SPREADSHEETS IN FUNCTION OF OPTIMISATION OF LOGISTICS NETWORK

PRORAČUNSKE TABLICE U FUNKCIJI OPTIMIZACIJE LOGISTIČKIH MREŽA

DRAGO PUPAVAC, Polytechnic of Rijeka
MIMO DRAŠKOVIĆ, Fakulty of Maritime Studies Kotor

Abstract: *This scientific paper discusses how estimated spreadsheets functions in logistics networks optimisation. The suggested working hypothesis for efficacy of estimated spreadsheets in designing logistics networks is proved and a practical example. In this way the given model can be applied to all logistics networks of similar problem capacity. Logistics network model confronting estimated spreadsheets present a real world at a level needed for understanding the problem of optimisation of logistic networks. Applied scientific research for recognition of the set hypothesis is based on analysis and synthesis method, mathematical method and information modelling method.*
Key words: *spreadsheets, optimisation, logistics network.*

Apstrakt: *U ovoj naučnoj raspravi razmatra se funkcionisanje proračunskih tablica u optimizaciji logističkih mreža. Postavljena hipoteza o efikasnosti proračunskih tablica u optimizaciji logističkih mreža dokazuje se na praktičnom primjeru, pri čemu se prezentirani model može koristiti za sve logističke mreže sličnog problemskog područja. Model logističke mreže kroz prizmu proračunske tablice predstavlja realan svijet u stepenu potrebnom za razumijevanje problema optimizacije logističkih mreža. Primijenjena naučna istraživanja pri dokazivanju hipoteze temelje se na metodi analize i sinteze, matematičkoj metodi i metodi informatičkog modeliranja.*
Ključne riječi: *proračunska tablica, optimizacija, logističke mreže.*

JEL clasification: L14; L80; L91; L92;
Original scientific paper; Recived: August 22, 2007

1. Introduction

The development of network of national, regional and global economies provides possibilities for taking advantages of volume economies, i.e. development of greater number of logistic operators which will, besides the services provided within national networks, offer them on regional level and ultimately, on global level. Spreading of logistics network leads to rationalisation in transport network, distribution network and decrease of stock within unique global logistics network. Technological breakthroughs, that form part new technology paradigm, offer the possibility of creating different structure of global logistics networks, which can be entirely optimised by use of information technologies.

Therefore, the following hypothesis has been set: Calculation tables form representative model in logistics networks' optimisation, i.e. model once created for a certain problem can be used for solving problems in all logistics networks of similar problem area. Scientific research applied for proving the hypothesis is based on methods of mathematical and information modelling.

2. Theoretical Characteristics of Logistics Network

Multiple networks between companies are becoming more of a rule than an exception nowadays. The world where single companies are competing among themselves for profit, in a kind of interpersonal market, does not actually exist. The world of modern business is characterised by networks of social and exchange relations between companies and surrounding factors. Companies choose co-operation as one of the ways of achieving competitiveness, enter different kinds of supply chains or logistics networks. In this way, multiple networking is being created which has marked modern global economy, and has made difficult drawing a line between co-operation and competition.

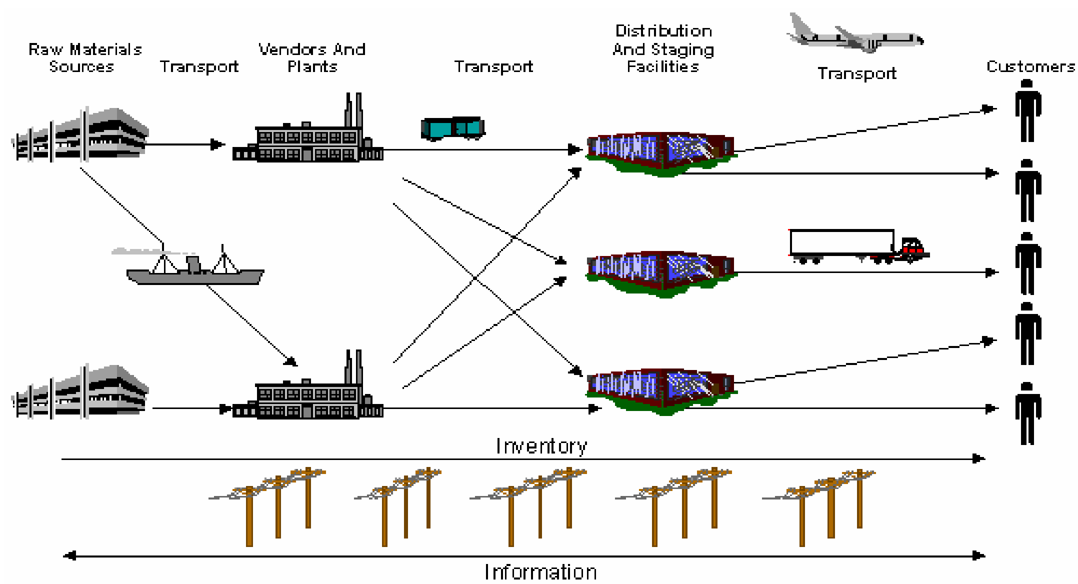
Complex inter-connected processes (networks) can be found in almost every kind of human activity, especially transport, logistics and economy. A network is made up of nodes and directed arcs connecting pairs of nodes. Networks can take all sorts of forms (cf. table 1).

