Information Technology Approach to Individual "Knapsack Problem" (Nanologistics)

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***Abstract* — The main aim of this article is shown new approach to the solving of the classical individual goods "knapsack problem" on the base of modern information technology. First of all in the frame of the modern logistics a new branch named nanologistics have been separated. It is oriented to investigation of an individual logistics behavior and design optimal solutions for his logistics goals. The individual logistics roles are presented und discussed. The basic ideas are introduced. A technique and a problem solving procedure for an individual goods basket forming are shown. The logistics cost less goods basket is formed with responsiveness to individual features and an allowance for risks and by fulfillment of some limitation.**

***Index Terms* — integer programming, Internet, logistics, management information systems, optimization methods**

I. INTRODUCTION

Today a basis for date gathering and communication is the Internet. To the middle of 2008 the user number regularly using the Internet has made nearby 1.5 billion persons (about a quarter of the population of the Earth) [1]. Under the forecast of analytical firm International Data Corporation (IDC) specializing on researches of the technology market by 2016 the number of Internet users will exceed 2 billion. About half of Internet users make shopping on-line.

The Internet gives on-line a wide spectrum of the information, since the information about availability of articles (web-sites of different shops, trading networks and manufacturers), about every possible advertising action of manufacturers and suppliers of the goods and finishing the information about road stoppers. And the majority of the articles already possess unique digital number – bar code EAN-13. It contains registration number of enterprise GCP (Global Company Prefix) and a serial number of enterprise production and is a key to goods date (grade, weight, kind, etc.) stored in those or other databases [2].

Computer account and management systems of trading enterprises have on-line a goods date base, e.g. the goods quantity error for a supermarket is only the number of goods, which are in the shopping trolleys of the supermarket buyers.

Modern personal and network computers possess high efficiency and great volume of memory that allows to process great volumes of data very quickly.

In the concept frame of "digital" (or "wiser") home [3] leading manufacturers of refrigerators (LG Electronics, Samsung) conduct workings out of new generation of the refrigerators equipped with a microcomputer and Internet connection [4, 5]. The loading goods are scanned; the name, weight and shelf life are read and recorded. Further these goods date are daily processed, and according to the established rules the list of necessary goods, which goes on the central computer, is made. At certain options the refrigerator can send itself the order in grocery Internet shop, releasing the owner from necessity to be engaged in similar household trifles.

Thus, today the individual receives great volume of the information on the given goods and the services, which human brain cannot any more process and find optimum in any sense the logistical decision, e.g. to receive the best parity «the price - quality». The individual gets to a situation «Buridan's ass» and falls in most cases a victim of "manipulators" and aggressive advertising. At the same time the correct use of information technologies and modern management methods presumes the individual to receive the optimum decision in the chosen sense and to do a comparison shopping [6]. And the aim of this paper is presenting one of the possible ways for solution above mentioned problem and explained what kind of date there are for this solution. The decision is based on the substantiation of expediency of new nanologistics level in logistics systems and solving on this level the general logistics problem connected with costs minimizations for moving of a material flow to an individual by given limitations.

The paper is outlined as follows. Section II deals with a brief explanation of used new nanologistics level. A presentation und discussion of an individual as a participator of the logical process is made in Section III. Section IV presets the problem of a goods basket (GB) forming by a consumer-personality individual and connected with its limitations. Risks that there are by the BG forming are described in Section V. Section VI considers a mathematical formalization of the selection problem of the optimal solution. The technique that could be used by solving this optimal problem and its data ware that illustrate the properties of the suggested solution are presented in Section VII followed by conclusions.

II. NANOLOGISTICS AIM AND BACIS CONCEPT

Since 60-70th of last century the logistics - «the scientifically practical direction of the managing consisting in efficient management of product flows and connected with them information and financial flows in spheres of production and stock-in-trades» [7, 8] starts to interfere in economy actively. The management purpose is cost minimization arising in the course of moving of a product flow from raw materials to final consumption. The basic preconditions for formation and logistics development were on the one hand competition strengthening in the market and transition to «the buyer's market», and on the other hand, development of the information technologies providing continuous monitoring of all stages of movement of a product flows.

