situation for its realization can vary. However, the internal structure of competence will be comparatively permanent. Therefore, it is possible to conclude that competence, from the point of view of its structural composition, is an objective characteristic (Fig. 1).

However, functional orientation (need, demand for a certain set of abilities) will define the internal content of structural components of competence, which will be exclusively personal (subjective). Thus, from the point of view of its content, competence is a subjective characteristic. The Systemic view brings together a formulation of one uniting principle that represents the source of all understanding – *a synthesis.*

To proceed from the theoretical analysis of numerous concepts and taking into account the definition accepted by DeSeCo, it is possible to define the concept of competence from the Systemic perspective as follows: *Competence is an objective characteristic determined by integral personal system of mental intelligence and abilities, assuming a synthesized unity of as follows:*

- *knowledge and acumen,*
- *cognitive skills and strategies,*
- *practical aptitudes and abilities,*

as well as social and behavioural components comprising

- *attitudes,*
- *emotions,*
- *values and ethics,*
- *motivations*

functionally orientated towards positive result achievement in a certain context.

Thus, any competence can be represented as a system of synthesized cognitive and practical skills, knowledge, motives, values and ethics, attitudes, emotions and other social and behavioural components which in their integrated unity can be mobilized for effective, productive functioning in any particular context.

It seems to be not very correct to apply the term ‘professional competence’ as the concept is too extensive and does not reflect its substantial essence, since one competence is not able to satisfy the needs of any profession. It is more expedient to speak about a set of function-orientated competences, necessary for successful performance of this or that professional task, which might constitute an *integrated professional competence module*.

2. 'Competence' Development and 'Competency' as a Personal Systemic Characteristic

Definition of competence cannot be limited to only a simple description of expected actions or behaviour. Competence can be viewed as an organizing activity characteristic, since it presupposes not just the application of knowledge to a certain situation but includes the ability to organize personal activity for successful adaptation to situational peculiarities. And in this respect competence can be understood as a dynamic, organizing the structure of activity characteristic allowing a person to adapt to various situations on the basis of gained experience and practice.

Competence is not restricted only to acquisition of knowledge and skills. It is formed and revealed through activities (acts of performance) as 'ability to make actions in various contexts in adequate, responsible form integrating a combination of knowledge, skills and attitudes' [11].

The definition offered by van der Blij is notable because it consistently integrates the basic components necessary for theoretical modelling of the concept of development and monitoring the development of competence in the context of higher education (Table 1).

Engaging the basic components of development, the model visually exposes characteristic preconditions (characteristics available at present) of an active individual, a contextual level of activity performance and a situational contextual level of standards for the adequate (corresponding) behaviour determined by a social consensus (consent).

Table 1. Competence Development from Three Levels of Observation (on the Basis of Schneckenberg D., and Wildt J. [12])

Components	*Characteristics*	*Levels of Observation*
Individual dispositions	Abilities, aptitudes, motivations, attitudes, values, ethics, emotions	Psychological – Pedagogical theory
↓ ↑ To act in ↓ ↑ Context-bound situations	Complex, undefined, not routinized, dynamic	Action theory
↓ ↑ According to ↓ ↑ Consensual standards	Appropriateness, responsibility	Sociological theory

The characteristics represent a set of corresponding influential factors in competence for the process of activity performance. A cyclic process in which these factors are interrelated in the process of competence development and where each stage is dependent upon the previous one, can be best of all illustrated in the form of a 'ladder', i.e. ascending steps (Fig. 2).

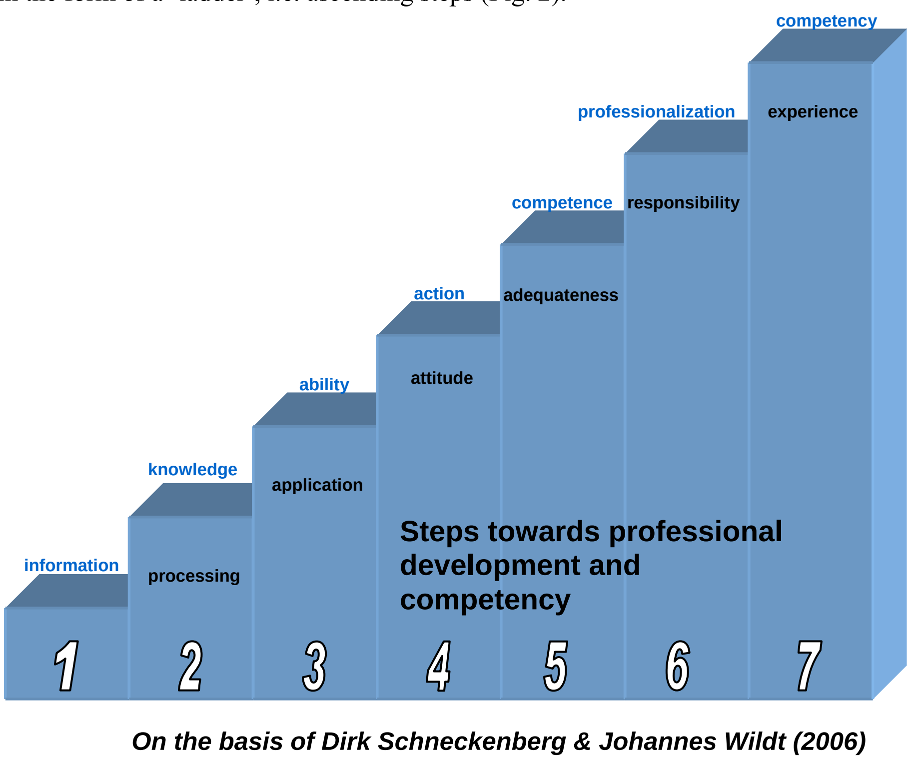

Figure 2. Competence development model

The process begins with perception of information. The information by means of semantic ties assimilates, accommodates and adapts in mental structures and leads to the second step i.e. to knowledge. If this knowledge is applied in a certain context, it can reach ability step (mental ability). Ability should be combined (at the fourth step) with a certain attitude which presupposes a value and motivational orientation and is finally realized in the activity performance.

If at the fifth step the activity is adequate to the required level (standard) then this adequate action leads to competence. It is necessary to emphasize, that adequacy demands knowledge of strategies. At the sixth step competence combined with a certain responsibility for the 'product' of activity will provide professionalism. And at the final step sufficient experience and a situational practice will lead to competency.

As we see, a variety of resources will be mobilized in activity for competence realization on the way to competency achievement. These resources have a structured function both in relation to activity and in relation to a person, thus, forming a dialectic interaction. Thus, there is no border between internal and external aspects of experience.

'From the point of view of situational cognition, a person and his activity in a certain contextual situation is the most essential resource for teaching' [1; p. 677].

As we have already emphasized, competence is a dynamic, objective characteristic which is strongly rooted in experience and situational practice. Through activities in various situations a person constructs *competency,* according to Ph. Jonnaert, 'the competent handling of a situation'.

Consequently, competency is a cumulative personal quality. Thus, competency as a personal quality is developed through socialization, through contextual situations, and through socialization leads to personification of activity and to individualization of a person in this activity.

Inferred from this is that competency is a personified manifestation of integral competences evolved in social experience and situational practices, which is necessary for successful/fruitful accomplishment of an activity.

Taking all the aforementioned into account, we can conclude that concepts 'competence' and 'competency' should not be mixed up, since competence is an objective characteristic, while competency is a subjective quality and hierarchically they are noticeably distinguished.

It is necessary to note that socialization is not contradictory to individualization. More likely on the contrary, in the process of socialization and social adaptation a person reveals his individuality. If to consider sociality as a congenital property of a person, the process of social adaptation should be considered not only as actively-adaptive, but also as actively-developing.

Competency, as a realization of a need for self-development, self-actualisation, is a basic component of a social mature person. The idea of self-development and self-realization is extremely significant for many modern humanistic psychological-pedagogical concepts concerning a person (Maslow A., Rogers C. R., Koķe T., Zimnaya I. A,). It gets a special importance in modern conditions of educating young specialists.

Competence is not a static characteristic. Since it is inseparably connected with socialization – communication and joint activities of people, the process of its development goes on during the whole life as life-long learning and self-education, as aspiration to self-development and self-realization in the fast changing world. Professional successes, achievement of professional blossoming, and also professional longevity have already been confirmed by lots of experimental data.

3. The Essence and Characteristics of Communicative Language Competence

So, we have made the conclusion that competence is developed only through activity in contextual situations. Now on the basis of the theoretical analysis and proceeding from its structurally-componential content, we will try to define the nature and the essence of communicative language competence.

The communicative competence as a linguistic term applied to a learner of a second language and reflecting the level of his/her proficiency, for the first time was put under discussion at the beginning of 1970s – by J. Habermas in 1970 and then D. Hymes joining in the discussion in 1971 and later S. J. Savignon in 1971. The term was first mentioned by D. Hymes as a reaction to inadequately adapted distinction between the concepts of 'competence' and 'performance' introduced by Noam Chomsky in 1965.

D. Hymes believes that we should be concerned with performance, which he defines as the actual use of language in a concrete situation, not an idealized speaker-listener situation in a completely homogeneous speech community. Therefore the term presupposes language learning through the communicative approach. The central theoretical concept in communicative learning is 'communicative competence' [13]. He deems it necessary to distinguish two kinds of competence: linguistic competence that deals with producing and understanding grammatically correct sentences, and communicative competence that deals with producing and understanding sentences that are appropriate and acceptable to a particular situation. Thus, Hymes coins a term 'communicative competence' and defines it as 'knowledge of the rules for understanding and producing both the referential and social meaning of language structures' as the ability to use language in a social context, observing corresponding socio-linguistic norms. Developing his theory of language teaching and learning, he considered language as social behaviour as well as integration of language, communication and culture. The core of his theory constitutes a definition of what the user of language has to know to be a competent communicator in a social language group.

Simultaneously, communicative approach developed in Europe and America. Language was considered as a 'meaningful potential', and 'a contextual situation' as the main condition to understanding the language system and the principles of its functioning.

British scientists in the field of applied linguistics – D. A. Wilkins, Ch. Candlin, H. Widdowson – gave greater significance to functional and communicative potential of language.

According to Widdowson, for example, to know a language means much more than just to understand, speak, read and write sentences. 'We do not only learn how to compose and comprehend correct sentences as isolated linguistic units of random occurrence, but also how to use sentences appropriately to achieve communicative purposes' [14]. According to Widdowson, the idea that once competence is acquired, performance will take care of itself is false. He states that six or more years of instruction in English does not guarantee normal language communication. He suggests that communicative abilities have to be developed at the same time as the linguistic skills; otherwise the mere acquisition of the linguistic skills may inhibit the development of communicative abilities. His idea seems to be influenced by Hymes' thought that learners acquire not only the knowledge of grammar, but also the knowledge of appropriateness, that is, they acquire knowledge of socio-cultural rules such as when to speak, when not to speak, what to talk about with whom and in what manner, at the same time as they acquire knowledge of grammatical rules. Widdowson distinguishes two aspects of performance: 'usage' and 'use'. He explains that 'usage' makes evident the extent to which the language user demonstrates his knowledge of linguistic rules, whereas 'use' makes evident the extent to which the language user demonstrates his ability to use his knowledge of linguistic rules for effective communication. He also distinguishes two aspects of meaning: 'significance' and 'value'. Significance is the meaning that sentences have in isolation from the particular situation in which the sentence is produced. Value is the meaning that sentences take on when they are used to communicate (Widdowson H., 1979). Thus, acquisition of linguistic competence is involved in use. Widdowson suggests that grammar must be based on semantic concepts and must help a learner to acquire a practical mastery of language for the natural communicative use of language.

Canale M. and Swain M. [15] believe that the socio-linguistic work of Hymes is important for development of a communicative approach to language learning. Their work focuses on the interaction of social context, grammar and meaning (more precisely, social meaning). However, just as Hymes says that there are values of grammar that would be useless without rules of language use; Canale and Swain maintain that there are rules of language use that would be useless without rules of grammar. They strongly believe that the study of grammatical competence is as essential as is the study of socio-linguistic competence. Furthermore, they point out that no detailed attention has been devoted to *communicative strategies* that speakers employ to handle breakdowns in communication. Examples of communication breakdowns include false starts, hesitations and other performance factors, avoiding grammatical forms that have not been fully mastered, addressing strangers when unsure of their social status, and keeping the communicative channel open. They consider such strategies to be important aspects of communicative competence that must be integrated with other competences. Canale and Swain define the communicative competence as integrating at least three main competences:

- grammatical competence (knowledge of lexis, rules of morphology and syntax, grammar rules for constructing sentences). The grammatical competence is important to know how to choose and accurately express literal meaning of utterances;
- socio-linguistic competence (knowledge of socio-linguistic rules – the correspondence of the language in use to its non-linguistic context and knowledge of discourse rules). The knowledge of these rules, in opinion of the authors, is decisive for interpretation of statements and catching of their meanings, especially, when a transparency is not observed between literal meaning of the statement and the communicative intentions of the speaker;
- strategic competence (the verbal and non-verbal communicative strategies promoting successful communication in case of insufficient grammar competence).

In 1984 Johnson K. and Littlewood W. considered acquisition of the communicative competence as a process of development of skills and abilities including cognitive and behavioural aspects.

Krashen S., however, denies 'practicing' language skills when learning a language. He considers that language comes only through its communicative use (communicatively) and makes distinction between 'language learning' and 'language acquisition' [16].

Later review of the communicative competence was made by L. Bachman. He divided the communicative competence into two comprehensive groups: organizational, including grammar and discursive/textual competence, and pragmatic, including socio-linguistic and idiomatic competence [17].

The communicative approach to teaching language has led to a widespread belief, that the communicative competence should become the aim of language learning and the basic classroom practice, paying attention to linguistic, social, cognitive and individual variables in language acquisition [18].

However, despite a sufficient level of scrutiny and a variety of approaches to the concept of the communicative competence, it is necessary to agree with many scientists, that the modern treatment of the concept from the point of view of preparing young specialists for adaptation in the multicultural environment needs to be revised [1, 19].

In a new millennium when changes in all spheres of life are accelerating in geometrical progression, the communicative language competence development cannot be considered as the one for specific purposes. Higher schools should prepare specialists not just supplying them with professional knowledge, but also encouraging them for self-development and self-realization in a global, multicultural environment, implementing all available resources, including language.

Therefore during the epoch of 'global communication' it is vital to speak about the communicative competence for international communication. And the talk is not as much about adaptation in the country of the target language where the future specialist, probably, will never get to. More likely, it is necessary to speak about numerous opportunities of interaction and communication on the 'third' party where professional, social, political and other interests of the broad audience of people representing various socio-cultural heritages (backgrounds) encounter, for example, business negotiations, in-trainings, professional and cultural exchange programmes, international symposiums, conferences. Such kind of communication requires acquisition of a variety of communicative strategies. Therefore 'communicative competence' from the point of view of the theory of language teaching and learning (Hymes D., [13]) is necessary to reconsider in reference to studying the English language for international communication [19]. Nunn emphasizes that the norms accepted in one country can be absolutely unacceptable in another.