Table 1: Type of network

Type of network	*Nodes*	*Arcs*	*Flow*
Communicaton networks	O-D pairs for massages	Transmission lines	Message routing
Computer networks	Storage device or computers	Transmission lines	Data, messages
Railway networks	Yard and junction pts.	Tracks	Trains
Logistics networks	Plants, warehouses, ...	Highways, railway tracks etc.	Trucks, trains, etc

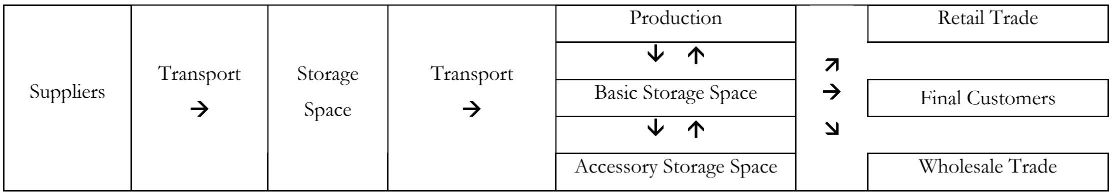
Companies develop logistics networks in order to obtain information, resources, markets and technologies, or in order to achieve economy effects of size and range. Logistics networks represent ultimate achievement of inter-logistic management or logistic chains management. In logistics terms network is the collection of locations and routes along which a product can be shipped. For example, a company needs to decide whether to ship products directly to customers or to use a series of distribution layers. Quick response to changes in demand requires effective solutions by all participants along the logistics network (cf scheme 1).