Similarly economic the logistics is subdivided on two basic areas depending on the sizes of research objects: macro- and micrologistics. The macrologistics studies large logistical systems that have the enterprises and the industry, the intermediary, trading and transport organizations located in different regions of the country and even in the different countries. Opposite the micrologistics pays attention to a class of intraindustrial logistical systems, which structure includes technologically connected manufactures united by a uniform infrastructure.

It is necessary to notice that as it was above mentioned a logistics ultimate goal is time and place utilities of consumer according their interests and requirements. However, any of above mentioned logistics does not consider logistical processes from the viewpoint of separate physical persons («individual logistics») though they are finishing sections of all logistical chain from extraction of raw materials before consumption of finished goods and their behaviors, finally, define efficiency of this chain.

This is why it's very important making a new logistics branch that would study the logistical behavior of individual - nanoligistics. (In this case a prefix "nano" is used as a dimension one by analogy with nanoeconomics that studies the economic behavior of individuals [9, 10].)

III. INDIVIDUAL CLASSIFICATION, AS PARTICIPANTS OF LOGISTICS PROCESS

A participated in a logistical process individual can play following roles:

1. **Consumer**. It is the end user of goods, i.e. forms the main estimation of activity of all logistical chain. Representations of the individual about quality of a life and, as consequence, its consumption essentially influences development local and regional logistical systems and economy as a whole. Any changes begin with these individuals; they transform these changes from insignificant into the defining.
2. **Businessman**. Today we see rapidly growing of microbusinesses. Its size reflects personal preferences of owners and underlies competitive strategy [11]. As a rule, it's a small-scale business often a family one with number of workers from 1 to 5 persons. In this case, the individual acts as an intermediate element of the general logistical chain. The basic of a business migration from work to home are high technologies. The spiral development of a civilization has led to that means of production were personified that was the unification and standardization negation, introduced by an epoch of industrial revolution. Instruments of labor are accessible, their cost is not much, and they could be stored at home and served by one person. An example of them is digital technologies that allow reducing material costs essentially. Thus, input barriers on the market decrease or liquidated. However, and without digital technologies operate set of the house enterprises, especially in settlements of rural type. As K. Meyer [12] has noted, process of transition from the monolithic organizations closed by own borders looking for a life from top to down, to a network atomic units staying in continuous process of formation of new relations and creating market cost from below upwards that changes representations about traffic control of material streams now begins. The logistical system becomes more and more dynamical. Multilevel marketing as will involve one of displays of this phenomenon of ten millions people worldwide, which act in two roles as consumers and as microbusinessmen at the same time.
3. **Personality.** The current period of time as never earlier is characterized by individual aspiration to the high life quality standards, care of his self-actualization, his health, of the well-being, eventually, about life interval and descendants, care of development of own person. A corner stone of this is a free time. As K. Marx wrote, there would be such society progress stage, when wealth measure will be not labor hours, but a free time [13]. Principles and different separate directions of management, such as time management, are transferred from a field of activity of the enterprises and the organizations to area of an individual life.

From the logistics viewpoint the individual could be described as three dimensions person. And a parity of these components in the individual depends on features of each person, his single-mindedness, psychotic etc. It must be emphasized that the personality component introduces the additional requirement of minimization of the time spent for the solution of a logistical problem in the primary goal of logistics.

IV. LOGISITICAL PROBLEM OF GOODS BASKET FORMING AND ITS LIMITATION

From the logistics viewpoint the individual uses all functional logistics by solving a logistics problem of GB forming:

- Purchasing one,
- Transport one,
- Warehouse one,
- Production one,
- Marketing one.

And efficiency of his activity by all means depends on features of each separate person, on his contribution, his behavior and his relation to a problem, his stimulus and motivation, his sources of the information. Practically all from the above-mentioned processes are clear and known enough. However the changing of life conditions, increasing offers and sets of alternative decisions, especially with application of the intellectual software and development of

information channels, demand at any levels of the logistical analysis an operative reaction to changing of possibilities, and also developments of strategic solutions with application of those tools, which are available at the nanologistics level.

The possibility of the optimal solution of this logistical problem will be shown on an example of GB forming by a consumer-personality individual.