Hence, considering unpredictability of contextual situations in which our graduates will be using the English language, it becomes absolutely clear that learning a language which can be used in restricted situations in the country of the target language is absolutely unacceptable. What makes 'acceptability' for international communication cannot be limited to the frameworks of one language [20]. However, meanwhile there is no a single, global language culture so far.

Nevertheless, the main function of language is to ensure interaction and communication and acquisition of linguistic knowledge remains the most essential part of any language learning. Phan Le Ha in 2005 has formulated: 'Language is a part of identity of the one who is capable to use it, and competence reflects a degree of language possession'.

At the same time, the analysis of modern publications on language teaching methods shows that some confusion and discrepancy in the use of 'communicative competence' concept can be observed. Some researchers, as A. Zernetskaya for example, treat components of the communicative competence as separately, independently existing competences – competence of writing, competence of reading, competence of listening and competence of speaking on the basis that for their realization different kinds of speech activities are engaged. It is not taken into consideration that the basis for all these operations provides language and thinking.

Moreover, the aim as the basic component of communication is excluded. Sometimes there is no precise unitary use of 'competence' and 'skills', no broadly accepted concepts of systemic and individual, personal character of competences.

Thus, considering our worked out definition of the concept 'competence', the theoretical analysis of the concept 'communicative competence', its structurally-componential content, and professional perspectives of young specialists as well as external demands, it is possible to model the definition of the concept of communicative language competence.

Communicative language competence is an integral personal system of cross-cultural verbal and non-verbal communicative strategies stipulated by linguistic communicative abilities, professional knowledge, skills, vitally-gained experience, attitudes and specific characteristics of an individual to achieve mutual understanding and communicative purposes in situations of direct and indirect communication.

We consider that such a vision of the concept will permit justifying its componential structure – a combination of key and special (function-orientated) competences necessary for a young specialist in the future, to determine the content of the educational process and to ensure the necessary conditions for its realization through personality-directed Systemic approach.

4. Definition, Selection and Substantiation of Communicative Competences Componential Contents

Now when we have defined the term 'communicative language competence' it is necessary to select and prove its componential contents to have a clear understanding of what to learn and what kind of knowledge, skills and human qualities will be necessary for the young specialist in the 21st century.

The structure of the key competences offered by various authors differs rather noticeably not only in their quantitative, but also in their qualitative and conceptual aspects. Some researchers define them as 'basic competences' and consider them as 'interim' skills, i.e. work with a computer, using databases and databanks, knowledge and understanding of ecology, economy and business, financial knowledge, commercial streak, skills to transfer technologies from one areas into others, skills of marketing, legal knowledge, intellectual property protection, normative conditions of enterprises' functioning, various patterns of ownership, presentation skills of technologies and production, knowledge of foreign languages, sanitary-medical knowledge, principles of survival in competitive conditions and possible unemployment; psychological readiness for change of profession or a field of activity and others.

Others use concept 'basic skills' as 'personal and interpersonal qualities, abilities, skills and knowledge which are expressed in various forms in diverse situations of work and social life'. The authors include communicative skills and abilities, creativity, ability to reflexive thinking, adaptability, ability to work in teams, ability to work independently, responsibility and self-esteem.

Key competences are not determined by arbitrary decisions about what personal qualities and cognitive skills are desirable; they are discovered by the analysis of external demands and by careful consideration of students' needs to provide them with a stance that gives firm grounding and an ability to coordinate their actions with high-speed changes in the world in a highly synchronized fashion. This demand-led approach asks what students need in order to cope with and function well in society as they find it. What competences they need to acquire and to hold down a job.

However, competence is also an important factor in the ways that individuals help to shape the society, not just to cope with it. Thus, as well as relating to key features and demands of modern life, competences are also determined by the nature of our goals, both as individuals and as society.

First, students need to be able to use a wide range of tools for interacting effectively with the environment: both physical ones such as information technology, and socio-cultural ones such as the use of language. They need to understand such tools well enough to adapt them for their own purposes – to use tools interactively.

Second, in an increasingly interdependent world, students need to be able to engage with others, and since they will encounter people from a range of backgrounds, it is important that they are able to interact in heterogeneous groups.

Third, students need to be able to take responsibility for managing their own lives, situate their lives in much broader social contexts and act autonomously. These categories, each with a specific focus, are interrelated, and integrally form a basis for identifying and mapping key competences. The need for students to think and act reflectively is central to this set of competences. Reflectivity involves not just the ability to apply routinely a formula or method for confronting a situation, but also the ability to deal with change, learn from experience and think and act with a critical stance.

Thus, keeping in view the analysis of the external requirements shown by a labour market, interdisciplinary perspectives of education, Professional standards and also priorities of students' needs, the following six competences have been selected as potentially significant for the future self-realization of each student. A system of integral *key competences* (based on the definitions of DeSeCo, [10]) and *special (function-oriented) competences* (based on the definitions of 'Common European Framework of Reference for Languages', 2004) *has been worked out* (Fig. 3).

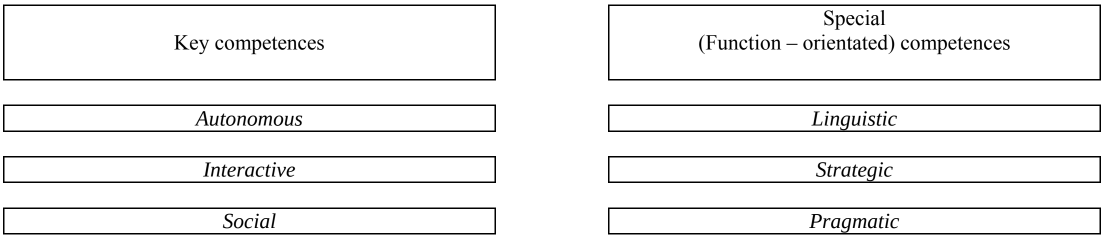

Figure 3. Structurally-componential contents of the communicative language competence

We focus on a functional approach since it is viewed to ensure students the ability to cope with complex tasks and requirements of multifaceted life. According to this viewpoint competences are structured around demands and tasks. Fulfilling complex demands and tasks requires not only knowledge and skills but also involves strategies needed to apply the knowledge and skills, as well as appropriate emotions and attitudes and effective management of these components.

We adopt a pragmatic conceptual approach restricting the competences with criteria which are more explicit, plausible and scientifically acceptable.

Within each kind of competence we allocate a certain constituent group (a cluster) of abilities (including knowledge and skills) without which this or that kind of competence cannot be realized. These clusters according to the character of the basic elements have determined the contents *of the key* and *special (function-orientated) competences.*

Key competences, according to DeSeCo, as necessary for each young man, provide an opportunity of effective participation and self-realization in a variety of educational contexts, professional and social areas, promote realization of educational potential of a person, which leads to highly significant personal and social results of education. Key competences are multifunctional. They are relevant not only to education or labour market, but also to the social networks, political processes, interpersonal relations and, most generally, to developing a sense of personal well-being. These competences are tools for the solution of challenges and fulfilment of the important requirements in a wide spectrum of educational, professional and social contexts.

Autonomous competence is an integrated personal system of knowledge (including professional and linguistic knowledge, skills, abilities), involving cognitive strategies needed to perform cognitive activities and apply the gained knowledge and skills to processing information, to adapting and transforming knowledge, to constructing personal knowledge and judgments. The autonomous competence includes two central interrelated ideas:

- development of identity on the basis of the acquired socio-linguistic knowledge; development of individuality, self-identity on the basis of intellectualisation; professionally-oriented language knowledge acquisition, development of cognitive skills, strategies and practical skills;
- performance of mental autonomy/independence as an active and reflective attitude towards life; reflectivity in organizing educational activities, research activities, autonomous work, in decision-making, in making meaningful choices/actions based on the development of social and behavioural norms – positive attitude, positive thinking, emotions, value priorities and motivations.

Today an individual's autonomy is viewed as a central feature of modernity, democracy and individualism. Autonomy does not imply functioning in social isolation. The fact that people live by internalised social norms and in the context of relationships to others is not incompatible with autonomy. On the contrary, scrutinizing and reflecting on these norms and relationships is an integral part of individual growth and maturation of identity (mental autonomy, involving active and reflective approach to life). Autonomy assumes the ability of individuals to assert their own rights and interests, to think and act for their own sake, to initiate interactions with their physical and social environment, to form and conduct their own educational projection and develop strategies to attain goals. Reflective exercise of autonomy requires awareness and understanding of one's environment: how it functions, how it evolves and how one fits into it. Autonomy implies the ability to manage and coordinate self-growth, self-realization, personal time, life circumstances, in other words, to play an active role in shaping personal environment and personal life.

The following abilities are necessary for this purpose:

- to take responsibility for personal actions and moods or emotions, to adequately represent oneself in the educational process, to manage personal educational activities showing realistic self-assessment and objectivity, to build one's educational trajectory (including *life-long learning*) to develop oneself as a personality, to be responsible as a student, one's own teacher, a participant of the educational process, a member of a team, a colleague etc.;
- to project and realize personal life plans to give life meaning and purpose in a changing environment, to set and reach the goals which have importance in life and are compatible with personal values, to build priorities, to effectively use all available resources;
- to act and make decisions within wider contexts – group, institutional, cultural or social contexts;
- to understand oneself and one's relationship to others in this context, be able to recognize how one's actions and decisions fit into this wider context;
- to be able to suspend judgements – to think before acting and expect long-term consequences of one's actions.

Since knowledge, skills and strategies are not given as ready-made, but constructed and developed through activities and communication, the first necessary condition for their acquisition is dialogue. Dialogue, in its turn, is not completely public or exclusively personal and can be expressed as 'inter-subjectively established social reality'.

A. Giddens adds that the use of language in speech is an activity or a form of life [21]. The central factor in teaching and learning activities in higher education is human communication, revealed in practicing knowledge and communication or, in other words, 'exercising one's 'Self' and language in specific academic social situations' [2]. Therefore the following integral communicative language competence has been defined as the interactive competence.

Interactive competence is an integrated personal system of knowledge and skills assuming employment of instruments/tools and resources that are relevant to meeting an active dialogue between individuals and their environment, as well as verbal and non-verbal strategies used for the achievement of (mutual) understanding, stipulated by the adequate perception of discourse or its production in situations of direct and indirect communication.

Interactive competence assumes an effective use of communicative tools and personal resources, the English language, for example, as well as knowledge, strategies, laws, information, new technologies according to requirements of a modern society for the solution of everyday-routine and professional tasks. The effective use of the English language as a communicative tool for an effective dialogue with one's environment does not mean simply 'possessing' the language, but also realizing how the use of it might influence our ways of interaction with the environment. The central idea is identifying how the tools affect our interaction with the environment, how we become competent through our interactions with it and how we deal with transformation and change. We contact with the world through our cognitive, interactive and physical communicative instruments. These contacts shape our comprehension of the world and the competence of communication.

Following abilities are necessary for this purpose:

- ability to use the English language, symbols and texts for effective dialogue in various forms (written and oral, in the form of schedules, tables, etc.), to develop knowledge and awareness of the new forms of interaction, using new cognitions and new social practices in various situations of multifaceted life, to understand the relationships between people and their situations – readiness to help;
- ability to use knowledge, strategies and information for effective and reflective communication, to interpret behaviour and emotional information, to understand how emotions combine and progress through relationship transitions and language communication and be able to appreciate such emotional meanings, to manage knowledge and information and to use them as the basis for understanding and comprehension of reality to make responsible choices, decisions and to form judgments;
- ability to use (new) technologies for effective communication, which means not simply technical skills required for the use of technologies (for example, the Internet), but also acquisition of new possible forms of communications promoting fast adaptation to modern life.

In the broad sense, the reflective competent professional is a critical practitioner of knowledge and language as a social being. It finds reflection in the social nature of communication and the social nature of a person. From this point of view teaching –learning activities in higher education can be considered as social communications through practice of the language use. Our understanding of how we communicate has substantial repercussions for how we understand our social relationship and ourselves. Therefore, the social competence is considered as necessary for everyone.

Social competence is an integrated personal system of knowledge, skills, verbal and non-verbal communicative strategies that provide the capacity to form, join and function effectively and democratically within complex, and socially heterogeneous groups.

Social relations are necessary for a sense of self, identity and one's social meaning. Social competence assumes the development of a socially mature personality. It promotes the development and expansion of identity since residing and socializing in multicultural, mobile societies require skills of effective communication and cooperation with people who do not necessarily share the same language, the same history, culture and religion. Hence, the social competence requires a set of abilities.

Following abilities are necessary for this purpose:

- ability to establish good mutual contacts, which allows an individual to initiate, support and operate personal close relations, to be a member of a multicultural society, a colleague, a friend, a neighbour, an employer, which implies the development of such qualities as tolerance, empathy, ability to sympathize as well as positive thinking and positive vision of reality;
- ability to cooperate, which allows people to work together over a common problem or purpose, accumulating personal social capital in the form of basic constituents as tolerance, responsibility, leadership qualities and positive attitude;
- ability to cope effectively with conflicts considering them as an aspect of human relations, ability to manage them in a positive manner, and ability to compromise.

The key competences are multifunctional and have a trans-disciplinary character. They span knowledge of various academic disciplines and transverse various aspects of human existence. They are important, but insufficient from the point of view today's complex requirements and challenges, as their presence is observed in all areas of activities including education, professional activities, political sphere and a family life.

To realize communicative intentions in international communications, a communicator integrates his key competences with more specific, language-related competences. Therefore special (function-oriented) competences serve as personal resources, 'supporting scaffolds' for the key competences with the purpose to ensure successful functioning in specific multicultural contexts of educational, professional and other social situations.

Special (function-oriented) competences are necessary as an important resource for self-realization in conditions of concrete multicultural contexts and situations.

Linguistic competence (according to 'Common European Framework of Reference for Languages', 2004) is an integrated personal system of linguistic knowledge and skills as well as cognitive strategies needed to perform certain actions with the knowledge and skills for adequate perception or production of grammatically correct functional structures (codes) in oral or written form. Linguistic competence assumes mobilization of all formerly acquired and stored in mind linguistic knowledge to be employed in a certain context. It is defined by majority of scientists as knowledge of, and ability to use all formal resources from which well-formed, meaningful messages may be assembled and formulated. Therefore, *linguistic competence* encompasses:

- lexical competence;
- grammatical competence;
- semantic competence;
- phonological competence;
- orthographic competence.

Lexical competence, consisting of lexical and grammatical elements, assumes knowledge of, and ability to use the vocabulary of the language, including general and professional lexicon, as well as the ability to distinguish lexical and grammatical elements in perception or production of messages. The student, who does not possess a sufficient amount of lexical knowledge and practical skills to perform cognitive actions with this knowledge, will not be able to neither adequately comprehend a meaningful discourse nor correctly produce utterances in oral or written form. Undoubtedly, general and special lexical knowledge is also vital for understanding or generating discourses.

Lexical elements include:

- fixed expressions, consisting of several words, which are used and learnt as wholes (forms of greetings, proverbs and sayings, phrasal idioms, intensifiers, phrasal verbs, compound prepositions, fixed collocations);
- Poly-semantics of separate words and parts of speech (a noun, a verb, an adjective, a participle).