Scheme 1: Logistics network



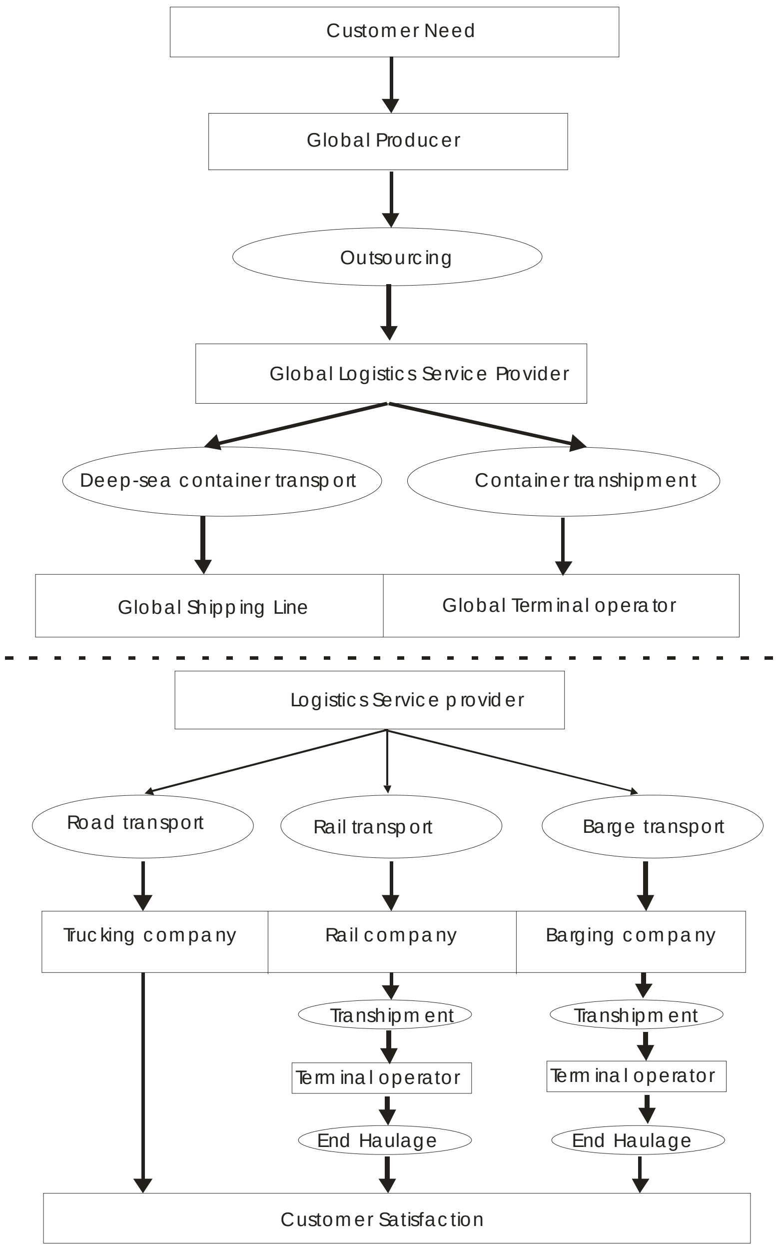
Logistics network in scheme 1 is made of four objective layers. Process of production is taking place down-stream from the production supplier, from production plant to distribution centres and from distribution centres to market. Logistics network can have any given number of objective layers. Furthermore, production layers sometimes take place down-stream even when semi-products or parts of products are being returned to production plants for finishing or when the products not intended for further sale are being returned from retail locations to distribution centres for recycling. In this way the there is no competition between single companies but between entire networks, and the prize goes to the company that has created a better network. Principle of operation is very simple: create a solid network of relations with key elements, aided by logistics operator as optimisation factor for logistic activity along the network, and the profit will follow.

Scheme 2: Logistics network in industrial firm



The network being created by global logistics operator between global producer and buyer can be viewed as follows (cf. scheme 3).

Scheme 3: Global logistics network



Source: Prepared author according: Wiegmans, W., et. al.: Intermodal Freight Terminals: An Analysis of the Freight Terminal Market, Research Memorandum 1998-55, Vrije Universiteit, Amsterdam, 1999.

By connecting supply and demand, i.e. production and consumption, logistics operators are creating national, regional and global logistics network which can provide following advantages to participants in global logistics chains: 1) decrease of costs (labour, taxes, customs and other duties), 2) improvement of effects for all the participants in supply chain that has been formed, 3) higher quality production inputs, and especially higher quality logistics services, 4) opening of new and more distant markets, and 5) improvement of own performance through development of partner relations with other participants of the chain.

3. Spreadsheet and Problem of Optimisation on Logistics Network

In the realm of accounitng jargon a «spread sheet» or spreadsheet was and is a large sheet of paper with columns and rows that organizes data about transactions for a business person to examine. An electronic spreadsheet organizes information into software defined columns and rows. The data can then be «added up» by a formula to give a total or sum. The market for electronic spreadsheet software was growing rapidly in the early 1980s and VisiCalc stakeholders were slow to respond to the introduction of the IBM PC that used an Intel computer chip. During this period, Mitch Kapor developed Lotus and his spreadheets program quickly became the new industry spreadsheet standard. In 1983, Lotus' first year of operations, the company reported revenues of $53 Million and had a successful public offering. In 1984, Lotus tripled in revenue to $156 Million [4].