Such test problem is, on the one hand, the most actual, and, on the other hand, allows to formulate the basic approaches since today the individual has enough considerable quantity of alternative offers, both on assortment, and on delivery, and has extensive information support.

For simplicity we will be limited to consideration of logistical system, which includes only purchasing, delivery and storage. It is necessary to notice, that first two functional logistics in case of the consumer-personality individual, on the one hand, have much information, and, on the other hand, have palliative offers. The third of them demands an expert estimation, however is enough important, proceeding from goods shelf life and volume occupied with them.

It is obvious, that the logistical costs caused production logistics (goods consumption) and marketing one (removal of a food waste and dust), are constant or slowly varying. It allows excluding them from consideration, at least, as a first approximation statements of the given problem. The separation of variables on "quickly" and "slowly" is one of traditional approaches of the optimum control theory.

The considered problem has following certain features that must be reflected by the further formalization:

- The goods are offered by various trading enterprises;
- The same goods could be offered by various manufacturers, in various packaging and differ on quality a little. In this case it is necessary to carry out subjective not strict ranging of the goods and to enter limitations on both minimum and maximum goods quantity;
- Delivery of the goods can be carried out both at own costs, and a delivery service. The variant selections could be palliative or rigid determinate;
- Presence of various accumulation discounts, discount cards etc., given by trading enterprises for the purpose of a buyers binding and sale stabilization;
- Expenses minimization both in monetary and in time expression;
- Limitation of financial and time possibilities of the individual;
- Limitation of possibilities of the individual, both on load-carrying capacity, and on cargo volume (type of a used vehicle etc.);
- Dependence of time spent for purchase on the selected trading enterprises, route of their detour, road situation etc.

It is obvious that variables and the parameters necessary for the solution of a logistical problem are established on the basis of expert estimations (ranging of the goods etc.) or observed. The last ones are received by Internet on-line.

V. RISKS

It is necessary to underline especially, that, as well as in all problems connected with forecasting, in the given problem there is the "uncertainty" connected with it is impossible to speak with 100%-s' confidence about size of real end results and expenses. The absence of the authentic unequivocal information on each of possible variants of formation of a GB does its realization in turns multiple. Each of these variants is realized with some probability. And it is a consequence, both external unpredictable circumstances, and properties of the goods. Owing to this it is necessary to consider the new additional factor – a risk factor by solving the logistical task [14, 15]. The generated it reasons are following:

- Baying goods with hidden faults;
- Possibility of damage of the got goods at storage;
- Excess of a goods shelf life;
- Absence of the goods at the buying moment, caused both the raised demand, and poor-quality work of information system of a trading enterprise, sometimes the deliberate;
- Goods obsolescence;
- Damages on goods moving, including transportation;
- Absence of the actual information on quantity of buyers in trade enterprise and "throughput" of serving divisions of trade enterprise (cash desk, packing, internal transportation, etc.);
- Absence of the actual information on intentions of other individuals regarding goods buying;
- Service damages (refusal risk, failures, etc.);
- Problem of compatibility of the blessings necessary for achievement of an ultimate goal (e.g. the standard paper of format A4 can be used in any printer, however the cartridge for the printer must be selected; there are the fixtures assuming capacity of an electro bulb no more then 60 Watt, etc.);
- Ecological compatibility of process of operation, fire danger etc.

VI. FORMALIZATION OF OPTIMIZATION PROBLEM OF GB FORMING

The presented problem can be considered as the combined problem of integer programming, when two classical problems of integer programming - «knapsack problem» and «traveling salesman problem» are simultaneously solved at a known GB, defining gone round trade enterprises [16]. And the problem dares in the conditions of specific limitations and in the presence of risks.

There is a list of the potentially possible trade enterprises, which quantity is *m*. About each of them there is following information:

- Price-list with date about all basic features of the goods (the price, weight, volume, availability of commodities);
- Location (in case of shipment at own costs) or conditions of goods delivery;
- Available discounts and bonuses, which are necessary for considering at calculation of cost of a goods set.

Additionally there is information about the necessary GB, financial assets, individual load-carrying capacity and cargo volume, having time for GB shopping (Fig. 1).

Figure 1. Nanologistics problem.