Grammatical elements include articles, quantifiers, personal pronouns, demonstratives, question words and relatives, possessives, prepositions, auxiliary verbs, conjunctions and particles.

Grammatical competence assumes knowledge of, and ability to use a system of principles governing the assembly of elements into meaningful organized sentences. This ability includes recognizing, understanding and expressing meaning by means of well-formed sentences in accordance with the rules of morphology, syntax, grammatical semantics of sentences and phonology.

The grammatical competence assumes ability to organize:

- Elements: morphemes, affixes, words;
- Categories: number, a case, gender, concrete/abstract, countable/uncountable, voice (active, passive), tenses (present, past, future), aspect (continuous, perfect);
- Classes: nouns, verbs, adjectives, adverbs, participles, etc.
- Structures: simple, compound and complex words, regular and irregular verbs, phrases (noun phrase, verb phrase, etc.), clauses (main, subordinate, co-ordinate), sentences (simple, compound, complex).

The ability to organize sentences to convey meaning is a central aspect of communicative competence.

Semantic competence assumes knowledge of, and ability to control and organize meaning. In lexical sense, it is conveying the meaning of words, including connotation, relation of words to general context, synonyms/antonyms, hyponymy, collocations, etc. In grammatical sense, it is conveying the meaning of grammatical elements (morphemes and affixes), categories (number, count-ability, time, and active/passive voice), and structures (complex and compound words, phraseological units, simple, complex and subordinate clauses. In pragmatic sense, it is conveying meaning through logical sequencing of sentences, expressing assumptions, indirect statements.

Phonological competence assumes knowledge of, and ability to recognize, perceive and produce distinct, meaningful sounds (phonemes), including consonants and vowels, assimilation of sounds, phonetic composition of words and sentences, including tones and intonations of a voice, rhythm, sentence stress and other characteristics carrying meaning.

Orthographic competence assumes knowledge of, and ability to distinguish, perceive and produce symbols of which written texts are composed (letters in the printed and italic form, spelling of words, logographical signs and rules of punctuation).

Strategic competence is an integrated personal system of knowledge and skills to solve (unexpectedly occurred) communicative problems, to organize and purposefully regulate a line of communicative verbal and non-verbal actions selected for the achievement of communicative goals in a certain context and in specific conditions especially if there is insufficiency in linguistic and socio-cultural knowledge.

Pragmatic competence is an integrated personal system of knowledge of principles according to which messages are:

- organized, structured and arranged in coherent messages (thematically, logically, stylistically) – *discursive competence;*
- used in oral and written form to perform a certain communicative function – *functional competence;*
- sequenced according to interactional and transactional communicative design (question – answer; statement – agreement/disagreement; request/offer/apology – acceptance/refusal; greeting – response) – *design competence.*

In the field of the English language teaching-learning there is an open question of intelligibility and linguistic competence. Achievement of understanding in many cases depends on pragmatic abilities. Sometimes achievement of understanding occurs among people not only using various linguistic norms but also having absolutely different levels of linguistic competence. At the same time pragmatic fiascos are suffered frequently by people possessing perfect linguistic competence. J. Moeschler, for example, argues that in some cases linguistic competence can make pragmatic understanding difficult.

5. The Systemic Approach to Communicative Competence Development

Implementation of the Systemic approach in pedagogy was restricted until 60–70-ies of the last century due to the fact that the pedagogical aspect of the Activity theory had been underdeveloped. In addition, the System theory was understudied to be adapted to pedagogy. The Systemic approach deprived of the activity basis, the systemic model of the educational process and the quantitative analysis of its resultant outcomes was unproductive. With the advent of the pedagogical activity theory, the systems analysis for managing educational results and an easy access to computer technologies nowadays, the Systemic approach has gained its new content [23].

The Systemic approach presupposes activity-based language teaching-learning, since language has not only to be learned, but it has to be practiced and internalised through the experience of implementation. From the Systemic perspective, language education is both individual and collective; it is scientific and spiritual, knowledge and imagination-based, society-and-student-centred. Pedagogical aspect, to be consistent, shows up in a multitude of expressions. Classrooms may be organized with one student working alone, two students working together, small groups working together, with or without a teacher, students addressing peers and the teacher, tutoring, etc. A variety of communicative activities, which foster language acquisition and play a significant role in perpetuating a behavioural pattern, can be employed to create a lively educational language environment such as role plays, simulations, business games, problem solving, case studies, etc.

In language teaching-learning, it was of paramount importance for us to single out *the basis of the educational process* which would ensure its qualitative preciseness. It has become *a communicative language activity* of teacher and students as a process through which potential resources of communicators are realized, including their general intellectual resources, personality development, their attitudes, motivations and values.

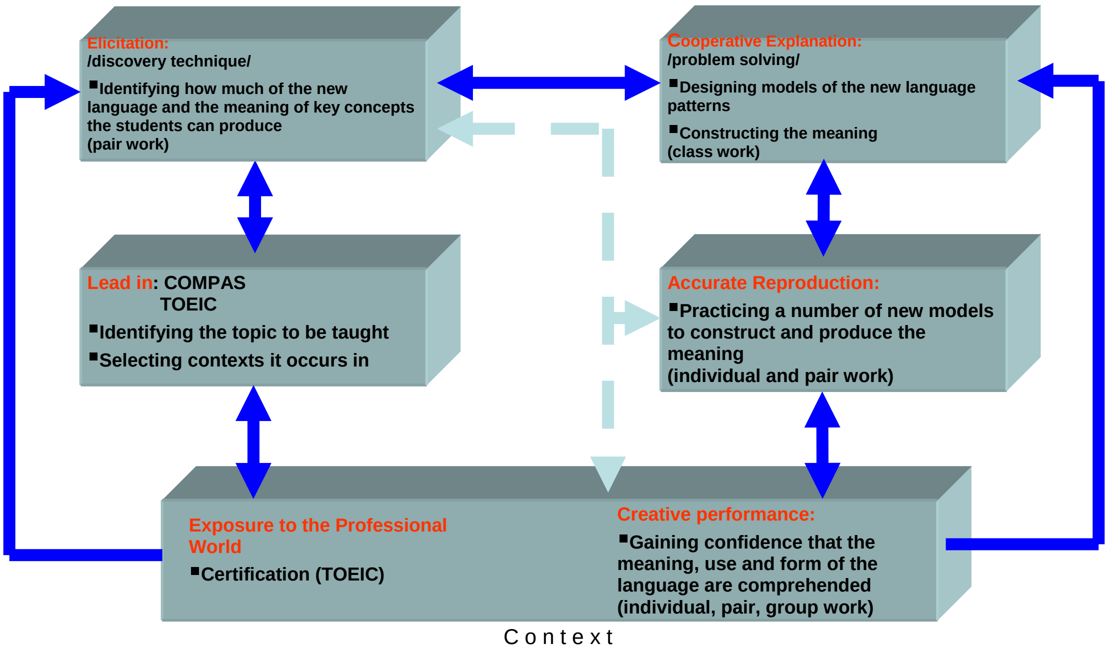

Figure 4. Interactive construction of meaning

A model for interactive construction of meaning, developed in the present research reflects five stages in interactive construction of meaning: *lead-in, elicitation, cooperative explanation, accurate reproduction* and *creative performance.*

The *lead-in stage* includes identifying the topic to be taught and selecting/creating contexts it occurs in. During this stage the context is introduced including the new language and the meaning, as well as the key concepts about the context are explained to students in order to understand the meaning and use of the new language.

The *elicitation stage* (based on discovery technique) includes identifying how much of the new language/meaning the students are aware of. It is a very important stage: it gives the teacher information upon which to act; it is motivating for the students and actively involves their learning competences. We get the students to look at a text or listen to a tape and find the examples of grammar or language structures we are interested in and ask them to discover how the language works. The teacher needs to know whether the students have understood the new meaning and are able to produce the new language so that to organize our teaching accordingly.

When the teacher asks the students what they have found and discusses the language with them, we have reached the *cooperative explanation stage*. This is the stage where the students' problems-solve to design models of the new language and learn to construct the meaning. Since the teacher is talking *with* the students rather than *to* them, the process appears to be more egalitarian and less dictatorial.

If the teacher finds that the students can produce the new language, it would be wasteful and de-motivating for them to spend a lot of time at the explanation stage. We may move straight to the *accurate reproduction stage* to eliminate these problems, if they can produce the new language, but with minor mistakes,. This stage focuses on practicing a number of models to construct and produce the meaning. The emphasis is on accuracy (on how accurately students construct and produce the meaning).

If the students know the new language but need a bit more practice in producing it, we may move directly to the *creative performance stage*, which is actually a referential learning stage (this is indicated by the dotted lines on Figure 4). This stage aims at gaining confidence that the meaning, use and form of the language are really understood. If the students are able to produce their own utterances, they can feel confident that their presentation has been a success.

Proceeding from the aforementioned, it is possible to conclude that the final point of a cycle reflects a certain level of communicative language competence – the ability to comprehend, construct and implement grammatically correct meaningful language units – utterances – in written or spoken form. Thus, every final organization of cognitive structures in a cycle differs from the initial one [23, 24].

As a result of the present research, the following presumption can be made: if the initial stage of a cycle is characterized by student readiness to solve cognitive and practical tasks, the focus of the final stage is on skills and strategies acquisition, their further implementation and transference onto other contexts and disciplines, generating new cognitive strategies, which promotes the appearance of new personal emergent qualities and ensures the conditions for successful adaptation within the following new cycle.

Inferred from this is the author's assumption that each cycle is a new systemic organization where modified interrelationships and interdependences of aims – motives – content – means – results are reproduced again on a new level. Thus, educational process which carries a cyclic character has a form of a spiral plan corresponding to the system of homeo-kinetic plateaus in the Systems theory (Fig. 6).

In the research, each cycle of communicative language activity is viewed as an organized, purposeful process, in the course of which a student is engaged in performing actions as a social agent, implementing a range of competences, both key competences (directed mostly to personality development) and function-directed, communicative language competences at his disposal to reach communicative goals. The monitoring of these cycles of communicative activities by the participants leads to reinforcement or positive modification of their competences. This process is conscious and at the beginning of a cycle the participants are aware of the expected results [25–27].

The research has proved that communicative competence development undergoes the following process: in the course of increasing complexity of communicative tasks, demanding the corresponding increase in language complexity (the content of communicative activity) and different kinds of thinking – creative, logical, critical, systems thinking, due to differentiation and individualization of the study process, the system components (mental/cognitive structures) and the ties between them restructure. New qualities of the system components emerge which form new ties between them. These new ties expand the network of the communicative language system. Restructurisation of semantic ties in cognitive structures results in appearance of a new system (network) with new emergent qualities and characteristics and, as a result, new behavioural patterns. Restructurisation implies 'reorganization of knowledge – conceptual changes' – i.e. 'mental/cognitive changes as a result of deeper understanding and awareness' [28].

The process is reproduced within the following new cycle, thus, forming a spiral plan. At this new level, students already show interest in the process of cognition. They are attracted by new knowledge acquisition; they try to find new ways of solving communicative problems, being actively involved into creative processes and demonstrating practical acumen. As a result, the ties between motives and means become harmoniously coordinated.

Changes in the character of motives and means cause the awareness of social meaningfulness of communicative language competence development, the responsibility for one's actions, for the results, for self-learning. Changes in behavioural patterns shape up professionally significant qualities – the ability to interact, to co-operate, to make positive mutual contacts, to find constructive solutions to conflict situations showing empathy, tolerance and positive thinking, to make responsible decisions and to communicate effectively.

As a result of the present research, the following statement can be made: communicative language activity in the process of its cyclic, spiral development acquires new qualities. Restructurisation and modification of the former mental/cognitive system result in the emergence of a new one, of a higher intelligence level. In this way the development of communicative competence transforms from the reproductive to the creative level (Fig. 4).

Still, as the research has revealed, the development of means is effective only provided they are adequate to the motives. Therefore it is of paramount importance to foster positive motivation and cognitive interest in students.

As practice proves, in the process of language teaching-learning, motivation very much depends on the culture of teacher-student communication and, namely, on the language complexity that a teacher (mentor) chooses to encourage students' interactive construction of meaning. We consider that the foundational factor in constructing meaning is not as much the content of the incoming educational information, as the process of its communication. If there is no adequate language contact between the two systems (a learning system, that is, a group of students, and the management system, that is, the teacher/mentor), however rich and interesting the content might be, it would never get the desirable positive result. The language of a learning system (students' communicative language competence) and the language of the management system (complexity and amount of educational message) are the crucial characteristics, which determine the choice of the necessary level of contact.

Well-coordinated language input, according to S. Krashen [16], should contain language that the students already 'know' as well as language that they have not previously heard; in other words, the input should be at a slightly higher level than the students are capable of using, but at a level that they are capable of understanding to cause students make discoveries and make sure that language learning occurs. In this case it is possible to speak about the learning system's structural stability since with the increase of educational language information semantic ties in cognitive structures and the inferential ties between communicative activity components set to rights, become well-arranged and orderly. This is beneficial for communicative competence development and for student motivation.

Uncoordinated managerial influence will remove the learning system from the boundaries of stability, leading to a functional disbalance, to communicative activity failure and, eventually, to educational information collapse (Fig. 6.). The reasons for uncoordinated managerial influence might include a mentor's low tone of voice, which is impossible to hear in a large auditorium, or the language abounding in specific terminology, which is incomprehensible and there will be no grounds for semantic ties formation and construction of meaning and, consequently, learning will not occur. The reason might be an excessive amount of educational information within limited boundaries of a lecture, which is physically impossible to comprehend, or if a mentor shows disinterest in students as personalities, he is just 'doing his job'. All these factors negatively affect communicative language development and are strongly de-motivating [29, 30].

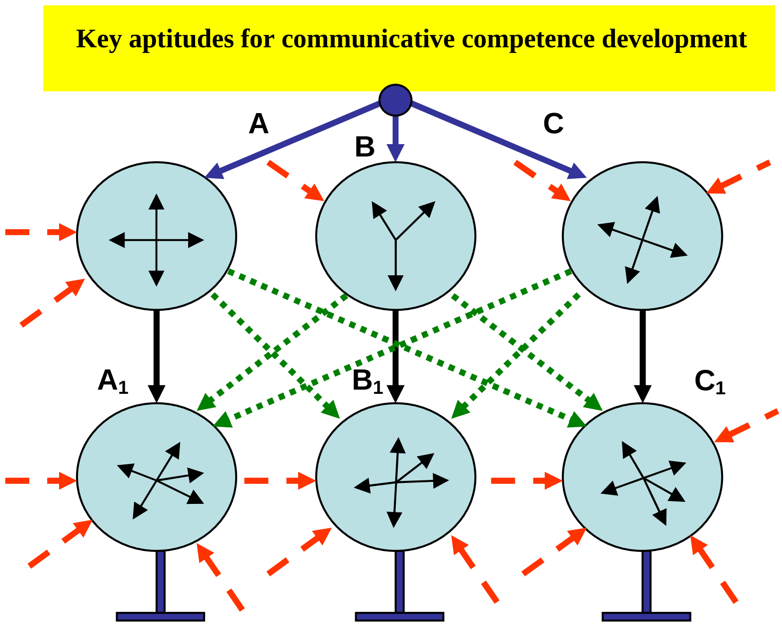

Figure 5. Communicative competence development under the systemic approach

The functional structure of the communicative language activity reveals the complexity of interdependent inferential ties between its participants and defines the development of communicative competence in time and space. The development of these ties allows identifying the ways for educational process improvement, to ensure the purposeful functioning of the system and the meaningful activity of teacher and students in the educational process. The developed structure helps to set educational goals and predetermine the final results, which is only possible to obtain following the functional structure of communicative language activity.