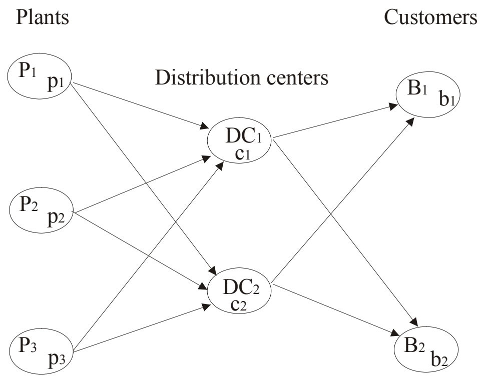
The next milestone was the Microsoft Excel spreadsheet. Excel was originally written for the 512K Apple Macintosh in 1984-1985. Excel was one of the first spreadsheets to use a graphical interface with pull down menus and a point and click capability using a mouse pointing device. When Microsoft launched the Windows operating system in 1987, Excel was one of the first application products released for it. When Windows finally gained wide acceptance with Version 3.0 in late 1989 Excel was Microsoft's flagship product. For nearly 3 years, Excel remained the only Windows spreadsheet program and it has only received competition from other spreadsheet products since the summer of 1992. Definition of a calculation table within new condition of technological paradigm is being transferred to functional nature of calculation tables from the system transition application state viewpoint [6]. In such paradigm a calculation table is being observed as an entirety made of four main components saved in address lines of lines, columns and matrixes. Such observation is pointed to calculation table as function of computer supported complex mathematical operation combined with matrix-network modelling. Such approach leads to new definition of calculation table: calculation table is collection of functions and formulas which, when inter-connected, can support the logic of data flows and establish development of complex computer supported mathematical algorithms to support quantity modelling of entire and complex problems.

Following expenses can be the object of optimisation on a logistics network [5]: 1) material cost, 2) acquisition costs, 3) investment costs, 4) production costs, 5) costs of distribution centres, 6) costs of keeping stock, 7) costs of internal and outbound transport. Execution of optimisation methods by use of calculation tables has the advantage in possibility of physical integration of programmed routines into self-generated applications. Computer supported optimisation methods are created in a manner that allows them to be parallel used in other relevant applications, to the point that they can be physically incorporated into them. Such methods fall under category of computer-integrated tools of applied mathematics. After programme execution the data remains permanently saved in template form, which is the basis for development of model base in logistics networks optimisation.

4. Computer-Supported Model of Logistics Network Optimisation

In order to illustrate the part of calculation tables in logistics network optimisation we will further on deliberate on logistics network which has "i" production plants, "j" distribution centres and "k" consumer points (cf. scheme 4). Production plants P_1, P_2 and P_3 produce same goods during the period in question in quantities p_1, p_2 and p_3. B_1 and B_2 are consumer points of the same goods with quantities b_1 and b_2. Every unit of goods is being transported from producer to consumer via one of distribution centres D_1 and D_2 which have capacities of c_1 and c_2. We will mark c_{ij} the cost of transport per unit from producer P_1 to distribution centre DC_j, and c_{jk} as cost of transport from distribution centre DC_j to buyer B_k. This is a classic two-layer transport problem [3, 161-162] because the transport is done from the place of production to the place of consumption through distribution centres.

Scheme 4: Crossdocking



One can ask which are the reasons that speak in favour of distribution centres in a logistics network. The reasons are many [1], and we will state only three: 1) decrease distribution costs (degression effect of cost from producer to distribution centres due to quantities being transported), 2) decrease of delivery time (from distribution centre to buyer due to stock), 3) possibility of combining shipments for one buyer with the possibility of reduction of transport costs. As the costs of shipments' processing in distribution centres are not an issue of this scientific debate, the total function of transport costs to be minimised on the suggested logistics network is [2]:

$$C = \sum_{i=1}^{m} \sum_{j=1}^{r} c_{ij}x_{ij} + \sum_{j=1}^{r} \sum_{k=1}^{n} c_{jk}x_{jk} \rightarrow \min \qquad (1)$$

Production centres produce one type of goods in quantities $p_1 = 200000$ t, $p_2 = 300000$ t and $p_3 = 100000$ t. Demand for such goods is $b_1 = 400000$ t and $b_2 = 180000$ t. Only 200000 t can be distributed from each production centre to each distribution centre, and the same can be done from each distribution centre to each consumer.

Transport costs differ and are shown in table 2 and table 3.