It is necessary selecting an optimum strategy of GB formation that first of all must be the financial and time performabilities. Their criterions are the maximum values of financial assets, load-carrying capacity and cargo volume and having time for GB shopping. And second the strategy must provide the GB formatting with the minimum logistical costs that consider financial and time expenses according to individual preferences.

The problem formalization will be done by entering following designations:

$k = \overline{1,K}$ is an index of the trading enterprise used for formation of a GB;

y^j is an GB article, $j = \overline{1,J}$;

$Y^T = (y^1,...,y^n)$ is a GB vector;

$\mathrm{Y} = \left\{ Y_i, i = \overline{1,I} \right\}$ is a GB forming variant set;

$y_k^j(a_k^j, b_k^j, d_k^j, r_k^j)$ is an article j of a trading enterprise with index k, which is characterized by price a_k^j, packing b_k^j, rang index r_k^j, volume d_k^j;

Z_k^j is a Boolean variable, $Z_k^j = 1$, if an article with index j is bought by the a trading enterprises with index k and $Z_k^j = 0$, if not;

$C_1^i = \sum_{j=1}^{J} \sum_{k=1}^{K_i} c_k^j a_k^j Z_k^j$ is a GB cost by using formatting goods set variant with index i; c_k^j is a quantity of the given article in pieces. In case of the quota formulation for quantity of the goods in weight measurement B_j and there are different article packing it could get out depending on individual preferences, as $c_k^j = \left[B_j / b_k^j \right] or \left[B_j / b_k^j \right] + 1$, where $\left[B_j / b_k^j \right]$ is an quotient integer part;

C_2^i is transport logistical costs in money terms, connected with used GB formatting variant and a transport type: public or personal. In the first case they include cost of a detour of all trading enterprises included in this variant. In the second case they include costs for the fuel necessary for a detour of trading enterprises, and also lubricant cost, moving one, maintenance service and rolling stock operating repair (including spare parts and materials) one and rolling stock amortization depended on number of kilometers traveled in a selected route.

C_3^i is storage costs. They are:

- Cost of the capital frozen in goods (depends on the current bank rate);
- Goods storage costs, including occupied space, the equipment and so one. (It is calculated, as a rule, also in percentage of cost of stored goods, makes (5–10)% a year more often);
- Losses cost connected with risks of storage: the casual breakages, not planned excess of a shelf life, goods obsolescence, including moral, goods "shrinkage – spillage", and also competent use of stocks. It also is expressed in percentage of cost of stored material resources.

Standard logistical storage costs C_3^i usually are calculated in percentage of goods costs and in the majority they make (15-30)% a year [7, 8].

The storage costs C_3^i are calculated proceeding from the average size of the goods during time t^j by assumption of the linear using [7, 8]:

$$C_3^i = \frac{\eta}{73000} \sum_{j=1}^{J} \sum_{k=1}^{K} t^j c_k^j a_k^j Z_k^j , \quad (1)$$

where η is storage costs as an annual percentage rate from the goods set cost C_1^i.

T_i is a time spent for realization of the i variant of the GB formation;

γ is an estimated all-in hourly rate.

Then the problem of minimization of logistical costs by formatting of reference GB by the given set of trading enterprises taking into account (1) is reduced to the goal function minimization

$$J = \alpha(C_1^i + C_2^i + C_3^i) + \beta\gamma T_i = \alpha[\sum_{j=1}^{J} \sum_{k=1}^{K} c_k^j a_k^j Z_k^j + \\ + \frac{\eta}{73000} \sum_{j=1}^{J} \sum_{k=1}^{K} t^j c_k^j a_k^j Z_k^j + C_2^i] + \beta\gamma T_i \to \min , \quad (2)$$

where α and β are weight factors, $(\alpha + \beta = 1)$. They characterize individual preferences from the viewpoint of costs and financial assets (the first summand) and of the time (the second summand).

