Taylor & Francis
Taylor & Francis Group

TRANSPORT
ISSN 1648-4142 print / ISSN 1648-3480 online
2011 Volume 26(4): 425–432
doi:10.3846/16484142.2011.635424

SYSTEMATIC LOCATION OF THE PUBLIC LOGISTIC CENTRES IN CZECH REPUBLIC

Rudolf Kampf[1], Petr Průša[2], Christopher Savage[3]

[1, 2]University of Pardubice, Studentská 95, 53210 Pardubice, Czech Republic
[3]University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, United Kingdom
E-mails: [1]kampf@upce.cz (corresponding author); [2]petr.prusa@upce.cz; [3]c.j.savage@hud.ac.uk

Submitted 18 November 2010; accepted 31 January 2011

Abstract. This article is focusing on exploring parameters, which are needed to determine the most suitable location for public logistic centres in the Czech Republic. There is a wide range of factors, which will have an impact on the chosen location. It is not easy to define all the factors and include them into one model, especially because some of them are difficult to quantify. The aim of the research is to design a suitable tool to support the decision making process for the location of the public logistic centres. As public logistic centres will be partly financed by the Czech government, it is necessary to find a sensible tool as decision support.

Keywords: Logistic centre, location system, logistic zones, multi-criteria analyse, logistic centre network, method of the weighted sum approach (WSP).

1. Introduction

The first real logistic companies in the Czech Republic had been created since 1990, most of them had a support from foreign sources. The supply of logistic services offered mostly by foreign companies, was generated as the product of the competitive market and it was allocated at the suitable places of great demand for logistic and transport services. The result is that the net of logistic centres is not rightly balanced over the Czech territory. The highest concentration of logistic centres can be found around Prague, Brno, Olomouc, Ostrava, and along the motorway D1 (Jihlava, Havlíčkův Brod, Humpolec).

In the present paper Logistic centre will be regarded as the central point and as a part of logistic chain between suppliers and costumers. Logistic center is offering wide range of logistic services, other services and reducing number of connections on a way between suppliers and costumer. Usually there are multimodal logistic centres which connect benefits of different modes of transport (Bruinsma *et al.* 2000; Montague 2002; Buková, Dvořáková 2007; Buková, Ondráš 2010; Knyvienė *et al.* 2010; Kampf, Roudná 2010).

2. The Situation of Logistic Centres in the Czech Republic

Nowadays, there is no Public Logistics Centre in the Czech Republic offering more than one mode of transport service. A small indication of change could be the projects 'Draft Methods of Index Benchmarking for Logistic Centres' and 'The Allocation of the Public Logistics Centres', which are currently being prepared. They aim at using the methods to find a solution to the public logistics, the increase of intermodality in the cargo transportation, and decrease of the transport factors adverse to the environment. Table 1 identifies the most important logistic areas in the Czech Republic (Cempírek, Kampf 2005).

2.1. Categorization of Logistic and Distribution Centres in the Czech Republic

Logistics centres in the Czech Republic are categorized as follows:

- corporate logistic centres;
- logistic centres owned by logistic companies;
- large logistic zones;
- logistic networks owned by providers of courier, express and parcel services;
- logistic centres for web-business companies.

The categorization is explained in chapters from 2.1.1 to 2.1.5 in details.

2.1.1. Corporate Logistic Centres

These logistic centres are owned and used by a single production company or a single business chain company. Due to the restructuring of the logistic distribution systems of large European international companies the number of local logistic and distribution centres has been limited.

