Novel Approach to the Microbusinesses Logistical System Design Based on the Information Technology (Nanologistics)

Sergey Ryvkin*, Denis Krasnovski**

*Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Moscow, 117997 Russia (Tel: 925-334-2310; e-mail: rivkin@ipu.ru)
**State Corporation “Bank for Development and Foreign Economic Affairs (Vnesheconombank)”, Moscow, Russia (e-mail: denis_krasnovski@mail.ru)

Abstract: The solution of a microbusinesses “knapsack problem”, i.e. article range forming one, using modern information technology is considered. The suggested approach is based on the logistical management of the material flow. The logistics is branched out to the new nanologistics branch that investigates a microbusinessman logistics behavior. Information technology backgrounds, two logistical types of the microbusinessmans, limitations and risks existing by the article range forming are presented and discussed. The mathematical problem definition and the problem solving procedure are shown.

Keywords: Information flows, integer programming, logistical system, management systems, optimization, traveling salesman problem.

1. INTRODUCTION

It is well known that the modern information technology changes the individual world. From one side it opens new possibilities that have to do the individual life more comfortable. However, from another one it causes new problems connected with the using these possibilities.

We see rapidly growing of microbusinesses. Its size reflects personal preferences of owners and underlies competitive strategy [Pink]. As a rule, it’s a small-scale business often a family one with number of workers from 1 to 5 persons. 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 labour 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 it has been noted [Camrass et al.], 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. Multilevel marketing could be involved as one of displays of this phenomenon that includes ten millions people worldwide.

From the logistics viewpoint the microbusiness is characterized by the quick-change business environmental conditions. The microbusiness businessman (MB) connections with the goods suppliers and consumers are not frequently regulated by period sale contract as by large enterprises. In each time moment MB takes into account the present-day situation and must make decision on the base of the current available information.

Nowadays the applied information technology gives large volume of the information. The human brain cannot process this great volume of the available information and find optimal solution, e.g. the best parity “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, e.g. a comparison shopping [Trachtengerts].

The direct using of the well-known management methods from the classical logistics [Gadzhinsky, Anikin ] is not possible because of the high dynamic of the microbusinesses logistical system and depending on its behaviour not only from the impact factors, but from the human factors as features of individual, his single-mindedness, psychotic etc.

And the aim of this paper is showing on the example of the solving the problem of a article range forming by a MB owner of a small shop a necessity and reasonability to introduce new logistics branch nanologistics. On this level the specific features of an individual as a member of the logistical process have been taken into account by solving the general logistics problem: costs minimizations by moving of a material flow to the end point of the logistical system.

The paper is outlined following. Section II presents available information technology preconditions for the solving above-mentioned problem. Section III deals with a brief explanation of an included nanologistics branch. Here a presentation and discussion of a MB as a participator of the logical process is made. Section IV presets the problem of article range
forming by a MB and connected with its limitations and risks 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.

2. INFORMATION TECHNOLOGY PRECONDITIONS

Today the majority of the trade articles and their different cases already possess unique digital number – global trade item number GTIN. It contains registration number of enterprise GCP (Global Company Prefix) and a serial number of enterprise production and is a key to articles date (grade, weight, kind, etc.) stored in those or other databases [www.gs1.org].

Modern computer account and management systems of trading enterprises with POS terminals have an urgent articles date base. E.g. the articles quantity error for a supermarket or cash & carry is only the number of articles, which are in the shopping trolleys of the buyers.

The wide spectrum of the information, since the information about availability of articles (web-sites of different shops, trading networks and manufacturers, Internet shops), about every possible advertising action of manufacturers and suppliers of the goods and finishing the information about road stoppers is today presented on-line in the Internet.

And the Internet itself is nowadays 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) [www.idc.com]. 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.

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 [www.myseshome.com] leading manufacturers of refrigerators (LG Electronics, Samsung) conduct workings out of new generation of the refrigerators equipped with a microcomputer and Internet connection [www.lge.com, www.robotsrule.com]. 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.

It could draw a conclusion that the information technology gives backgrounds for the optimal forming of the article range.

3. NANOLOGISTICS

3.1 Aim and Bases 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» [Gadzhinsky, Anikin] 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 all above-mentioned logistics intervene with the slow-changed logistical processes that are regulated by period sale contracts (macrologistics) or by produce management (micrologistics). In opposite to this the MB has to react immediately on the current situation and to solve each moment the problem of the supplier selection on the assumption of the current available information and his individual features and preferences.