Figure 5 shows a graphical presentation of communicative competence development under the systemic approach demonstrated by the author to the target students in a concrete educational situation. The model has been viewed to help the students visualize the development of basic communicative abilities depending on the influence of internal and external factors where the continuous lines represent the ways of basic abilities development and the dotted lines – reflect the influence of various factors on this development.

Thus, in the interactive process of communicative activities new abilities appear – emergent abilities, which reinforce communicative language competence and contribute to its development (see Fig. 5 – arrows inside the circles).

It is necessary to emphasize that the essence of mechanisms showing the emergence of new abilities can be demonstrated only by means of models created within the framework of the systemic approach. For example, the cybernetic approach does not assume any emergent properties of a system as these ‘new’ properties have to be additive.

In the research, the foundational factor is the educational process as an interactive process of communication and meaning making. As we have already emphasized, getting the level of language complexity right is crucial for the process. It is possible to illustrate this idea by presenting a few sentences taken at random from different scientific articles:

- The second repercussion of epistemological pandemonium is the management of the university itself.
- The stochasticity of quasi-singular substance precipitate adequately correlates with consistence anisotropy.
- Endocasts have been taken to indicate that some phenomena in human ontogeny are recapitulating in hominid phylogeny.

The messages seem rather confusing. The given examples show how difficult it could be to talk to a layman on professional topics. It is even more difficult for an unprepared student to listen and comprehend such things that would never find any response in mind.

What means ensure successful intersystem communication? First of all, it is the language of management, the language of communication with a learning group.

Goldowsky B. and Newport E. J. in their discourse about language complexity have come to the conclusion that ‘…a limitation on the ability to perceive or remember the full complexity of linguistic input may have unexpected benefits’, because ‘for *any* structure in the language there is a filter that produces optimal learning of that structure. If you start with very limited capabilities and then mature, you will have each size of filter in turn, and therefore have the chance to learn each structure in the language at the time appropriate for that structure – and you end up learning the entire language optimally’ [32].

As a result of his scientific experiments, Jeffrey Elman points out that acquisition of language is significantly facilitated by arranging the acquisition device (a recurrent neural net) in such a way that its ‘working memory’ is small at the outset of learning, and grows incrementally during the learning process. ‘Specifically, successful language learning may depend on starting small’ [33].

Our systemic approach to language acquisition takes into consideration managerial language complexity, the level of student communicative competence and educational information amount, as decisive factors in communicative competence development. The systemic linguo-didactic model of communicative competence development, created by the author (Fig. 6.), utilizes the learning from the theories of systems and the notion of homeokinetic plateau (L. von Bertalanfy, [22]) which, actually, reflects different levels of communicative language competence/development or sequenced changes of the system’s conditions.

The model implies context-dependent management of the educational process based on the analysis of semantic changes in data relations (*the paradigm of concordance of data relations* or *the paradigm of contextual management*). Since the increase of the language complexity goes on as a continuous process, the system at every moment of its existence experiences a state of ‘disbalance’ – homeokinesis (the term introduced by the founder of the General Systems theory – fon Bertalanfy, [22]).

The main principle of this cognitive process is to ensure stability – a state of homeokinetic 'plateau' or concordance between assimilation and accommodation of educational language information, the idea which Piaget J. [34] introduced into the pedagogical science and called it 'balancing' (Fig. 6).

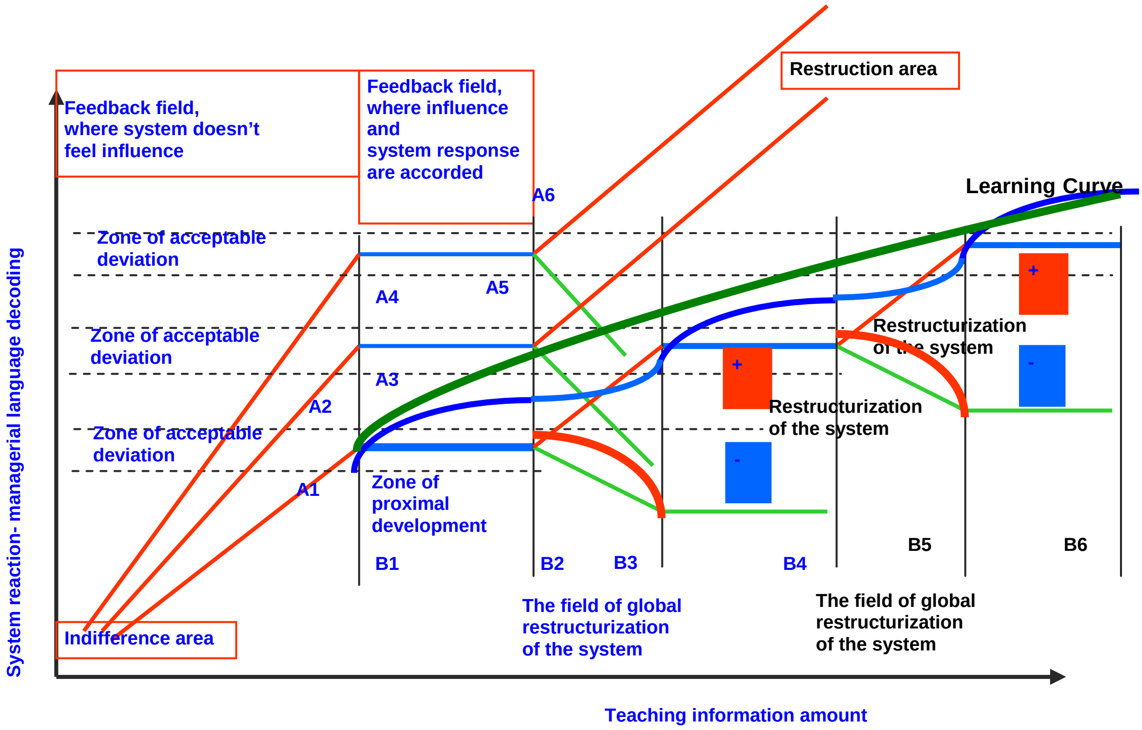

Figure 6. Systemic linguo-didactic model of communicative language competence development stipulated by increasing language complexity with incorporated **Learning Curve Model** of forecasting of study result [31–32]

The language of intelligent management (i.e. the level of complexity of communicated educational information) is the factor that ensures a relative stability of the plateau and, thus, promotes communicative language competence development within the zone of proximal development (ZPD) from the beginning of a study course to its end (Feedback fields B1-B2, B3-B4, B5-B6). To the right of B2 and B4 there are the areas where the system shows signs of losing its former properties having acquired new ones. These new properties – knowledge, skills, abilities, competences – cause 'global inner restructurisation' affecting emotional domain, including behaviour, and transform the system into a new state of intelligence. In other words, the appropriate managerial language, which is adequate to the learners' current decoding abilities, enables the learning system to remain within the boundaries of the informational homeokinetic plateau (boundaries of the system stability A1-A2, A3-A4, A5-A6 – within the 'zone of proximal development'. This is the area where managerial functional elements can be amended in case the system experiences any deflections or deviations from the purposeful predetermined results. The teacher's instructional events, personal resources and technical resources serve as 'scaffolds' to support the process [35]. As a result of the acquired knowledge and the global inner restructurisation, a new system with new qualities and characteristics appears, a system of higher intelligence level, with a higher level of communicative language proficiency. The process is reproduced again and again at a new level of the educational cycle (plateau).

Every new level of communicative competence development incorporates the results of the previous level. In this way the development of communicative language competence corresponds to the 'spiral plan' that is useful for constructing knowledge in higher education.

Uncoordinated managerial influence will remove the learning system from the boundaries of stability, causing a functional disbalance and, eventually, informational collapse. In this case, the learners will not be able to adapt to the purposeful functioning of the total system. As a result, the whole system might be destroyed. In some cases the scattering of the learning system might be observed (Feedback fields B3-B4, B5-B6). Some of more successful students due to self-management skills (self-education) can acquire a reasonable amount of knowledge and move upwards to a higher intelligence level. Less successful ones will just become marginal candidates. To the left of A1 there is an 'indifference' area, where students do not perceive the mentor's educational message in case the language complexity is not adequate to the learner's comprehension.

A study course can be implemented intensively, within limited time frames, promoting a rather fast transition from one level of the educational *cycle/plateau* onto another. It concerns fast in-training professional (profile) courses generally considered as English for Specific (or Occupational) Purposes (A1-A6).

If we speak about a pedagogical process, we assume an extensive course with much wider time frames, significantly bigger educational information amount and far-reaching educational goals (the field of global restructurisation B1-B6).

The process engages not only the development of communicative language competence as one of the aspects of mental/cognitive intelligence, but also general human competences of language learners, including existential competence (the sum of individual characteristics, personality traits and attitudes which concern self-image, and one's view of others and willingness to engage with other people in social interaction), and also their ability to learn.

The Systemic approach to communicative language competence development is not only about learning the language, but also about understanding oneself as a user of the language how this 'knowing' can contribute to one's being heard, understood, perceived and honoured in the world of multiple racial, ethnic, economic, social, educational, religious, etc., expressions.

The Learning Curve reflects not only the current level of student achievement, but also the purposeful level of communicative language competence, which can be achieved.

It is a dynamic view on a student's potential of learning, a certain 'cognitive map' of a learner, aiming to develop the general intelligence and a wide spectrum of integral competences making up communicative language competence, via trans-disciplinary modules. The Learning Curve model gives the possibility to coordinate the dynamism of communicative competence development helping students become skilful manipulators, synthesizers and creators of their own knowledge [31, 32].

The model has been supported by a worked out Competence-Oriented Modular Programme for Autonomous Students (COMPAS) to ensure conditions for communicative language competence development. It is a typical, chronologically applicable set of educational modules, which allow starting the educational process at any level of competence, as well as, coordinating the interim results and the quality of student achievement after each module, to guarantee each learner tangible, efficient results in language acquisition. The modules utilize the materials of the TOEIC test – Test of English for International Communication, an internationally recognized standard that documents perspective employees' English proficiency for many organizations around the world, and students' language proficiency seeking admission to colleges and universities where education is in the English language.

The TOEIC test has been accepted as a criterion-referenced test for language learners as both a diagnostic and the final measurement test for the students of control and experimental groups. TOEIC practice tests are totally congruent with the competences (key competences and function-oriented competences) selected by us as potentially significant for the future self-realization of every student. The tests cover the English language as it is used internationally in business, commerce and industry as well as in various social settings, thus, promoting the interdisciplinary synthesis of knowledge and skills. They help teachers specify clear educational aims and objectives to provide significant influence over content selection with a high degree of authenticity, promote individualization of learning and motivation and ensure objective measurement scale of students' progress.

What practical results the implementation of the linguo-didactic model Learning Curve and the accompanying COMPAS programme has given in the experimental group: the overall communicative language competence of students increased by 20%, which proved to be 16% higher than in the control group where students were taught according to the traditional study programme.

In parallel with the positive changes in students' language competence, the corresponding changes in their motivation and behaviour could also be observed. In fact, the achieved positive results in the experimental group can be directly correlated with the students' increased motivation. Motivation as a major designator of emotional intelligence has positively changed in the experimental group and has shown up in love of learning, empathy, self-awareness, optimism, even in the face of failure, seeking creative challenges and commitment. The English language has now been viewed as a necessity for self-realization in a multicultural environment by 77% of the students (formerly – 48%). In the control group, motivation has changed very insignificantly, if any; 49% of the students have considered the English language as a necessity for self-realization in a multicultural environment (formerly– 44%).

From this vantage point, the educational process is viewed as a dynamic, integral system. The interconnectedness and interdependency of the cycles of student development from conception to graduation are viewed through the lens of the mental/cognitive, linguistic, emotional and spiritual intelligences and their integration. Systems philosophy brings forth a reorientation of thought and worldview.

Conclusions

The Systemic approach to language education, as a systemic approach to anything, requires a commitment to be inclusive on many different levels. For the individual it embraces the 'whole', the physical, mental/cognitive, emotional, spiritual, etc., domains of what it means to be a human being. When our physical intelligence is recognized for its *fundamental* contribution to our lives, we honour its wisdom and relate to our bodies with respect and partnership. When our mental intelligence, and the primary role of language in it, is seen as a *natural* expression of being human, the knowledge to be gained is encouraged in its *natural* discovery and trust that is inherent in the learning process. When our emotional intelligence is seen as our *relational* bridge making multiple connections continually, meaning making becomes animated, vital and more easily embodied. When the environment in which education occurs is created by our spiritual intelligence, that is, seeing oneself in relation to a larger world, feeling connected to oneself, others, a society/culture and nature, the knowing would be of a different order. These personality traits, attitudes and temperaments are parameters which have to be taken into account in language learning and teaching.

We can judge about the efficiency, effectiveness and success of the educational process only by the final result, by students' level of achievement. If one of the individual results is lacking behind, it will pull backwards the success of the whole group and, eventually, show a lower functional level of the learning system.

The educational process is distinguished by its functional mobility and flexibility, which allows at *any* time to introduce a regulating factor by changing *any* functional element of the process. Comparing a predetermined purposeful result with an actual interim result, the system can rearrange its activities at any stage, at any time to amend individual intermediate deflections or deviations to avoid the destruction of the whole system.

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SIMULATIONS OF PROPERTIES OF CARBON NANOTUBES USING THE EFFECTIVE MEDIA APPROACH

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The continuous miniaturization of devices, the high integration level and the increase of the working frequencies and power density require the use of adequate materials as well as innovative chip interconnections and vias, in order to avoid a bottleneck in the existing technologies. Basic attention is paid for carbon nanotubes (CNT), including their contacts with other elements of the nanocircuit. Due to their unique physical properties, CNTs attract a permanently growing technological interest, for example as promising candidates for nano-interconnects in future high-speed electronics. We demonstrate our efforts undertaken to construct a multiscale design tool containing a bundle of CNTs as a basic element, by means of implementation of advanced multifunctional simulation models at different space scales. Both local and integral properties have been simulated on nanotube prototype models such as a dispersion law, the electronic density of states (EDOS), the specific resistivity, the effective masses, *etc*.