Table 1. The most important logistic areas in the Czech Republic, as of May 2010

Project	Location	Area, m^2	Developer	Customers
Prologis Park Prague D1	Praha	148000	Prologis	DHL, Rossmann, Tesco Stores
CTP Park Modřice	Modřice	43000	CTP Invest	UPS, Electro World, DHL
Rudná Logistics Park	Rudná	162000	Viterna/Heitman	Schenker, Telefonica O2
Airport Brno Logistics Park	Brno	102000	CB Richard Ellis	NZ
CTP Park Bor	Bor	539485	CTP Invest	Tech Data, Bridgestone
D8 Eurpoean Park	Kozomín	90000	NTP	NZ
Raiffeisen Airport Logistic Park	Kněževes	52000	Raiffeissen ProInvest	Ecco Paper, ESA
Rudná Logistics Park II	Rudná	50000	DTZ	Papirius, Schenker, DFDS, Frans Maas
Southpoint D1 Distribution Park	Strančice	170000	Pinnacle	DHL, Schenker, Hopi
CTP Park Divišov	Divišov	3070	CTP Invest	Mattel, Danone
Airport Logistic Park	Praha	50000	ESA s.r.o	Setuza, SCJ, Lybar, Sedba-Baking
Logistic Park Lovosice	Ústí nad L.	17135	Selectra spol. s.r.o.	Selectra spol. s.r.o.
Tulipán Park Prague	Praha	60000	Cushman & Wakefield	Maersk logistics, Domo Service, Valeo
Northpoint D8 Distribution Park	Zdiby	150 000	Feico	VF Czech Service, Finnforest, Spedition
Orange Park	Plzeň	700000	Mayfield Plzeň, s.r.o.	–

There is mostly one large European centre associated with several regional centres. Some companies establish only one logistic centre in the countries of comparable size to the Czech Republic. The disadvantage of these corporate logistic centres consists of the concomitant increase of transport distances, as there might be cases of counter transport or detour transport because the goods are transported from the sources to the destination via the logistic centre. As a result of this, there is an adverse higher traffic load on infrastructure (i.e. roads), although the system provider might achieve total savings because of the limited number of logistic points.

Companies having their own logistic centres deal with various fields, such as food industry (Lekkerland, Nuget), chemical industry (Den Braven, Siad-Praxair), building industry (Baumit, Cesaro), printing and advertisement (Optys, Jackstädt), electric industry (Tedom, ELKO Valenta), metal pieces and coupling material, kitchen equipment, garden accessory, floor and wall tile production and some others.

The significant logistic branch is associated especially with the automotive production, such as Inter Cars Company supplying spare parts both for personal cars and lorries, as well as the tires. In the Czech market it is especially the biggest logistic centre for SKODA AUTO a.s. located in the Plazy industrial zone near Mlada Boleslav. In comparison, the automotive TPCA company in Kolín has chosen a different way of supplying without any logistic centres. Most of the components are transported on road by semi-trailers of NYK Logistic and Gefko companies, and the semi-trailers are used as the 'stock-on-wheels' at the TPCA parking lot. TPCA then handles with the semi-trailers and unloads them according to their wishes.

Investa International, company dealing with textile and leather machines, has one of the largest corporate logistic centres with the area of 40000 m^2 in Kuřim near Brno. The Electro World Company owns another large centre with the area of 28000 m^2 located in Brno Modřice. This centre was finished in 2004 and it is used by the company for fast distribution of goods not only in the Czech Republic, but also in Hungary. The logistic centre of Tescoma World covers about 16000 m^2 and it was opened in 2004 as well.

The business chain logistic centres form a special type of corporate logistic centres. The central warehouse of Kaufland in Modletice near Prague ranks among the largest business chain logistic and distribution centres. Its area is 19 ha. A logistic centre in Klecan covering the area of 12 ha is owned by Ahold Company, and it supplies the Hypernova and Albert stores all over Bohemia.

Depending on the kind of goods, the warehouses are designed to accommodate the kind of goods that need to be handled, for example; cooled goods, fruit and vegetables, meat products and non-disposable packages. The employees can use modern handling equipment and a high-quality computer system. There are other distribution centres of Ahold in cities Olomouc and Příbram, however the Klecany centre is a logistic heart of this company. There are also 7 ha warehouses in Lipník nad Bečvou and Jirny near Prague that are owned by REWE (Penny Market Company), and Lidl company owns a similar warehouse in Bystrovany near Olomouc. SPAR chain-company has used outsourcing to solve its central warehousing questions and co-operates with Excel logistic company. SPAR currently operates 19 Interspar hypermarkets and its 8000 m^2 central warehouse in Prague Ruzyň started operation in 2002. Its area was doubled by 2007 and a cooled warehouse was built in this period as well.

2.1.2. Logistic centres of logistic companies

These are logistic centres operated by providers of logistic services that are available for special contracting customers. The offered services consider the requirements of contracting partners adapting to their needs and create new solutions to logistic services for them that results in building extensive systems. The logistic companies focus mostly on big-size customers. Some smaller size companies may become contracting partners as well, but they must guarantee a certain level of the special logistic services used by them in order to guarantee the service profitability. These logistic centres are usually established by foreign logistic companies or their branches at the production or consumption centres near high-capacity thoroughfares.