This is why it’s very important making a new logistics branch that would study the logistical behaviour of individual - nanologistics. (In this case a prefix “nano” is used as a dimension one by analogy with nanoeconomics that studies the economic behaviour of individuals [Arrow, Kleiner].)

3.2 Logistical MB Classification

By the article range forming a MB would like to solve two problems at the same time: cost minimizing and minimizing article range forming time. It must be emphasized that 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 labour hours, but a
It is obvious, that the logistical costs caused production logistics (goods sales) 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. 4.2. Certain Features of the Logistical Process The considered problem has following certain features that must be reflected by the further formalization:

- The articles 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.
- Limitation of delivery possibilities: on the time of delivery by the delivery service or a on both load-carrying capacity, and a cargo volume (type of a used vehicle etc.) by MB.
- 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 MB.
- Limitation of the storage place with due regard for the storage conditions of the different goods.
- Limitation of the maximal purchasing price of each goods.
- 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 could be received on-line from the Internet.

4.3 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 GR 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 [Holmes, Evstaf’ev]. 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.

5. FORMALIZATION OF OPTIMIZATION PROBLEM OF ARTICLE RANGE FORMING

The presented problem can be considered as the specifically problem of integer programming that is based on two classical problems of integer programming - «knapsack problem» and «travelling salesman problem». It is solved at a known article range, defining gone round trade enterprises [Sigal et al.]. 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 \( \mathcal{K} \). 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 articles range.

Additionally there is information about the necessary article range, financial assets, individual load-carrying capacity and cargo volume, having time for article range shopping.

It is necessary selecting an optimum strategy of article range 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 article range shopping. And second the strategy must provide the article range 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:

\[
k = 1, \mathcal{K} \quad \text{is an index of the trading enterprise used for formation of an article range};
\]

\[
y^j \quad \text{is an article of the article range reference, } j = 1, \mathcal{J};
\]

\[
Y^T = (y^1, \ldots, y^\mathcal{J}) \quad \text{is an article range reference vector};
\]

\[
y_j^k (a_j^k, b_j^k, d_j^k, r_j^k) \quad \text{is an article } j \text{ of a trading enterprise with index } k, \text{ which is characterized by price } a_j^k, \text{ packing } b_j^k, \text{ rang index } r_j^k, \text{ volume } d_j^k;
\]

\[
Z_j^k \quad \text{is a Boolean variable, } Z_j^k = 1, \text{ if an article with index } j \text{ is bought by the } j \text{ trading enterprises with index } k \text{ and } Z_j^k = 0, \text{ if not};
\]

\[
Y = \{y_i, i = 1, \mathcal{I}\} \quad \text{is an article range forming variant set depending on the Boolean variables values};
\]

\[
C_i = \sum_{j=1}^{\mathcal{J}} \sum_{k=1}^{\mathcal{K}} c_j^k a_j^k Z_j^k \quad \text{is an article range cost by using formatting goods set variant with index } i; \quad c_j^k \quad \text{is a quantity of the given article in pieces. In case of the quota formulation for quantity of the goods in weight measurement } B_j \text{ and there are different article packing it could get out depending on individual preferences, as } c_j^k = \left[ B_j / b_j^k \right] \text{ or } \left[ B_j / b_j^k \right] + 1, \text{ where } \left[ B_j / b_j^k \right] \text{ is an quotient integer part;}
\]

\[
C_2 \quad \text{is transport logistical costs in money terms, connected with an } i\text{-th article range formatting variant and a transport type: public or personal. In the first case they include cost of a detour of all trading enterprises included in this variant. In the second case they include costs for the fuel necessary for a detour of trading enterprises, and also lubricant cost, moving one, maintenance service and rolling stock operating repair}
\]

14237
(including spare parts and materials) one and rolling stock amortization depended on number of kilometres travelled in a selected route.

\(C_i^3\) is storage costs. They are:

- Cost of the capital frozen in articles (depends on the current bank rate);
- Articles 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, articles “shrinkage – spillage”, and also competent use of stocks. It also is expressed in percentage of cost of stored material resources.