Keywords: Carbon nanotubes (CNT), CNT-Ni interconnects, resistivity, multiple scattering theory, effective medium approximation

1. Introduction

The electrical resistance of contacts between the carbon nanotubes (CNT) and the nickel catalytic substrate can considerably exceed that observed in separate parts of these interconnects [1, 2]. Conductance between real metals and CNT still occurs, however, mainly due to scattering processes which are estimated rather weak [3]. Fig. 1 depicts the idealized image of contacts between the CNTs and Ni substrate. The toroidal region (C-Ni) is the object of microscopic approach responsible for the main contribution into resistance. As to the nanotube itself and the metallic substrate, their resistances may be considered as the macroscopic parameters. The electronic structure for the CNT-Ni interconnect can be evaluated through the electronic density of states (DOS) for C-Ni contact considered as 'disordered alloy', where clusters containing both C and Ni atoms are the centres of scattering. The computational procedure developed by us for these calculations [4] is based on the construction of the cluster potentials and the evaluation of the *S*- and *T*-matrices of scattering and transfer, respectively (Fig. 2). The cluster formalism was successfully implemented for metallic

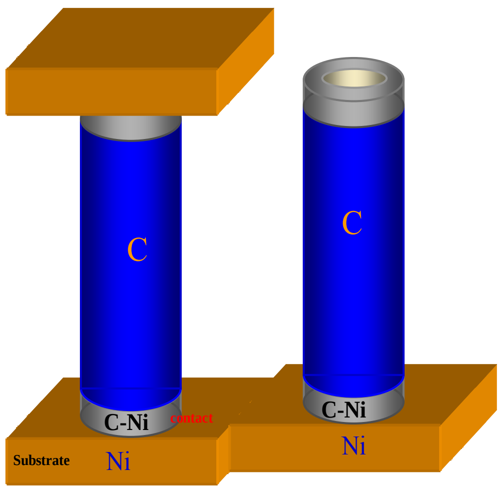

Figure 1. Fragment of interconnects between the Ni substrate and C nanotubes

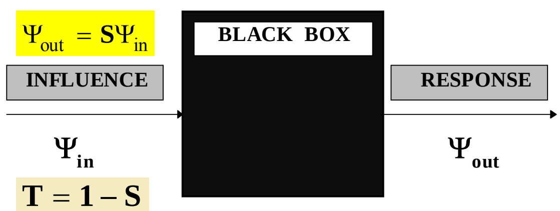

Figure 2. Scattering principle

Cu [4] as well as for both elemental (Ge and Si) and binary (As-, Sb-, and Se-containing) semiconductors [5] (see also Fig. 3). Special attention was paid to the latter since As_xSe_{1-x} and Sb_xSe_{1-x} are not only prospective materials for the optical recording – the concept of statistical weighing was applied here for the binary components [4, 5]. Using the coherent potential approach (CPA) as an effective-medium-approximation (EMA) the resistance of the interconnect can be evaluated through the Kubo-Greenwood formalism [6] and Ziman model [7].

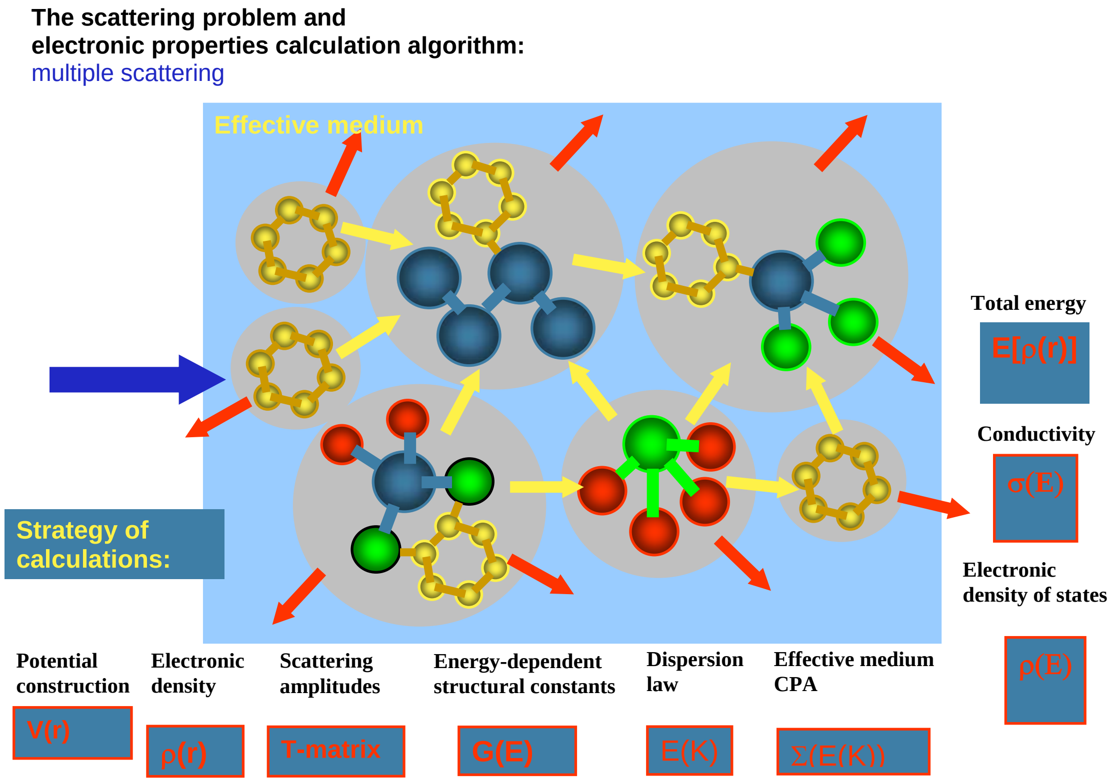

Figure 3. Multiple scattering problem for the system of clusters: strategy of calculations of fundamental properties of condensed medium

2. Effective Media Electronic Structure Calculations of CNT-Ni Interconnects

The scattering theory approach gives us the possibility to calculate an electronic structure and elastic properties of condensed media, which should be considered as static phenomena. At the same time this approach is convenient for the electron transport modelling, which is a dynamical problem. It is the principal distinctive feature as compared to a tight-binding theory, where transport phenomena defy description. Meanwhile, the scattering theory approach (when using quasi-free electron formalism) is also not free of shortcomings. Certain simplifications are necessary to obtain reliable results [4], for example, the CPA considered as an effective-medium-approximation.

2.1. Potential Constructions: Atomic and Crystalline

An electronic structure calculation is considered here as a scattering problem, where centres of scattering are atoms of clusters. The first step of modelling is the construction of potentials, both atomic and crystalline. The Gaspar's potential (*G*) of screened atomic nucleus looks as follows:

$$V_{coul}^{G}(r) = -\frac{2Z}{r}\frac{\exp(-\lambda r/\mu)}{(1+Ar/\mu)}, \qquad (1)$$

where $\lambda = 0{,}1837$, $\mu = 0{,}8853Z^{-1/3}$, A = 1,05. Therefore, $V_e(r) = 2Z/r + V^G(r)$ is the electronic part of Gaspar's potential. Using a statistical approach of atoms, one usually applies X_α and $X_{\alpha\beta}$ presentations for the electronic exchange and correlation:

$$V_{X\alpha}(\mathbf{r}) = -6\alpha(3\rho_e(\mathbf{r})/8\pi)^{1/3}, \tag{2}$$

where α depends on the charge number Z, and

$$V_{X\alpha\beta}(\mathbf{r}) = \left[1 + \frac{\beta}{\alpha} G(\rho_e(\mathbf{r}))\right] V_{X\alpha}, \tag{3}$$

where $G(\rho_e) = \frac{4}{3}\left(\frac{\nabla\rho_e}{\rho_e}\right)^2 - 2\frac{\nabla^2}{\rho_e}\rho_e$, constants α = 0.67 and β = 0.003, whereas the electron density function $\rho_e(\mathbf{r}) = \nabla_r V_e / 8\pi$. Thus, the atomic potential of a neutral atom can be expressed as:

$$V_{at}(\mathbf{r}) = V_{coul}(\mathbf{r}) + V_{ex-corr}(\mathbf{r}), \tag{4}$$

where we consider V_{coul} as Gaspar's potential and $V_{ex-corr}$ as potentials $V_{X\alpha}$ or $V_{X\alpha\beta}$.

The crystalline potential and electronic density can be expressed by formulae:

$$V_{coul}(\mathbf{r}) = V^G_{coul}(r) + \sum_{\gamma,n_\gamma} V^G_{coul,\gamma}(|\mathbf{r} - \mathbf{R}^\gamma_{n_\gamma}|), \tag{5}$$

$$\rho_{e,cryst}(\mathbf{r}) = \rho_e(r) + \sum_{\gamma,n_\gamma} \rho_{e,\gamma}(|\mathbf{r} - \mathbf{R}^\gamma_{n_\gamma}|), \tag{6}$$

where γ defines a sort of atom and summing up over the crystalline unit cells and are the corresponding $\mathbf{R}^\gamma_{\mathbf{n}_\gamma}$ atom positions and R^γ_n interatomic distances. (Fig. 4 shows both atomic and crystalline potentials for carbon in comparison with Hartree-Fock atomic potential). Then, we apply the so-called muffin tin approximation (*MTA*):

$$V_{MT}(\mathbf{r}) = \langle V_{cryst}(\mathbf{r}) \rangle - V_{MTZ}, \tag{7}$$

$$V_{cryst}(\mathbf{r}) = V_{coul}(\mathbf{r}) + V_{ex-corr}(\mathbf{r}), \tag{8}$$

where $V_{ex-corr}$ are the same potentials $V_{X\alpha}$ or $V_{X\alpha\beta}$ as in atomic case except for the electronic density, which is defined according to Eq. (6), V_{MTZ} the *MT*-zero estimate of potential calculation. To obtain the electronic structure, the calculation of scattering properties is necessary, generally, in the form of *S*- and *T*-matrices (Fig. 2). An important case of *MT*-potentials has been widely studied, but more attention was paid to the spherical non-symmetrical potentials. The results of potential modelling and phase shifts in the framework of the *MT*-approximation are presented in Refs. [4, 5].

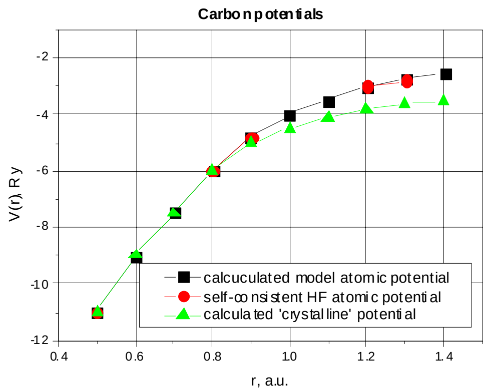

Figure 4. Analytical C potentials compared with results of HF calculations

2.2. Electronic Structure and Conductivity

The electronic structure calculations start from the definition of the initial atomic structure to produce a medium for solution of the scattering problem for a trial electronic wave (see Fig. 5) [4]. The formalism we use for electronic structure calculations is based on the CPA, the multiple scattering theory and cluster approach. As the first step in the modelling procedure, one postulates the atomic structure on the level of short- and medium-range orders.

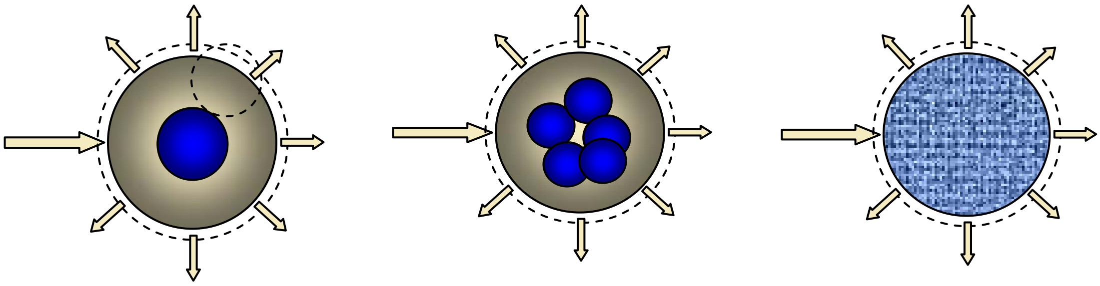

Figure 5. Models of the scattering clusters: a) single atom cluster; b) many-atom cluster; c) cluster with the general type potential in an effective medium, with the dispersion relation $E(\mathbf{k})$ and a complex energy-dependent coherent potential $\Sigma(E)$, which is found self-consistently in the framework of the CPA

The next step is to construct a "crystalline" potential and introduce the *MTA*. This is accomplished by using realistic analytical potential functions.

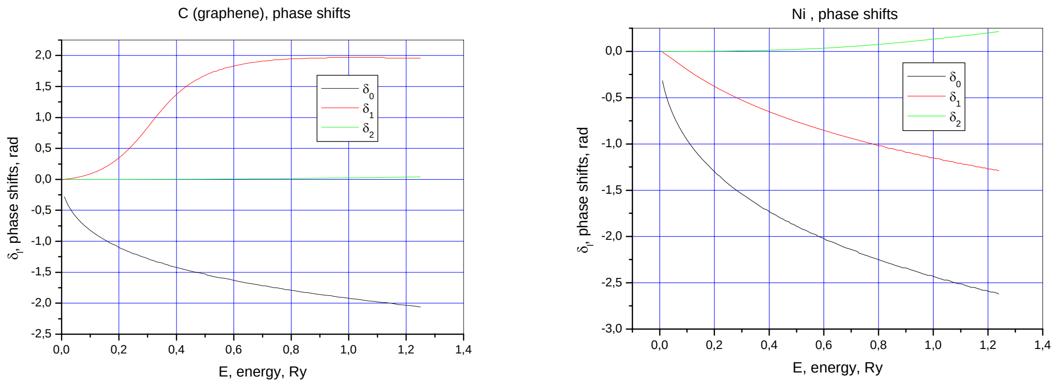

Figure 6. Phase shifts for carbon (C) and nickel (Ni) atomic clusters

Then, the electronic wave scattering problem is solved, and the energy dependence of the scattering properties for isolated muffin-tin scatterers is obtained in the form of *phase shifts* $\delta_{lm}(E)$ (see Fig. 6), and the T-matrix of the cluster as a whole is found. The indices l and m arise as a result of expansions of the functions as Bessel's functions j_l , Hankel's functions h_l and spherical harmonics Y_{lm}. We note that the introduction for the potentials simplifies the solution of the scattering problem considerably since this procedure makes symmetric the potentials. In this case, the scattering is defined by radial component R_l only. However, the analysis of the scattering problem for potential functions of a general type not possessing spherical symmetry within the confines of the cluster volume has demonstrated that the *MTA* is applicable for a wide class of disordered materials, both metals and semiconductors. In the procedure of constructing the potentials, the $X_{\alpha\beta}$-approximation for the exchange-correlation interaction has also been used. This approximation has important advantages for describing binary materials since its α and β parameters are practically constant for different elements.