As an example of a logistic company with its own centres we can notice the RTR transport company that has branch offices in Prague, Ústí nad Labem and Liberci, Weindel company in Jihlava, or CZECH – LOGISTIC in Louny and Chomutov. One of the large providers in logistic services that owns and operates own logistic centres is M. Preymesser logistika, company Limited. Its main customers come from automotive industry, and they are represented by Škoda Auto joint-stock company and its suppliers. The centres of the logistic company are connected to the highway and railway networks in Řepov near Mladá Boleslav, centre with as much as 18 ha land area and 220 employees, in Lipovec near Kvasiny, centre with nearly 26 ha land area and 30 employees, and in Jičín, centre with 4 ha land area and 160 employees (Kampf 2003).

2.1.3. Logistic Zones

There are more logistic companies providing their services in logistic zones. Most of the property and building lessees are foreign companies, especially logistic and retail operators. Czech companies represent only about 20÷25% of all lessees. The following developers of logistic parks and warehouses rank among the most important ones in our country: Dutch companies CTP and Grontmij Real Estate, Austrian company AHI group, Israelis company Africa Israel Investments, US company ProLogis, and Swedish company Skanska.

The largest Czech logistic zone founded in 2003 is the Industrial and Logistic Centre in Lovosice, covering the area of 40 ha. The companies established here are Tris company, a producer of carbon brushes for motors and generators, and Aoyama Seisakusho company, dealing with car parts. Logistic park Rudná u Prahy, whose area is 15 ha, ranks among the largest ones in the Czech Republic. It originated from 1997, and there are many companies established here, such as logistic companies of Schenker company, O.T.E.C. International, Danzas or Čechofracht, there is also a central warehouse of the Czech Telecom, and the companies, such as First International Computers, dealing in assembly and distribution of electric appliances, Zepter, a producer and distributor of luxurious consumption goods, or Papirius company, a distributor of office equipment and stationery. Papirius Company has also got other redistribution centres for example in Brno, Ostrava, Plzeň etc. The Tulipán Park Logistic centre in Prague-Hostivice covers an area of about 8 ha and the main companies using its services are Maersk Logistics and Cushman & Wakefield Healey & Baker, dealing in international consulting services and real estate services. ProLogis Park Prague (8 ha) opened in 2002, ranks among the greatest zones. It is owned by ProLogis developer company and there are represented various logistic and trade companies, such as Danzas, Rossman and Bruhn Transport. As for other logistic zones, we could mention Northpoint D8 Distribution Park in Prague – Zdiby, which covers an area of 4 ha, or Brno – Slatina zone covering half of that area.

The above-mentioned Airport Logistic Park, that is one of the first, is used by the dealers for distribution of Mazda and Hyundai automotive spare parts. You can find SETTO transport company there, a supplier of logistic services for Auto Palace Group (a sole importer of Mazda and Hyundai cars). Within the last two year, CTP logistic hall in Brno Modřice came into existence – its premises are used by Nunner and Exel companies – as well a logistic centre in Liberec – used by Benteler company (automotive equipment) and Baumatic (kitchen electric appliances).

2.1.4. Logistic Networks Owned by Providers of Courier, Express and Parcel Services

Logistic networks owned by providers are a special form of logistic centres (Průša, Babić 2007; Průša, Kampf 2007; Průša 2008). These services are provided by large and small specialized companies, or by companies providing transport, dispatching and storing services, and also transport of single consignments and some other logistic services offered by centres in the Prague region as well as in other regions within the Czech Republic. Apart from door-to-door road transport and air transport, there is also railway transport available, namely the CD Messenger, InterMessenger, and door-to-door transport organized by CD (Czech Railways) in co-operation with Cesky Kuryr, Company Limited – Direkt Expres. Courier, express and parcel services are logistic services aimed at small-size goods transport that changes in time and at which the short time of delivery plays the crucial role (Gašparík, Lendel 2010). These services prove indispensable in trade – mail-order business and Internet shopping through cell phones or television. The demand for these services and their incorporation is increasing in the logistic chains.