Standard logistical storage costs usually are calculated in percentage of goods costs and in the majority they make (15-30)% a year [Gadzhinskins, Ankin]. Based on this and by assumption of the linear using the storage costs \(C_i^3\) could be calculated proceeding from the average size of the articles during time \(t^i\):

\[
C_i^3 = \frac{\eta}{73000} \sum_{j=1}^{J} \sum_{k=1}^{K} t^i \cdot c^j_k \cdot a^j_k \cdot Z^j_k .
\]

(1)

where \(\eta\) is storage costs as an annual percentage rate from the goods set cost \(C_i\). The factor 1/73000 is a product of two ones. First one is a conversions factor 1/36500, i.e. one from the annual percentage rate to the overnight one. Second one is \(\frac{1}{2}\), i.e. one of the articles costs arithmetical mean by the linear article consumption. \(T_i\) is a time spent for realization of the \(i\)-th variant of the article range formation; \(\gamma\) is an estimated all-in hourly rate.

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

\[
J = \alpha(C_i^1 + C_i^2 + C_i^3) + \beta \gamma T_i = \alpha \left( \sum_{j=1}^{J} \sum_{k=1}^{K} c^j_k a^j_k Z^j_k \right) + \beta \gamma T_i + \eta \left( \sum_{j=1}^{J} \sum_{k=1}^{K} t^i \cdot c^j_k \cdot a^j_k \cdot Z^j_k + C_i^3 \right) \rightarrow \min
\]

(2)

where \(\alpha\) and \(\beta\) 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
  \[
  C_{i_{\min}} \leq C_i \leq C_{i_{\max}} .
  \]
  (3)

- Time limitation
  \[
  T_{i_{\min}} \leq T_i \leq T_{i_{\max}} .
  \]
  (4)

- Weight limitation
  \[
  \sum_{j=1}^{n} c^j_i b^j_i \leq B_{i_{\max}} .
  \]
  (5)

- Volume limitation
  \[
  \sum_{j=1}^{n} c^j_i d^j_i \leq D_{i_{\max}} .
  \]
  (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 \(\alpha\) and \(\beta\) and an estimated all-in hourly rate \(\gamma\), 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 optimisation. The minimum cost of the article range \(C_{i_{\min}}\) is defined, how the solution of an optimum problem without time expenses \((\beta = 0)\). The minimum time spent for purchase of goods set \(T_{i_{\min}}\) without the monetary costs connected with formation of the article range. These both limitations consider features of "environment".

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

6. FEATURES OF THE PROBLEM SOLUTION

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

\[
J = \left[ \sum_{j=1}^{J} \sum_{k=1}^{K} c^j_k a^j_k Z^j_k + \frac{\eta}{73000} \sum_{j=1}^{J} \sum_{k=1}^{K} t^i \cdot c^j_k \cdot a^j_k \cdot Z^j_k \right] + (\alpha C_i^3 + \beta \gamma T_i) \rightarrow \min
\]

(7)

The first summand in (7) are the logistical costs connected with formation of the article range, i.e. classical «knapsack problem». By using the classical logistical approach to an estimation of storage costs \(C_i^3\) based on an annual percentage rate from the goods set cost \(C_i\) this summand is well enough defined, thanks to presence of the price-lists containing the full information on the goods. The information
on articles 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 MB has is limited by quantity of the given articles, 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 $C_i^1$, and expenditure of time $T_i$, connected with realization variant of the article range formation. These logistical costs depended on a route, i.e. on classical «travelling 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 behaviour of other individuals, i.e. the game situation takes place.

The optimising problem solution 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 not be empty. Otherwise a problem must be rewritten by change of a article range or/and the list of the used enterprises or/and limitations, first of all financial and time ones since weight and volume ones are conservative enough.

At the second step the optimising problem (2) - (6) on the basis of the available information received at the first stage, is solved. As a result there is such selected article range formatting variant or such ones that satisfy limitations (3) - (6) and minimize total logistical costs of the individual at formation of the article range reference (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.

7. CONCLUSION

Modern information technologies allow supporting a MB by shopping, i.e. organizing comparison-shopping. The logistics is spread on “atomic” level of individual relations. Such approach 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 optimisation is offered. As an assessment criterion the goal function considering MB 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 MB. Such approach assumes construction of computer logistical model of individual behaviour and filling it with actual information.

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 article range forming. There are such additional problems, e.g. the game problem connected with the behaviour of another individual, or the enterprise selection one depended on the nonstrict ordering of enterprises, or the article range forming with an allowance for nonstrict ranging of goods, could be studied.

REFERENCES


http://www.gs1.org/