This conditional minimum must be found with the allowances of following limitations:

- Financial limitation

$$C_{1\min} \le C_1 \le C_{1\max} , \quad (3)$$

- Time limitation

$$T_{\min} \le T \le T_{\max}, \quad (4)$$

- Weight limitation

$$\sum_{j=1}^{n} c_k^j b_k^j \le B_{\max}, \quad (5)$$

- Volume limitation

$$\sum_{j=1}^{n} c_k^j d_k^j \le D_{\max}, \quad (6)$$

where maximum (max) values of corresponding indicators are defined on the basis of individual expert estimations. The individual preferences are shown not only in a choice of weight factors α and β and an estimated all-in hourly rate γ, but also in a choice of these limitations that consider features of the individual as a society element. And minimum (min) values of corresponding indicators are particular solutions of an initial problem of integer optimization. The minimum cost of a GB $C_{\min}$ is defined, how the solution of an optimum problem without time expenses $(\beta = 0)$. The minimum time spent for purchase of goods set $T_{\min}$, without the monetary costs connected with formation of a GB. These both limitations consider features of "environment".

The problem (2) - (6) belongs to the class of optimizing problems of mathematical programming with Boolean variables and represents symbiosis of two classical problems: «knapsack problem» and «traveling salesman problem» with specific limitations (3) - (6) and bad definiteness of a part of variables. It is possible using for their solutions well-known methods [16].

VII. FEATURES OF THE PROBLEM SOLUTION

Let's analyze each of criterion summands. For this purpose the criterion function (2) is rewritten in a following form

$$J = \left[\sum_{j=1}^{J} \sum_{k=1}^{K} c_k^j a_k^j Z_k^j + \frac{\eta}{73000} \sum_{j=1}^{J} \sum_{k=1}^{K} t^j c_k^j a_k^j Z_k^j \right] + \\ + (\alpha C_2^i + \beta \gamma T_i). \quad (7)$$

The first summand in (7) are the logistical costs connected with formation of a GB, i.e. classical «knapsack problem». By using the classical logistical approach to an estimation of storage costs C_3^i based on an annual percentage rate from the goods set cost C_1^i this summand is well enough defined, thanks to presence of the price-lists containing the full information on the goods. The information on goods presence in trading enterprises is directly connected with features construction of their information system and construction principles to their databases. In an ideal there is a possibility to give to the individual this information on-line with accuracy «to cash desk». Modern computer systems of the account and management of trading enterprises fix passage by the cash desk goods. Therefore inaccuracy of the information that the individual has is limited by quantity of the given goods, which is selected by other individuals, but is not paid yet in cash desk. By essential excess of supply over demand it cannot take into account. This discrepancy is essential only in case of deficiency of the given goods.

The second summand is the logistical costs connected with transportation of a goods set. It includes as transport logistical costs in money terms C_2^i, and expenditure of time T_i, connected with realization variant of a GD formation. These logistical costs depended on a route, i.e. on classical «traveling salesman problem». They could be calculated by the account of the current information on a condition of a transport network, characteristics of a vehicle and weather conditions, and on the basis of expert estimations. First of all it concerns to expenditure of time T_i, and the values depending on it, e.g. petrol consumption. It must be emphasized that the time spent on trading enterprises, are very sensitive to behavior of other individuals, i.e. the game situation takes place.

The optimizing problem solution presented in Fig. 2 has some steps.

At the first step the problem performability based on the reference goods set and the list of used trading enterprises and taking into account limitations restrictions (3) - (6) is checked. The set Y should be not empty. Otherwise a problem must be rewritten by change of a goods set or/and the list of the used enterprises or/and used limitations, first of all financial and time ones since weight and volume ones are conservative enough and taking into account limitations restrictions (3) - (6) is checked. The set Y should be not empty. Otherwise a problem must be rewritten by change of a goods set or/and the list of the used enterprises or/and used limitations, first of all financial and time ones since weight and volume ones are conservative enough.

At the second step the optimizing problem (2) - (6) on the basis of the available information received at the first stage, is solved. As a result there is such selected GB formatting variant or such ones that satisfy limitations (3) - (6) and minimize total logistical costs of the individual at formation of the reference GB (2). In case of several variants the individual makes the decision on a choice of this or that variant from own preferences that are not considered in a proposed model.