Table 2: Transportation costs (€ 000 t)

Plant to DC	DC 1	DC 2
Plant 1	5	5
Plant 2	1	1
Plant 3	1	0,5

Table 3: Transportation costs (€ 000 t)

DC to Customer	DC 1	DC 2
Customer 1	2	2
Customer 2	12	12

In table 4 we have set solution for minimum cost network flow problem by us of Excel calculation table, or its add-in Solver.

Firstly, single transport costs from production centres to distribution centres and from distribution centres to consumer centres (upper left part of the table) are entered into table 4, followed by information on transport capacities and distribution centres capacities (upper right part of the table). The decision variables represent quantities being transported from production centres to distribution centres and from distribution centres to consumer centres (lower left part of the table). Transport costs from production centres to distribution centres, from distribution centres to consumer centres, as well as total transport costs are shown in lower right part of the table.

Table 4: Minimum Cost Network Flow Problem

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minimum Cost Network Flow Problem												
2													
3	Unit Shipping Costs								Arc Capacities				
4	**Transportation Costs ($ 000/Ton)**								**Transportation Capacities**				
5		Plant to DC	DC 1	DC 2		Costs				Plant to DC	DC 1	DC 2	
6		Plant 1	5	5		Capacities			Costs	Plant 1	200	200	
7		Plant 2	1	1		Flows			Flows	Plant 2	200	200	
8		Plant 3	1	0,5		Payments			Payments	Plant 3	200	200	
9													
10		DC to Custome	DC 1	DC 2						DC to Customer	DC 1	DC 2	
11		Customer 1	2	2						Customer 1	200	200	
12		Customer 2	12	12						Customer 2	200	200	
13													
14	**Shipments**								**Payments**				
15													
16		Plant to DC	DC 1	DC 2	Total Out	Supply				Plant to DC	DC 1	DC 2	Total Out
17		Plant 1	0	0	0	200				Plant 1	0	0	0
18		Plant 2	0	0	0	300			Costs	Plant 2	0	0	0
19		Plant 3	0	0	0	100			Capacitie	Plant 3	0	0	0
20		Total In	0	0	0				Flows	Total In	0	0	0
21	Costs												
22	Capacitie	DC to Custome	DC 1	DC 2	Total In	Demand				DC to Customer	DC 1	DC 2	Total Out
23	Payments	Customer 1	0	0	0	400				Customer 1	0	0	0
24		Customer 2	0	0	0	180				Customer 2	0	0	0
25		Total Out	0	0						Total In	0	0	0
26													
27		Net Flow	DC 1	DC 2									
28			0	0					**Total Shipping Cost**		0		
29													

A Solver Model is build in this way:
Objective: Minimize $K$28
Variables: $C$17:$D$19;$C$23:$D$24
Constraints:
Do not exceed supply at the plants
$E$17:$E$19 ≤ $F$17:$F$19
Meet customer demand
$E$23:$E$24 ≥ $F$23:$F$24
Do not exceed shipping capacity
$C$17:$D$19 ≤ $K$6:$L$8
$C$23:$D$24 ≤ $K$11:$L$12
Flow conservation at the DCs
$C$28:$D$28 = 0

After formulating the model in this manner in Solver Parameters, click on Solve which activates the Solver programme calculating the value of variables in address sequence $C$17:$D$19 and $C$23:$D$24.

Decision variables calculated in address sequence $C$17:$D$19 and $C$23:$D$24 define the optimum solution. Table 5 show the optimal solution to the problem by use of calculation table MS Excel.

Table 5: Optimal Minimum Cost Network Flow Problem solution by use of calculation table