The modelling of disordered materials represent them as a set of atoms or clusters immersed in an effective medium with the dispersion $E(\mathbf{K})$ and a complex energy-dependent coherent potential $\Sigma(E)$ found self-consistently in the framework of the CPA. The basic equations of this approach are as follows:

$$\Sigma(E) = V_e + \langle T\rangle(1 + \mathrm{G}_e\langle T\rangle)^{-1}, \tag{9}$$

$$\mathrm{G}(E) = \mathrm{G}_e + \mathrm{G}_e\langle T\rangle\mathrm{G}_e = \langle \mathrm{G}\rangle, \tag{10}$$

$$\langle T(E,\mathbf{K})\rangle = 0, \tag{11}$$

$$\Sigma(E) = V_e, \tag{12}$$

$$\langle \mathrm{G}\rangle = \mathrm{G}(E) = \mathrm{G}_e, \tag{13}$$

$$N(E) = -(2/\pi)\ln\{\det\|\mathrm{G}(E)\|\} \tag{14}$$

Here <...> denotes configuration averaging, *V* and G are the potential and the Green's function of the effective medium, respectively, *T(E,***K***)* the *T* matrix of the cluster, and *N(E)* the integral density of the electronic states. Eq. (11) can be re-written in the following form:

$$\left\langle T(E,\mathbf{K})\right\rangle = \mathbf{Sp}T(E,\mathbf{K}) = \int \left\langle \mathbf{K}\right| T(E,\mathbf{K}) \left|\mathbf{K}\right\rangle d\Omega_{\mathbf{K}} = 0\,, \tag{15}$$

where $\left|\mathbf{K}\right\rangle = 4\pi \sum_{l,m} i^l j_l(kr) Y^{*}_{lm}(\mathbf{K}) Y_{lm}(\mathbf{r})$ is the one-electron wave function and integration is performed over all angles of **K** inside the volume Ω. Equation (15) enables one to obtain the dispersion relation *E*(**K**) of the effective medium. The calculation of the density of the electronic states in the form of equation (14) can be done using the variation procedure:

$$\rho(E) = \frac{\delta N(E)}{\delta E}\,. \tag{16}$$

The calculations of conductivity are usually performed using Kubo-Greenwood formula [5, 8]:

$$\sigma_E(\omega) = (\pi\,\Omega/4\omega)\int\left[f(E) - f(E+\hbar\omega)\right]\left|D_E\right|^2 \rho(E)\rho(E+\hbar\omega)dE\,, \tag{17}$$

where ω is a real frequency parameter of Fourier transform for the time-dependent functions , *f(E)* the Fermi-Dirac distribution function, $D_{E,E'} = \int_{\Omega} \Psi^{*}_{E'} \nabla \Psi_E d\mathbf{r}$, and $\Psi_{E(\mathbf{K})} = A\exp(\mathrm{i}\mathbf{Kr})$ the complex wave vector of the effective medium. The dispersion function *E*(**K**) determines the properties of the wave function $\Psi_{E(\mathbf{K})}$ on the isoenergy surface in **K**-space. The imaginary part of **K** causes damping of the electron wave, due to the absence of long-range structural order.

The second the simplest possibility for estimating the conductivity comes from the Thouless's model [13], where the loss of phase of the electron wave is linked with the structural disorder and is taken into account in a purely phenomenological way through the coherence length λ. The complex wave number $K = K_R + \mathrm{i}(1/2\lambda)$ in this model can now be attributed to the calculated dispersion relation *E*(**K**), where K_R denotes the real part of wave number $\mathrm{Re}\{K\}$. If we calculate the coherence length $\lambda = (1/2)\,\mathrm{Im}\{K\}$, then the conductivity can be expressed *via* Fermi's level ε_F:

$$\sigma_E(\omega) = (16/3)\pi^2\lambda n^2(\varepsilon_F)\left[1 + \omega^2\lambda^2/(4\varepsilon_F)\right]. \tag{18}$$

Using the dispersion law, the effective mass of electrons can be defined as:

$$m^{*} = (\partial^2 E/\partial K_R^2)^{-1}\,. \tag{19}$$

Thus, the static conductivity can be re-written using Drude formula [14]:

$$\sigma_{E(K)} = \frac{e^2 n^{*}}{m^{*}}\tau\,, \tag{20}$$

where n^* is the effective electron density, with a relaxation time $\tau \approx \frac{l}{v_h}, v_h = \left(\frac{3k\mathrm{T}}{m^{*}}\right)^{\frac{1}{2}}$, and *l*(T) denoting the free path.

Thus, there exist some ideas to estimate the conductivity in static and frequency regimes and take into account temperature effects. However, in the case of CNT we must consider not only the diffusive mechanism of conductivity, but also the 'so-called' ballistic one. This is an evident complication of the interpretation of electrical properties of CNT and their systems.

2.3. Liquid Metal Model

The term "liquid" means the structural disorder of the substance involved, more precisely, only the nearest order is taken into account, as usual considered in the liquid. It also means that the interatomic distance with the nearest neighbour (first coordination sphere) is fixed whereas the angular coordinates are random. Another condition is that the average density of matter is maintained also locally. The term "metal" does not mean the applicability of model only for metals, it was successfully implemented for semiconductors too [4, 5]. Thin metal layers as well as nanotubes can be also described in the framework of the formalism of a glass-like structure [9, 10].

To implement this model, we focus the matter into a single atom (Fig. 7) which will be associated with a crystalline potential in *MT*-approach, to consider the influence of the nearest vicinity. The neighbour atom around the studied atom is spread and, in fact, we are working on the one bond distance.

The area **2** is a sphere of R_C radius determined from the condition of average matter density maintenance. However, to consider the influence of medium we need to "load" the sphere (2) with an effective complex potential, which defines the fading of electromagnetic waves, thereby modelling the disordered medium. The region **3** is under the influence of coherent potential $\Sigma(E)$. After that we must sew the wave functions on the border of regions **2** and **3**, superposing the Soven's condition [11], which correspond to the statement that disordered media do not allow the forward scattering.

The spherical symmetry of this system allows us to use partial decomposition techniques and the scattered wave outside the MT-sphere (2), where the potential is constant, can be defined as:

$$\psi_l^{(2)} = j_l(kr) - \text{tg}\,\delta_l n_l(kr)\,. \qquad (21)$$

The next step is to find the dispersion law of the effective medium and the electronic density of states (EDOS). In "liquid" model, the argument **K** of dispersion function $E(\mathbf{K})$ is a complex: $\mathbf{K}_R + i\mathbf{K}_I$. CPA approach ($\int_{\Omega_\mathbf{K}} \langle \mathbf{K}|\tilde{t}|\mathbf{K}\rangle d\Omega_\mathbf{K} = 0$ [4]) allows us to get the dispersion law (see Fig. 8).

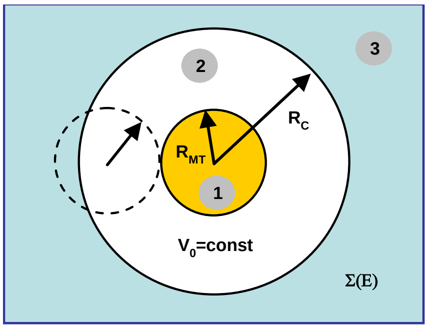

Figure 7. The "liquid" metal model

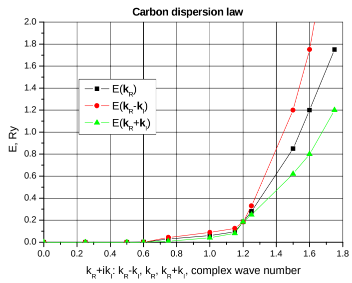

Figure 8. Dispersion of C in 'liquid metal model'

The calculation of the EDOS using the formalism of scattering theory is based on Luttinger's theorem [16]. The electron inside a large sphere with the radius R moves in the spherically symmetric potential $V(\mathbf{r})$ decreasing faster than r^{-2}. The scattered partial wave here is as follows:

$$\psi_l(r) = \frac{1}{r}\sin(k'r + \delta_l - \frac{1}{2}l\pi)\,, \qquad (22)$$

approaching to zero at $r \to \infty$. For wave equation, the Green's function G(**r**,**r**') can be used [8]:

$$(\nabla^2 - V(\mathbf{r}) - E)\mathrm{G}(\mathbf{r},\mathbf{r}') = \delta(\mathbf{r}-\mathbf{r}')\,, \qquad (23)$$

where $\mathrm{G}(\mathbf{r},\mathbf{r}') = \sum_{l,m} Y_{lm}(\mathbf{r})Y_{lm}(\mathbf{r}')\mathrm{G}_l(\mathbf{r},\mathbf{r}')$, whereas δ(**r**-**r**') is the Dirac's function and $\int_\Omega Y_{lm}(\mathbf{r})Y_{lm}(\mathbf{r}')d\Omega = 1$.

The simplest expression for the EDOS through the Green's function can be written as:

$$\rho(E) = \frac{\delta N(E)}{\delta E} = \frac{2}{\pi}\int \mathrm{Im}\{Sp\mathrm{G}(\mathbf{r},\mathbf{r}',E)\}d\mathbf{r}\,. \qquad (24)$$

Obviously, the Green's function should describe the scattered wave outside the *MT* sphere; from the other side, it should be the outgoing wave, *i.e.*, satisfied the asymptotic condition in the infinity:

$$\mathrm{G}_l(r,r') = cF_l(kr_>)J_l(kr_<), \qquad (25)$$

where $J_l = \cos\delta_l \cdot j_l(kr) - \sin\delta_l \cdot n_l(kr)$, $N_l = -\cos\delta_l \cdot n_l(kr) + \sin\delta_l \cdot j_l(kr)$ [(shifted on phase by 90^0) – similar to small j_l *and* n_l (Bessel and Neumann functions), $h_l = j_l + in_l$, the using of n_l and h_l are equivalent].

Then we introduce $F_l = N_l + I_l J_l = [\sin\delta_l j_l(kr) - \cos\delta_l \cdot n_l(kr)] + I_l[\cos\delta_l j_l(kr) - \sin\delta_l \cdot n_l(kr)]$,

and, using condition on the continuity of logarithmic derivatives, we obtain:

$$k\frac{N_L'(kR_C)+I_LJ_L'(kR_C)}{N_L+I_LJ_L}=K\frac{h_l'^{+}(KR_C)}{h_l^{+}(KR_C)}, \qquad (26)$$

where $h_l^{+}(kr)\propto\frac{\exp(\mathrm{i}kr)}{kr}$ – is the modified Hankel's function $h_l^{+}(kr)=n_l-ij_l$, R_C – is the cluster radius, K – the complex wave number of the effective medium, $k=\sqrt{E}$ – the wave number within the cluster.

After the integration of (24) by angular and radial coordinates using approximation of "one-atom" cluster in the effective medium with radius R_C (Fig. 7) and the right normalization for the Green's function, the density function of the electronic states can be written as:

$$\rho(E)=\frac{2}{\pi}\sum_{l=0}^{\infty}(2l+1)\left(\frac{d\delta_l}{dE}-R_C^2\sqrt{E}\left[j_l(kR_C)-tg\,\delta_l n_l(kR_C)\right]^2\frac{\partial\gamma_l(E,R_C)}{\partial E}\mathrm{Im}\{I_l\}\right), \qquad (27)$$

where $\gamma(E,R_C)=k\frac{\cos\delta_l j_l'(kR_C)-\sin\delta_l n_L'(kR_C)}{\cos\delta_l j_l(kR_C)-\sin\delta_l n_l(kR_C)_L}$ are the logarithmic derivatives on the cluster boundary.

The dispersion law looks as follows:

$$\frac{1}{K}\sum_l(2l+1)\exp(\mathrm{i}\delta_l(E,K)\sin\delta_l(E,K)=0\ . \qquad (28)$$

Another promising application for the *MT*-approach using the "liquid metal model" is the possibility to estimate the specific resistance ρ in the framework of the Ziman's model [7]. The basic definition is the modified Drude formula for conductivity [14]:

$$\sigma=\frac{1}{\rho}=\frac{ne^2\tau}{m^*}, \qquad (29)$$

where the τ is the effective time free movement, m^* the effective mass.

If the atoms of liquid metal (or amorphous metal film) are dispersing centres, their distribution is not completely random (while the amplitude of scattering from two atoms located one from another on a distance, circumscribed by a radius-vector **R**, is equal: [1 + exp (i**qR**)] $f(\theta)$, where **q = k – k'**, and taking into account multiple scattering [13]:

$$\frac{1}{\sigma}=\rho=\frac{3\pi}{\hbar^2e^2v_F\Omega}\int_0^{2k_F}\frac{|V(q)|^2\,S(q)q^3dq}{4k_F^4}\ , \qquad (30)$$

where $\frac{1}{\tau}=N_Cv_f\int_0^{\pi}I(\theta)(1-\cos\theta)2\pi\sin\theta d\theta$, $I(\theta)=|f(\theta)|^2$, $f(\theta)=\left(\frac{m}{2\pi\hbar^2}\right)\int V(\mathbf{r})\exp(i\mathbf{qr})d\mathbf{r}$ – is the scattering amplitude function, $S(\mathbf{q})=\frac{1}{N_C}\int(1+\exp(i\mathbf{qR}))g(R)d\mathbf{R}$ is the structural factor, whereas $V(\mathbf{q})=\frac{1}{\Omega}\int V(\mathbf{r})\exp(i\mathbf{qr})d\mathbf{r}$ the Fourier image of potential-scatterer, $L=v_f\tau$ the distance of free path, v_f the Fermi's velocity, τ the free path time, N_C the number of scattering centres within the volume Ω, θ – is the scattering angle, $\mathbf{q}=\mathbf{k}-\mathbf{k}'$, **k**, $\mathbf{k}'$ – are the wave vectors before and after a scattering, $g(R)$ – is the pair correlation function of atomic distribution.

2.4. Application of the Theory to the Ni-CNT Contact

A liquid metal model for CNT-Ni interconnect is based on calculation of the 'mixed' dispersion law (Figs. 9, 10):

$$E_{C-Ni}(\mathbf{K}_R)=xE_C(\mathbf{K}_R)+(1-x)E_{Ni}(\mathbf{K}_R). \qquad (31)$$

This model is very sensitive to *ab initio* parameters such as *MT*-radius, cluster radius, potential configurations, *etc*, which evidently must be optimised.