2.1.5. Logistic Centres for Web-Business Companies

Logistic centres of the Internet shops that offer catalogue sale of goods and that are able to deliver goods to customers within three days became new during the last few years. These centres are similar to the corporate logistic centres that partly incorporate the features of logistic centres owned by logistic companies. The companies dealing with the Internet sale and that also have their own logistic centres are, for example, Triangl or EUROCOMM Group companies. Their sale assortment is very wide, from household appliances, to sport equip-

ment, IT technology, garden accessories, etc. The Internet Mall Company represents a sort of sale gallery that incorporates various Internet shops. The logistic centres of these Internet shops came into existence quite lately, mostly after 2004. There is the Internet sale logistic centre in the centre of Brno. Its area is 700 m^2, it is used by more shops, and it offers storing and packaging services. The customers can also collect their goods in person. Of course, there are similar logistic centres in Prague and some smaller towns, such as Mladá Boleslav and Kutná Hora.

2.2. Logistic Service Providers in the Czech Republic

Logistic services provided by Czech logistic service providers (Cempírek, Kampf 2005) are shown in Table 2.

This overview confirms the fact that the volume of provided services has a distinct increasing tendency such as Cross-Docking (transfer, separation and combination of consignments), EDI between the providers of logistic services and customers, just-in-time deliveries, i.e. deliveries of the required quantity, precisely at a specified time, and purchase logistic ensuring production sub-deliveries.

2.3. Approaches to the Construction of the Public Logistic Centre network

2.3.1. The Public Logistic Centres (PLC)

The PLC is a logistic centre – as understood in the Czech Republic – with a multi-functional aspect where incorporated more than two modes of transport. The PLC is established according to uniform regional principles with the help of public budgets upon the call of applications, and there are many logistics companies providing a wide spectrum of logistic services to all regional clients, including small-size and middle-size companies. The logistic services are offered to all interested parties without any restrictions.

PLC is a point designed for concentration of a wide variety of logistic services including combined transportation, and there should be a possibility to organize services through at least two transport modes (road, railway, waterway, airway transport). Its foundation and location is determined by the local sufficient production or consumption availability, as well as by the best possible connection to a high-capacity transport infrastructure of various transport modes. The main public target/contribution is maximizing the local logistic support and minimizing the adverse factors resulting the increased road transport that are hazardous to environment and public health.

Arising and development of these centres is impossible without uniform regional principles and chances to get subsidies from the state and public budgets, including the EU budgets.

PLC should be built in co-operation with the public and private sectors. This can guarantee fair availability of the PLC provided services to all relevant subjects, and this should also guarantee the maximum positive affect of PLC to the whole society.

2.3.2. Financing of PLC construction

Some contribution coming from the public resources in the form of tax-deductible expenses (see item A), is necessary in order to support construction of logistic centres in the Czech Republic.

Financing of PLC (Fig. 1) must come from more sources, such as:

1. public financial means (state budget, regional and municipal budgets):
   - expenses associated with land purchase;
   - construction of service network, power supply;
   - access roads to the state highway, railway and waterway network;
   - supplementary roads for technological work associated with the transport modes – sidings, etc.;
   - interconnection of information and control systems;
   - support in purchase of personal and freight means of transport;
   - waste management (recycling, disposal);
   - necessary transfer of service network, waterways, etc.;
   - environmental friendly measures (noise absorption walls, retention cesspools, …);

Table 2. Logistic services provided by Czech logistic service providers

Provided services	Number of logistics companies providing this kind of services
Storage	89 % of all companies with total surface area of 860000 m^2
Consignment assembly	76.3 % of all companies in 85.3 % of all stock premises
Packaging of goods	82.8 % of all companies in 92.6 % of all stock premises
Consolidation of goods	77.6 % of all companies in 86.7 % of all stock premises
Cross-Docking	59.2 % of all companies in 66.2 % of all stock premises
Electronic Data Collection; EDC	53.9 % of all companies are equipped with auto-identification
Electronic Data Interchange; EDI	48.7 % of all logistic companies
Consulting	73.6 % of all logistic companies
Just-In-Time	44.7 % of all logistic companies
Combined/Multi-Modal Transport	2.5 % of all transport volume, used by 43.3 % of all logistic companies