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minimum Cost Network Flow Problem												
2													
3	Unit Shipping Costs								Arc Capacities				
4	**Transportation Costs ($ 000/Ton)**								**Transportation Capacities**				
5		Plant to DC	DC 1	DC 2		Costs				Plant to DC	DC 1	DC 2	
6		Plant 1	5	5		Capacities			Costs	Plant 1	200	200	
7		Plant 2	1	1		Flows			Flows	Plant 2	200	200	
8		Plant 3	1	0,5		Payments			Payments	Plant 3	200	200	
9													
10		DC to Custome	DC 1	DC 2						DC to Customer	DC 1	DC 2	
11		Customer 1	2	2						Customer 1	200	200	
12		Customer 2	12	12						Customer 2	200	200	
13													
14	**Shipments**								**Payments**				
15													
16		Plant to DC	DC 1	DC 2	Total Out	Supply				Plant to DC	DC 1	DC 2	Total Out
17		Plant 1	180	0	180	200				Plant 1	900	0	900
18		Plant 2	200	100	300	300			Costs	Plant 2	200	100	300
19		Plant 3	0	100	100	100			Capacitie	Plant 3	0	50	50
20		Total In	380	200	580				Flows	Total In	1100	150	1250
21	Costs												
22	Capacitie	DC to Custome	DC 1	DC 2	Total In	Demand				DC to Customer	DC 1	DC 2	Total Out
23	Payments	Customer 1	200	200	400	400				Customer 1	400	400	800
24		Customer 2	180	0	180	180				Customer 2	2160	0	2160
25		Total Out	380	200						Total In	2560	400	2960
26													
27		Net Flow	DC 1	DC 2									
28			0	0					**Total Shipping Cost**		4210		
29													

Based on the information from the table 5 it is clear that 180 t of goods should be shipped from the first production centre to first distribution centre, 200 tons of goods from second production to first distribution centre and 100 tons of goods to second distribution centre. 100 tons of goods should be shipped from third production centre to second distribution centre. Therefore, 380 tons of goods will be shipped through first distribution centre as follows: to first consumer centre 200 tons of goods and 180 tons to second consumer centre. Second distribution centre will have shipped 200 tons of goods to first consumer centre. Minimum cost of such shipment amount to EUR 4 210 000 and are EUR 390 000 or 9,26% more favourable from the least acceptable solution obtained when the function is resolved by maximum.

5. Conclusion

Modern supply chains represent dynamic, flexible and responsive networks operating on "predict and process" principle, which is opposed to traditional approach "produce then sell". Quick response to changes in demand requires effective solution in all stages of supply chain: production, acquisition, stocking, transport and distribution. Lower number of participants, but also the domination of logistics operator characterize modern logistics network. Logistics operator is a factor, which successfully designs and optimises the logistics network, which is more and more integrated into national, regional and/or global economic system. This is the main reason for transformation of traditional forwarders into logistic operators offering not only transport, but also warehousing, information technology, and even production and global approach.

The use of computer and computer applications has become basic tool in logistics network optimisation process. This is especially important because logistics network management represents new management concept that is trying to manage resources on the entire logistics network. In order for participant to complete their tasks it is necessary to have the logistics network competitively profiled. This is done through improvement of at least one of following three dimensions: service, speed and property. When solving the problems on the network, user orientation of calculation tables has been proved, as it is not necessary to use programming methods, or writing of programming instructions. In the example shown for use of calculation table in network problem solving it is clear that all the activities are automated by use of functions and formulas in preparing the table through user application Solver.

Literature:

[1] Barković, D., Meler, M., Novak, B. (1986) Odlučivanje u marketingu, Informator, Zagreb.

[2] Pašagić, H., Pašagić, J., Markić, B. (2004), „Transport nafte kao modificirani dvoetapni transportni problem“, Suvremeni promet, Vol. 24, N° 5-6, 429 - 435.

[3] Pašagić, H. (2003) Matematičke metode u prometu, Sveučilište u Zagrebu, Fakultet prometnih znanosti, Zagreb.

[4] Power, D.J.: A Brief History of Spreadsheets, DSSResources. COM, World Wide Web, http://dssresources.com/history/sshistory.html, version 3.6, 08/30/2004.

[5] Pupavac, D., Zelenika, R. (2004) Design optimal transport network – prerequisite competitivity of supply chain, Fourth scientific colloquium: Modern logistics and distribution in globalization conditions, Economic Faculty of Osijek, Osijek.

[6] Vukmirović, S., Zelenika, R., Pupavac, D. (2004), „Spreadsheets in forming of flexible models of complex transport network”, 15th International Conference on Information and Intelligent Systems IIS 2004, University of Zagreb Faculty of Organization and Informatics Varaždin, Conference Proceeding, Varaždin, 22.-24. 09. 2004.

[7] Drašković, M. (2004), „Osnovni elementi i značaj logističke strategije razvoja lučkog sistema”, Tehnika br. 3, god. LIX, 53-7.