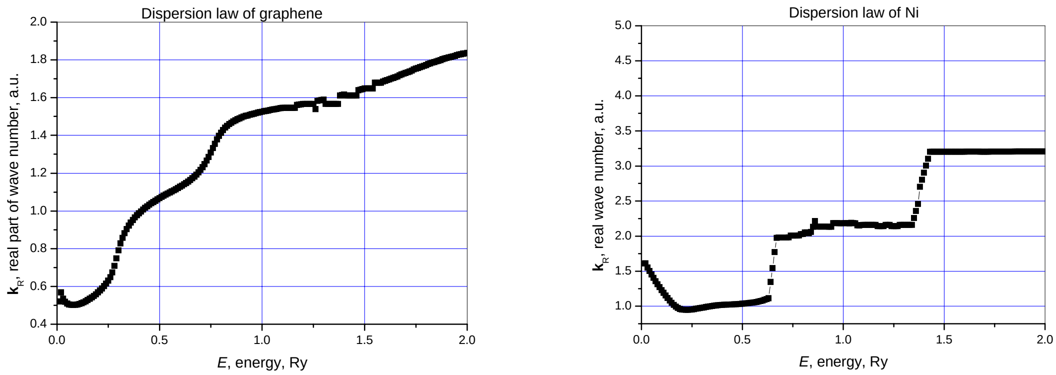

Figure 9. Model dispersion laws

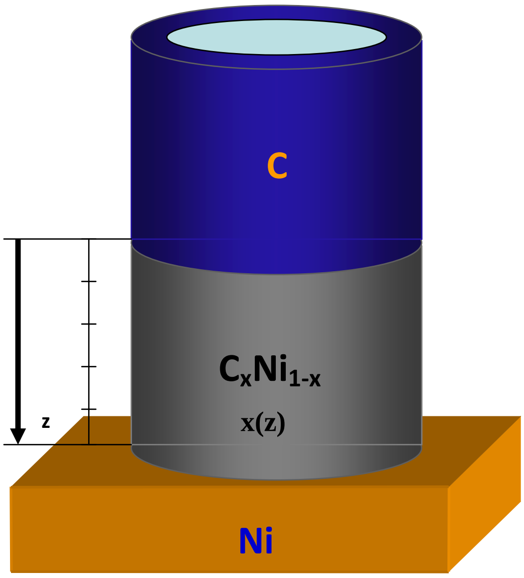

Figure 10. Model of Ni/CNT interconnect

The metal alloy model is used for evaluation of mixed effective mass $m^*_{C\text{–}Ni}(E)$. Dependence of effective masses and specific resistance on x are presented in Fig. 10 and Table 1. Taking into account the spectral dependence of the effective mass $m^*(E)$ and estimating the spectral resistivity $\rho_x(E)$, we should estimate the average layer resistivity $\rho_{x,av}$ as follows:

$$\rho_{x,av} = \frac{\int_0^{E_{fin}} \rho_x(E)dE}{E_{fin}}, \qquad (32)$$

where E_{fin} is the evaluation of conduction band width. The stoichiometry coefficient $x(z)$, where z is the ring layer coordinate.

Table 1. Dependence of specific resistivity $\rho_{x,av}$ on alloy composition (x)

No.	x	C_xNi_{1-x} layer resistivity, $\rho_{x,av}$, Ohm·nm
1	0.00	0.80724504E+02
2	0.10	0.81333489E+02
3	0.20	0.82188841E+02
4	0.30	0.83330555E+02
5	0.40	0.84871658E+02
6	0.50	0.87061935E+02
7	0.60	0.90460375E+02
8	0.70	0.96249458E+02
9	0.80	0.10819738E+03
10	0.90	0.14581056E+03
11	1.00	0.82312308E+04

The integral resistivity of the contact C-Ni ring imaged in Fig. 10 can be obtained by integration:

$$R = \int_0^{l_0} \rho_{x,av}(x(z))\frac{dz}{S} = \frac{1}{\pi(r_2^2 - r_1^2)}\int_0^{l_0} \rho(x(z))dz\,, \qquad (33)$$

where S is the nanotube cross-section, r_1 and r_2 are radii of internal and external walls of CNT. If $z = c_o x$ is proposed as linear, where c_o is the scaling coefficient, we can rewrite Eq. (33) as:

$$R = \frac{k_0}{\pi(k_2^2 R_2^2 - k_1^2 R_1^2)} \int_0^1 \rho_{x,av}(x)dx, \quad (34)$$

which can be applied for any geometry of the nanotube on the basis of the calculated resistance unit. Resistance of the C-Ni contact = 0.1064E+04 Ohm, where $R_1 = 0.10\text{E}-08$ m, $R_2 = 0.20\text{E}-08$ m are the internal and external radii of conventional nanotube, $k_1 = 1, k_2 = 1, k_0 = 20$ nm are the scaling coefficients, $\int_0^1 \rho_{x,av}(x)dx = 0.5015\text{E}+03\,\text{Ohm}\cdot\text{nm}$ is the integral resistivity of a contact area, $w = \frac{k_0}{\pi(k_2^2 R_2^2 - k_1^2 R_1^2)} = 0.2122\text{E}+10\ \text{m}^{-1}$, k_0 = 0.20E-07 m, S = 0.9425E-17 m^2.

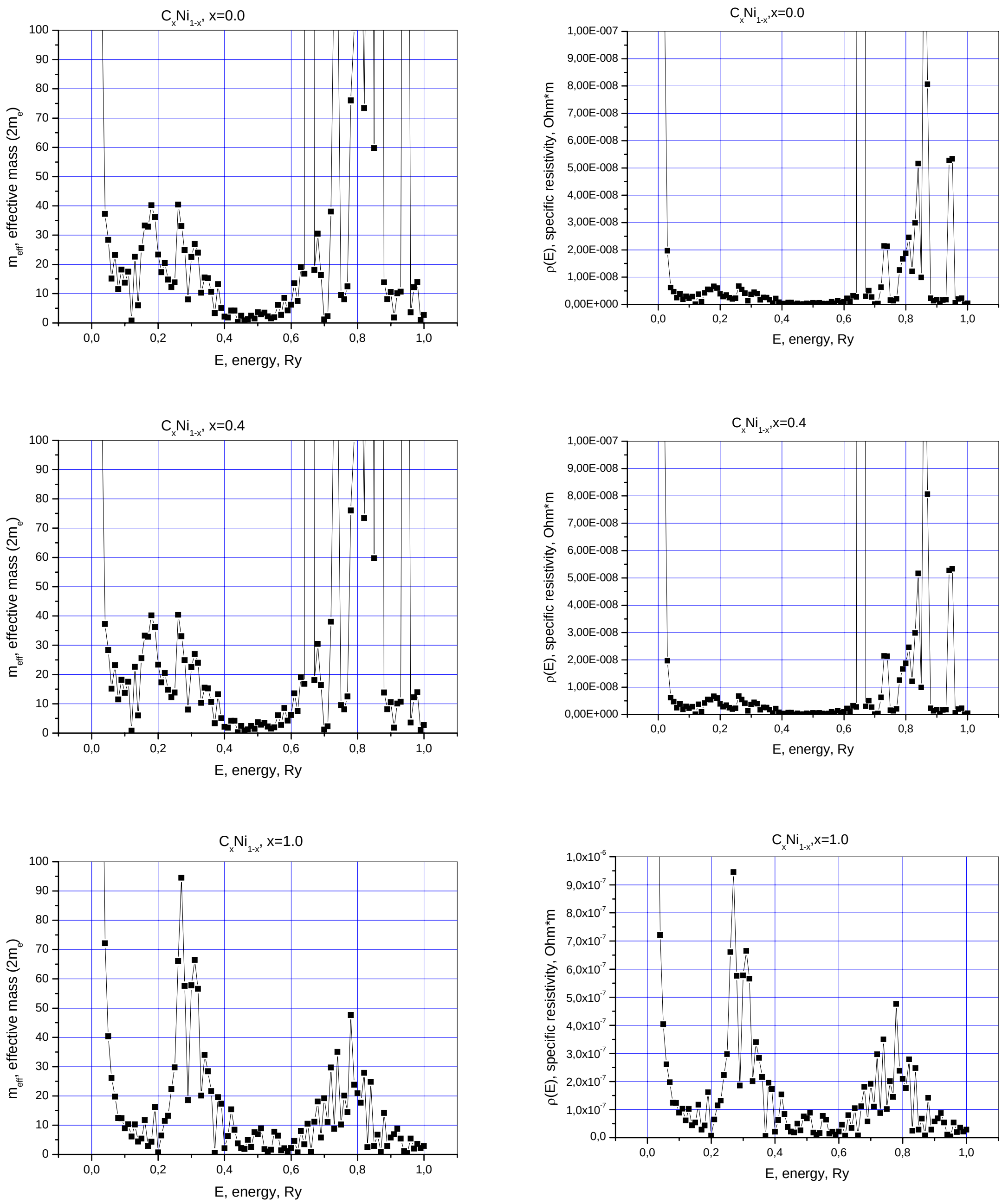

Figure 11. Effective masses and specific resistivities C_xNi_{1-x}

3. Ballistic Conductance Model

Considering nanowires or nanotubes not so long the electrons are not scattered too much by any imperfection of the wire material [15, 18]. The effect of charge accumulations can be neglected. We are dealing with the so called 'ballistic' mechanism of the electronic transport. This situation is similar to an ideal billiard with moving elastic balls-electrons. The simple estimations give us the well-known result $j_{LR} = n(2e^2/h)V_{bi}$, where V_{bi} is a bias voltage, j_{RL} is the corresponding current density, n is the number of 'conducting channels' per cross-section of a nanowire and $2e^2/h = 0.77 \cdot 10^{-4}\,\mathrm{Ohm}^{-1}$ is the quantum conductivity (this means about 13 kOhm). This model can be considered also in terms of a scattering problem. According to the Landauer model, $g_{mn} = (e^2/h)Tr(T_{mn}T^{+}_{mn}), m \neq n$, where the current flowing between two reservoirs with chemical potential difference $\Delta\mu = \mu_1 - \mu_2$ is just $(e^2/h)T_{12}\Delta\mu$ where T_{12} is the transmission coefficient from one to two in the one-channel case .

4. CNT Simulation in the CPA

For CNT simulation, the cylindrical symmetry scattering formalism is used. Thus, this means that the trial electronic waves after a scattering give the radial and axial (z-axis) components as shown in Fig. 12. According to this symmetry demands the potential models are developed (see Fig. 13). The potential modelling is based on the well-tested analytical procedures of Gaspar's type with the use of exchange-correlation corrections ($X\alpha$ – and $X\alpha\beta$ – approximations) and muffin-tin (MT) models [4, 5, 15, 17, 18].

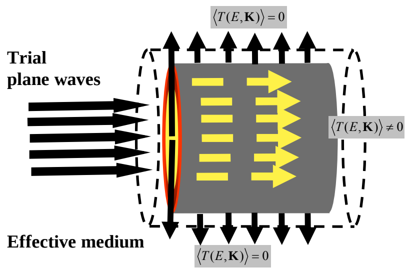

Figure 12. Scattering model for a nanotube fragment: expansions on the radial and axial scattering

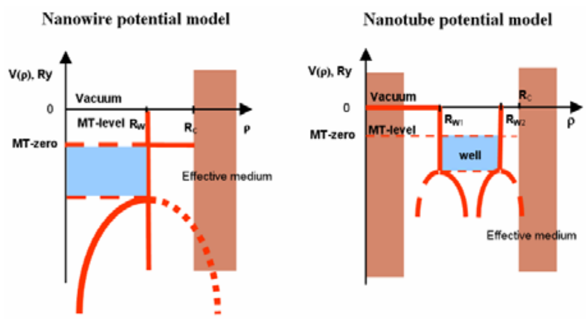

Figure 13. Potential models for nanotubes and nanowires

To solve the central problem of simulation, *i.e.,* the problem of chirality we use the ring cluster conception (Figs. 14–16). The main idea is the rotation of carbon ring in respect to the axis of CNT.

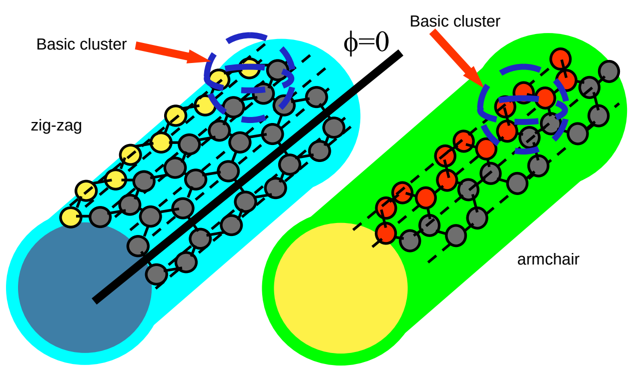

Figure 14. C-rings in CNT as clusters

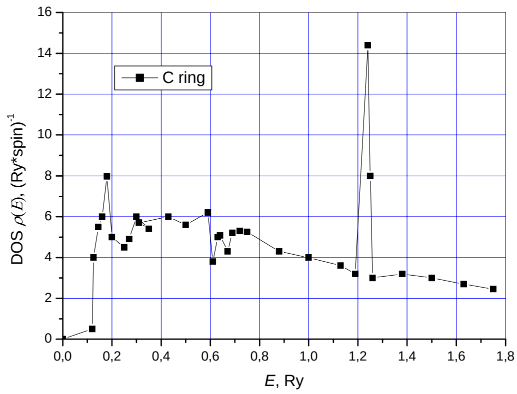

Figure 15. The EDOS for graphene ring in the effective medium (CPA calculations)

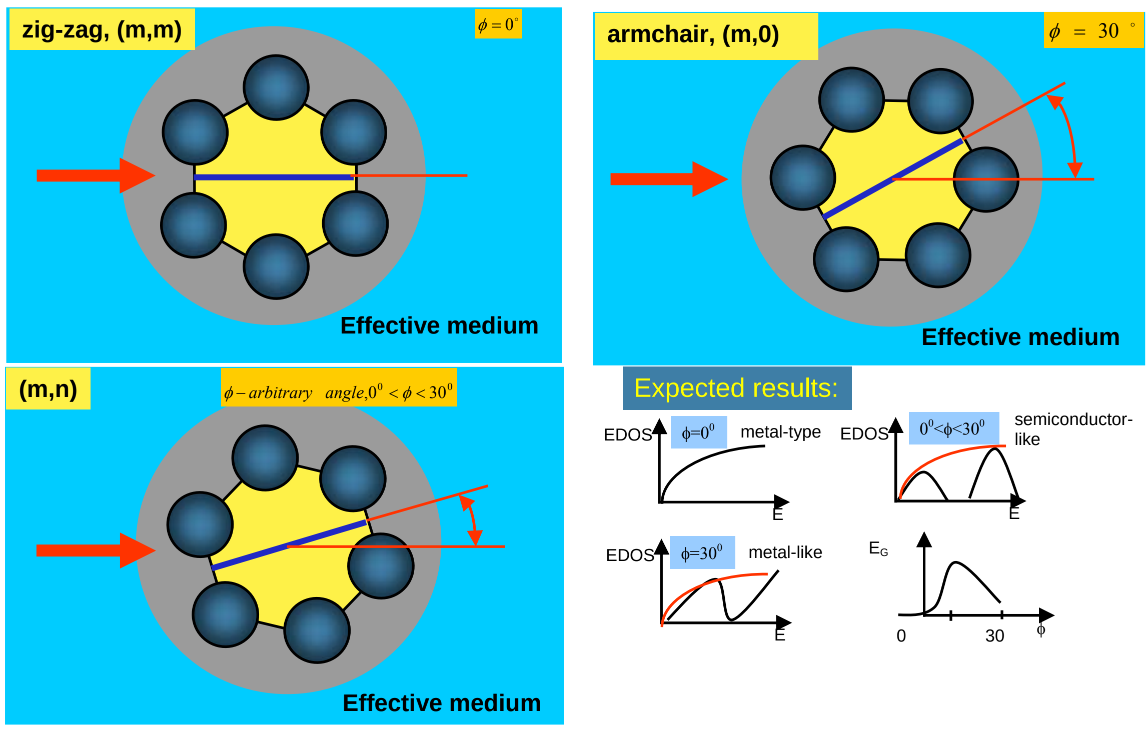

Figure 16. Modelling of chirality effects and expected results: EDOS and energy gap via chirality angle ϕ

5. CNT-Ni Nanodevice Model

The basic model shown in Fig. 17 has the following assumptions.