VIII. CONCLUSION

Modern information technologies allow supporting an individual by shopping, i.e. organizing comparison-shopping. The logistics is spread on "atomic" level of individual relations and inclusion in its structure “nanologistics”. Its main feature defining its boundary position among logistics is its closest neighborhood with other, not logistical, not economic disciplines. The nanologistics should base on results of psychology, sociology, history, ergonomics, axiology (sciences about values, i.e. the importance of those or other objects for the person or social group), management and other disciplines.

In the article the nanologistics approach is presented and its possibility and expediency are proved. The solution methodology for the given problem on the basis of application of methods of discrete optimization to estimation and a choice of the logistical scenario that minimizes logistical costs of the individual by performance of some limitations is offered. Such approach assumes construction

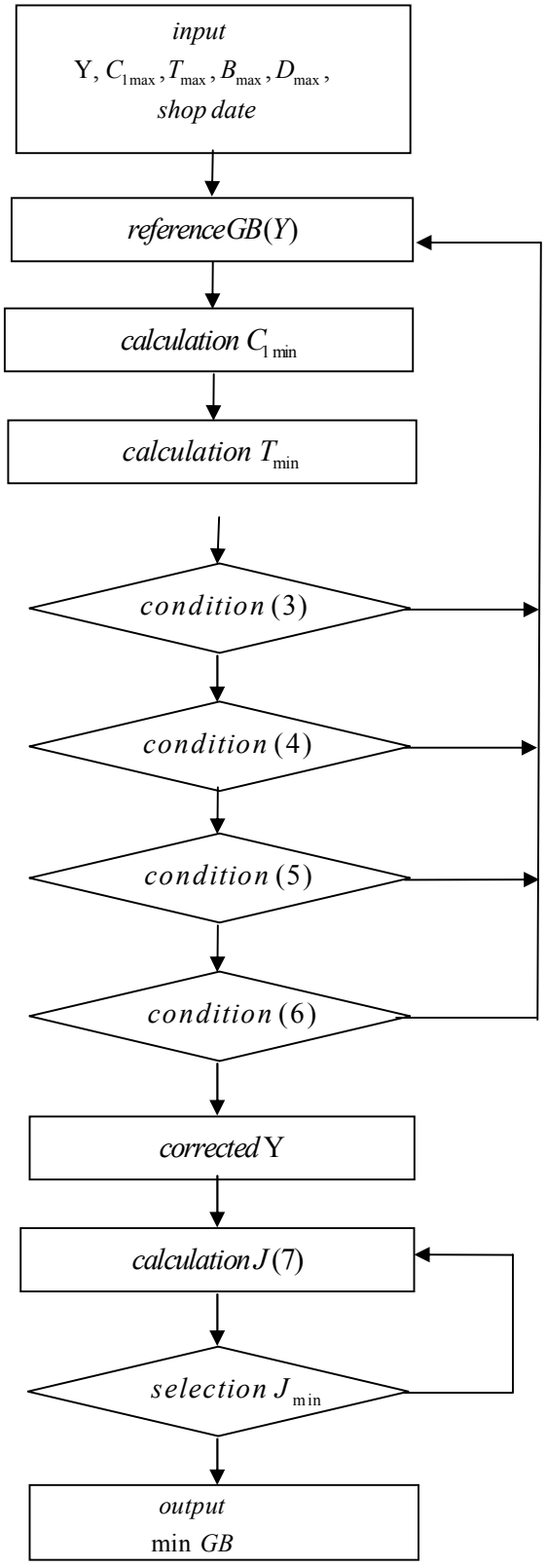

Figure 2. Flow of GB selection.

of computer logistical model of individual behavior and filling it with actual information.

As an assessment criterion the goal function considering individual logistical costs both in monetary terms and expenditure of time and allowing considering its individual preferences is used. Used limitations allow considering features of individual environment along with personal features of the individual.

There upon the offered computer model can be considered as organizational structure of realization of the chosen strategy that allows the individual to expand his possibilities on measurement, to an estimation and decision-making in the field of logistics.

This first step in the field of nanologistics opens the wide rage of the various research opportunities in the frame of the main problem of the GB forming. There are such additional problems, e.g. the game problem connected with the behavior of another individual, or the enterprise selection one depended on the nonstrict ordering of enterprises, or the GB forming by with an allowance for nonstrict ranging of goods, could be studied.

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