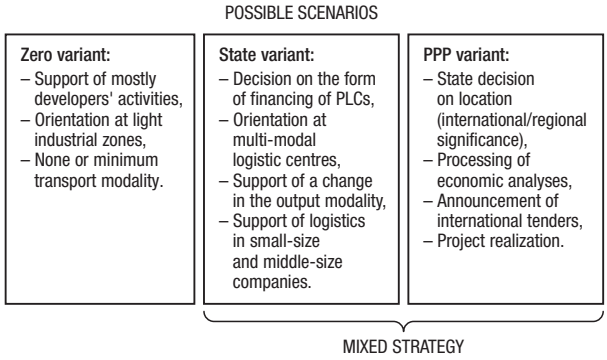


Fig. 1. Strategies of PLC financing

2. private financial means:
   - construction of facilities, including technological equipment;
   - information systems;
   - supplementary bank services and the claim system;
   - associated services;
3. the EU financial means:
   - grant in the form of a public contribution that could be calculated according to the total tax-deductible investment costs of the project. It should not exceed 46÷50% of the tax-deductible investment costs of the project. The public contribution towards purchase of services could amount as much as 50% of the respective tax-deductible expenses.

The subsidies always relate to the benefits resulting from creation of new, long-term and stable work positions in the field of manufacturing industry with a high added value that strengthen co-operation between the companies and stimulates the export of local products. It should be noted that the use of PPP projects in the Czech Republic has received strong support from Martin Janeček, from the Ministry of Transport. He stated that 'One of the quickest ways to unlock a region's economic potential is to improve its transport infrastructure and develop better trading links with other areas' (Janeček 2010).

3. Draft of a Multi-Criterion Model

The importance of the geographical dimension in logistics has long been recognized by academics (Hesse, Rodrigue 2004). This importance has not always been reflected in government's policy or action. For instance, at present neither the state bodies nor self-governing bodies in the Czech Republic coordinate or stimulate the construction of logistic centres. No general organization coordinating the location of logistic centres and taking care of them exists.

This section presents a draft method of a PLC location, considering the recommendations of the currently introduced projects 'Draft Methods of Index Benchmarking for Logistic Centres' and 'The Allocation of the Public Logistics Centres', at which the authors participate.

The aim of the proposed method is to enable the responsible persons to decide a suitable PLC location. The procedure consists in the following steps:

- determination of a set of criteria;
- determination of the criteria affects that expresses the different criteria importance within the whole project;
- selection of the optimum variant of PLC locations.

3.1. Determination of a Set of Criteria

To evaluate each particular variant of a PLC location, we need to specify the evaluation criteria at first. It is necessary to choose the criteria that can be detachedly measured, so that they can correspond to the real situation as much as possible. After some consideration, the most important criteria having the substantial affect to an independent evaluation and judgment of the projects have been chosen.

All criteria can be divided into two basic groups. One group consists of the criteria showing the total price of connection to different mode of transport. They are the criteria oriented at the costs. The other group consists of functional criteria that are supposed to reflect operational aspects, i.e. the criteria that consider the regional economic strength and that guarantee the use and operation of the regional logistic centre up to some extent. The Table 3 shows the definition and importance of each individual criterion.

To determine the priorities, we used the expert opinions resulting from the generally known situation, definition of a logistic centre, national logistic concept, and interim results of the projects 'Draft Methods of Index Benchmarking for Logistic Centres' and 'The Allocation of the Public Logistics Centres'.

The investment costs of possible connection to various transport modes, shown in Table 3, are used only for reader's orientation and for demonstration of the model purposefulness. Number of inhabitants and GNP value represent real figures in the following regions: Pardubice, Central Bohemia, South Moravia, Moravia-Silesia.

3.2. Determination of the Criteria Weight

Estimation Method for Weight Criteria – Saaty Method

To determinate the weight criteria, the authors used the Saaty method, whose principle consists in the fact that it is not always possible to determine precisely the weight criteria, so that the comparison method has to be used, i.e. the weight of individual criteria needs to be mutually compared. The individual criteria are compared with each other. As a result we get the numerical weight of individual criteria.

The Saaty method enables the referees to express their preferences both in numerical value and verbally, which is an advantage of this method.

The input is so-called Saaty matrix (formula 3.2.1) where the individual components represent the ratios of the given criteria (formula 3.2.2).