- The CNT-Ni device model consists of two regions from the point of view of the electronic transport, which support, in general, different electron transport mechanisms: ballistic (elastic) and collision-like (non-elastic).
- These electron transport processes are simulated by the corresponding boundary conditions in the form of the effective medium.
- The chirality is simulated by the corresponding orientation of carbon rings in the scattering problem (Fig. 14).
- The more problematic region of simulation is the CNT-Ni interconnect space, where the atomic structural disorder is observed and the conductivity mechanism is changed.

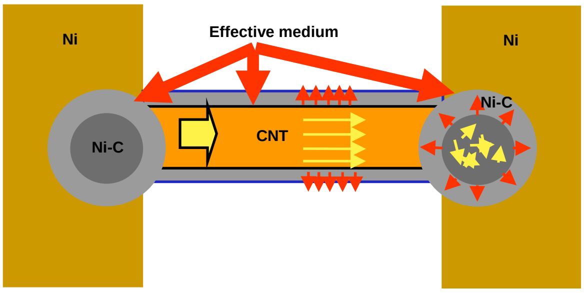

Figure 17. CNT-Ni device model

Conclusions

The model of liquid metal alloy model is a convenient calculation scheme, which is based on the simplest atomic configuration. However, the multiple scattering theory and cluster approach lead to reasonable results. At the same time, there exist some essential parameters of calculation which may demand the optimisation procedure. These parameters are R_{MT}, R_C, E_{fin}, r_1, r_2, k_0. In particular, the dispersion law and electronic density of states calculations are very sensitive to R_{MT} and R_C. At the same time the geometry (r_1, r_2, k_0) and conduction band width, Fermi's velocity, the length of free path, structure factor, *etc.*, which define the kinetics of electronic transport must be carefully analysed. The temperature dependence of a contact resistance must be investigated also using formalism of kinetics electron gas. The dependence of integral resistance on structural modifications in C_xN_{1-x} contact can be taken into account in the framework of polyatomic cluster model, using the same multiple scattering conception and effective medium approach (namely, CPA-coherent potential approximation).

The proposed model of conductivity for CNT-Ni device based on the scattering theory principles and effective medium approach takes into account the atomic short range order peculiarities in a flexible way. This allows us to simulate all possible technological variants for production of CNT-based electronic systems with a definite symmetry, various chiralities and structural disorder elements.

Acknowledgments

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CUMULATIVE INDEX

COMPUTER MODELLING and NEW TECHNOLOGIES, volume 12, No. 2, 2008

(Abstracts)

E. Bassan, J. Kreimer. Multiserver and Multichannel Real-Time Systems with Separate Queues and Pre-Emptive Priorities, *Computer Modelling and New Technologies*, vol. 12, No 2, 2008, pp. 7–16.

We consider a real-time data acquisition and processing multiserver system with identical servers (such as machine controllers, unmanned air vehicles, medical monitoring devices, overhearing devices, etc.) which can be maintained/programmed for different kinds of activities (e.g. passive or active). This system provides a service for real-time tasks arriving via several channels (such as assembly lines, surveillance regions, communication channels, etc.) and involves maintenance. We focus on the worst case analysis of the system working under maximum load with *pre-emptive* priorities assigned for servers of different activity type.

We consider two models (with ample and limited maintenance facilities respectively) with separate queue to each channel. We show how to compute steady state probabilities and various performance measures, when both operation and maintenance times are exponentially distributed.

Keywords: *availability, performance, pre-emptive priority, real-time system*

A. Vasilis Vasiliauskas, J. Barysienė. Review of Current State of European 3PL Market and its Main Challenges, *Computer Modelling and New Technologies*, vol. 12, No 2, 2008, pp. 17–21.

This article examines basic reasons behind the use of 3 PL, i.e. the main drivers of outsourcing (Chapter 2) as well as explains the essence of 3PL service (Chapter 3). Chapter 4 deals with the analysis of current state of 3 PL market in Europe. Finally, Chapter 5 gives an overview of main challenges that European 3 PL service providers currently are facing.

Keywords: *3PL service, outsourcing, logistics service providers*

A. Jarasunienė. Research on Information Systems Development in Lithuanian Railways, *Computer Modelling and New Technologies*, vol. 12, No 2, 2008, pp. 22–25.

As a modest-size country having limited natural resources and market, Lithuania should be very interested in becoming much more open to the world and playing traditional role of mediator between the East and the West. Among the most important conditions for the openness is a wide range of interrelated links between the maritime, road, railway and air transport with the foreign countries, as well as the relevant national transport infrastructure and the development and application of Information Systems (IS).

Keywords: *railway, information system (IS), IS selection, management, model of systems*

J.-R. Kalnins, V. Bardacenko. Fluctuations and Control in Management, *Computer Modelling and New Technologies*, vol. 12, No 2, 2008, pp. 26–35.

Goldratt's Game for the simulation purpose in the management course was presented in two different visual forms (Vensim and Excel). The first model is clearly controllable and attractive for classroom. The second one is carefully investigated under the several control rules.

Keywords: *simulation, fluctuations, control, chain*

D. Golenko-Ginzburg, A. Ben-Yair, Y. Hadad, **N. Badarna.** Resource Allocation Model for Customers with Different Priorities, *Computer Modelling and New Technologies*, vol. 12, No 2, 2008, pp. 36–44.

A resource delivery system which supplies several customers by homogenous non-renewable resources is considered. For each customer its minimal and maximal amounts of resources to be delivered, are pre-determined, as well as its preference (importance) rate. A real-time model which at any decision-making moment reallocates optimally the total available amount of resources among the customers, is presented. The values to be optimised are the resource amounts actually delivered to each customer, while the objective to be maximized is the summarized product of the delivered resource amounts and the customers' rates. A numerical example is presented.

Keywords: *resource reallocation, homogenous consumable resources, resource delivery model, customer's preference rate, precise resource reallocation algorithm.*

The article gives a brief review of competence-based professional higher education today and its underlying principles. Following this overview is an appraisal of literature that illuminates the heritage of competence-based education and contains current writings that offer further understanding of the research subject matter. This section analyses and distinguishes the concepts “competence” and “competency”, identifies and defines integral structure and contents of the communicative language competence, substantiates the choice of the key competences necessary for everyone, and function-orientated competences, which in their unity stipulate the successful adaptation and self-realization of a young specialist in the modern fast changing world. At the end of the article the authors offer an innovative exploitation of the Systemic approach contributing to the development of a Systemic linguo-didactic model, its theoretical grounding with definitions of key concepts. The model implies context-dependent management of the educational activities based on the analysis of semantic changes in data relations – contextual concordance of relations within an intelligent system.

Keywords: communicative language competence, Systemic approach, Systemic linguo-didactic model

The continuous miniaturization of devices, the high integration level and the increase of the working frequencies and power density require the use of adequate materials as well as innovative chip interconnections and vias, in order to avoid a bottleneck in the existing technologies. Basic attention is paid for carbon nanotubes (CNT), including their contacts with other elements of the nanocircuit. Due to their unique physical properties, CNTs attract a permanently growing technological interest, for example as promising candidates for nano-interconnects in future high-speed electronics. We demonstrate our efforts undertaken to construct a multiscale design tool containing a bundle of CNTs as a basic element, by means of implementation of advanced multifunctional simulation models at different space scales. Both local and integral properties have been simulated on nanotube prototype models such as a dispersion law, the electronic density of states (EDOS), the specific resistivity, the effective masses, *etc*.

Keywords: Carbon nanotubes (CNT), CNT-Ni interconnects, resistivity, multiple scattering theory, effective medium approximation

COMPUTER MODELLING and NEW TECHNOLOGIES, 12.sējums, Nr. 2, 2008 (Anotācijas)

E. Basans, J. Kreimers. Reālā laika sistēmu ar atsevišķām rindām un priekšrocības prioritātēm multiserveri un multikanāli, *Computer Modelling and New Technologies,* 12.sēj., Nr.2, 2008, 7.–16. lpp.

Autori rakstā izskata reālā laika datu apguvi un multiservera sistēmas darbību ar identiskiem serveriem (tādi kā iekārtas kontrolieri, vadāmie lidaparāti, medicīniskās monitoringa iekārtas, noklausīšanās ierīces u.c.), , kuri var būt izmantoti/ieprogrammēti dažāda veida darbībās (piem., pasīvās vai aktīvās). Šī sistēma nodrošina reālā laika uzdevuma izpildi, kas ierodas caur vairākiem serveriem (tādi kā sapulces līnijas, uzraudzības rajoni, sarunu kanāli u.c.) un ietver uzturēšanu. Autori vērš uzmanību uz sistēmas darbības ar maksimālo ielādējumu ar priekšrocību prioritāšu, kas paredzētas serveriem ar dažādu tipu aktivitātēm, sliktāko gadījumu analīzi.

Tiek izskatīti divi modeļi (atbilstoši ar pietiekami plašiem un ierobežotiem ekspluatācijas līdzekļiem) ar atsevišķu rindu katram kanālam. Autori parāda kā izskaitļot nekustīga stāvokļa varbūtības un dažādu darbību pasākumus, kad kā darbības, tā arī uzturēšanas laiki ir eksponenciāli sadalīti.

Atslēgvārdi: *pieejamība, darbība, priekšrocību prioritāte, reālā laika sistēma*

A. Vasilis-Vasiliauskas, J. Barisiene. Eiropas *3PL* tirgus pašreizējā stāvokļa pārskats un tā galvenie izaicinājumi, *Computer Modelling and New Technologies,* 12.sēj., Nr.2, 2008, 17.–21. lpp.

Šajā rakstā autori izskata pamata gadījumus *3PL* lietošanā, t.i. galvenos līgumdarbu vadītājus (2. nodaļa), kā arī izskaidro 3PL pakalpojuma būtību (3. nodaļa). Pašreizējais *3PL* tirgus stāvoklis Eiropā tiek izskatīts 4. nodaļā. Visbeidzot, 5. nodaļā autori dod pārskatu par tām problēmām un izaicinājumiem, ar ko sastopas *3PL* tirgus apgādātāji Eiropā.

Atslēgvārdi: *3PL pakalpojums, līgumdarbs, loģistikas pakalpojuma nodrošinātāji*

A. Jarasuniene. Informācijas sistēmu attīstības izpēte Lietuvas dzelzceļā, *Computer Modelling and New Technologies,* 12.sēj., Nr.2, 2008, 22.–25. lpp.

Lietuvai, esot pieticīgai valstij gan pēc izmēriem, gan pēc derīogajiem izrakteņiem, ir jābūt īpaši vērīgai un atvērtai visai pasaulei un tās notikumiem, kā arī jābūt tiltam starp Austrumiem un Rietumiem. Starp visām citām svarīgām lietām Lietuvai ir jāattīsta jūrs ceļi, sauszemes ceļi dzelzceļš un gaisa transports, kur ļoti nozīmīgu vietu ieņem Informācijas sistēmas (IS).

Atslēgvārdi: *dzelzceļš, informācijas sistēmas, pārvaldība, sistēmu modelis*

J. R. Kalniņš, V. Bardacenko. Fluktuācijas un kontrole pārvaldībā, *Computer Modelling and New Technologies,* 12.sēj., Nr.2, 2008, 26.–35. lpp.

Goldrata spēle tika parādīta divās dažādās vizuālās formās (Vensim un Excel), lai imitētu menedžmenta kursā. Pirmais modelis ir skaidri kontrolējams un ir piemērots klases nodarbībās. Otrais ir rūpīgi izpētīts saskaņā ar dažiem kontroles likumiem.

Atslēgvārdi: imitācija, fluktuācijas, kontrole, ķēde

D. Golenko-Ginzburgs, A. Ben-Jears, J. Hadads, N. Badarna. Resursu Asignējuma Modelis Pircējiem Ar Dažādām Priekšrocībām, *Computer Modelling and New Technologies,* 12.sēj., Nr.2, 2008, 36.–44. lpp.

Resursu piegādes sistēma, kas apgādā vairākus pircējus ar homogēniem neatjaunojamiem resursiem, tiek izskatīta dotajā rakstā. Katram pircējam, tas minimālais un maksimālais resursu daudzums, kas jāpiegādā, tiek paredzēts, kā arī tā izvēles (svarīguma) likme. Rakstā tiek parādīts reālā laika modelis, kurš jebkurā lēmumu pieņemšanas momentā optimāli pārdala kopējo pieejamo resursu daudzumu starp pircējiem. Optimizējamās vērtības ir faktiski piegādātais resursu daudzums katram pircējam, kamēr maksimizēšanas mērķis ir piegādāto resursu daudzumu summētais produkts un pircēju likme. Rakstā tiek doti arī skaitliskie piemēri.

Atslēgvārdi: *resursu pārdale, homogēnie izlietojamie resursi, resursu piegādes modelis, pircēju izvēles likme, precīzs resursu pārdales algoritms*

COMPUTER MODELLING & NEW TECHNOLOGIES

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Conference Proceedings: author; title of an article; proceedings (in italics); title of a conference, date and place of a conference; publishing house, year, pages.
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19. ***Authors Index***
Editors form the author's index of a whole Volume. Thus, all contributors are expected to present personal colour photos with the short information on the education, scientific titles and activities.
20. ***Acknowledgements***
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The purpose of the conference is to bring together academics and professionals from all over the world to discuss the themes of the conference:

- Theory and Applications of Reliability and Statistics
- Reliability and Safety of Transport Systems
- Rare Events and Risk Management
- Modelling and Simulation
- Intelligent Transport Systems
- Transport Logistics
- Education Programmes and Academic Research in Reliability and Statistics

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The Conference is devoted to the memory of Prof. Kh.Kordonsky.

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English and Russian will be the official languages of the Conference.

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DEADLINES AND REQUIREMENTS

Submission of abstracts:	**3 July**	**2009**
Acceptance of abstracts:	**17 July**	**2009**
Submission of final papers:	**14 August**	**2009**
Acceptance of final papers:	**4 September**	**2009**

Abstracts (about 600 words in length) and papers submitted for review should be in English and, should present a clear and concise view of the motivation of the subject, give an outline, and include information on all authors (the full name, affiliation, address, telephone number, fax number, and e-mail address of the corresponding author).

Submitted abstracts and papers will be reviewed. Accepted and invited papers will be published in the proceedings of the conference and in the journal "Transport and Telecommunication" (ISSN 1407-6160).

Instruction for papers preparing can be found on the conference WWW page: http://RelStat.tsi.lv.

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Proposals for invited sessions (workshops) within the technical scope of the conference are accepted. Each proposal should describe the theme and scope of the proposed session. The proposal must contain the title and theme of the session and a list of paper titles, names and email addresses of the corresponding authors. Session proposals must be submitted by **1 June 2009**.

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FURTHER INFORMATION

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