Table 3. Draft evaluation criteria

Criterion number	Criterion		Priority	Unit	VLC 1	VLC2	VLC 3	VLC 4
Price for connection to:								
1	Motorway	PHW	1	mil. CZK	13	8	30	180
2	Highway – 1st class	PR1	3	mil. CZK	2	7	90	3
3	Highway – 2nd class	PR2	3	mil. CZK	9	6	11	8
4	National railway	PRA1	1	mil. CZK	320	160	9	19
5	Regional railway	PRA2	4	mil. CZK	90	40	7	11
6	Airport	PAIR	3	mil. CZK	1800	30	1800	1800
7	Waterway	PWA	4	mil. CZK	20	3000	8000	90
Regional characteristics								
8	Number of inhabitants	NNI	5	Number of inhabitants (million)	0.506	1.166	1.13	1.249
9	GNP value	GDP	1	mil. CZK	130295	331990	323533	337926

Matrix example:

$$S = \begin{bmatrix} 1 & 3 & 3 & 1 & 4 & 3 & 4 & 5 & 1 \\ 1/3 & 1 & 1 & 1/3 & 4/3 & 1 & 4/3 & 5/3 & 1/3 \\ 1/3 & 1 & 1 & 1/3 & 4/3 & 1 & 4/3 & 5/3 & 1/3 \\ 1 & 3 & 3 & 1 & 4 & 3 & 4 & 5 & 1 \\ 1/4 & 3/4 & 3/4 & 1/4 & 1 & 3/4 & 1 & 5/4 & 1/4 \\ 1/3 & 1 & 1 & 1/3 & 4/3 & 1 & 4/3 & 5/3 & 1/3 \\ 1/4 & 3/4 & 3/4 & 1/4 & 1 & 3/4 & 1 & 5/4 & 1/4 \\ 1/5 & 3/5 & 3/5 & 1/5 & 4/5 & 3/5 & 4/5 & 1 & 1/5 \\ 1 & 3 & 3 & 1 & 4 & 3 & 4 & 5 & 1 \end{bmatrix}. \quad (3.2.1)$$

That means there are only '1's' down the main diagonal and the following relation applies $s_{ij} = 1/s_{ji}$, $i, j = 1, 2, \ldots, k$, i.e. all elements are reciprocal values of symmetric elements according to the main diagonal (Jablonský 2002):

$$s_{ij} \approx \frac{v_i}{v_j}; \quad i, j = 1, 2, ..., k . \quad (3.2.2)$$

The proper calculation of absolute weights out of from these relative weights is a complicated matter (Jablonský 2002). Saaty, for example, proposed the calculation of the a characteristic vector corresponding to the maximum value of the matrix (Jablonský 2002):

$$Sv = \lambda_{\max} \cdot v . \quad (3.2.3)$$

This characteristic vector represents the solution. As it was mentioned previously, this approach of a characteristic vector calculation (formula 3.2.3) is not a trivial task, therefore Saaty proposes the following simplification (Jablonský 2002):

$$v_i = \left(\prod_{j=1}^{k} s_{ij} \right)^{1/k}; \quad i, j = 1, 2, ..., k;$$

$$v_i = \frac{v_i'}{\sum_{i=1}^{k} v_i'}; \quad i, j = 1, 2, ..., k . \quad (3.2.4)$$

The calculation of the matrix characteristic vector represents a certain simplification, although it is a 'good estimate'. It is also possible that one might set in counter criteria, which leads to non-consistent results (Jablonský 2002):

$$C.I. = \frac{\lambda_{\max} - k}{k - 1} . \quad (3.2.5)$$

As more accurate results are required for the weight criteria estimation, various alternatives have been considered. These included the use of 'Trade-Off' analysis (Johnson 1976) based on the premise that all decisions are determined by some kind of compromise, for example, when buying a house one may choose to sacrifice size for location or location for size. Therefore, it is important to find the relative weighting which will give the most attributes their appropriate significance. After considering various options, the authors recommend the use of the Saaty approach, but supplementing this by verifying the calculations with the Monte Carlo method.

The base still lays in the Saaty method (formula 3.2.4). The main idea of the Monte Carlo approach is that in the algorithm we generate a 'random fluctuation' around the results obtained by the Saaty method (Fabian, Kluiber 1998). Next, the program has to analyze whether this random number is better than the Saaty value. For this we compare the 'optimum solution', i.e. zero variation, with the random number. In this case it is not possible to obtain such an optimum result and the results are inconsistent (formula 3.2.5), so the result with the smallest variation is chosen. And of course, the closer the value is to zero, the better this result is.

The higher the number of iterations, the more precise the calculations are (the difference approached to zero).

The Monte Carlo method is the valuable aid in case the referee did not set the ratios of the individual crite-

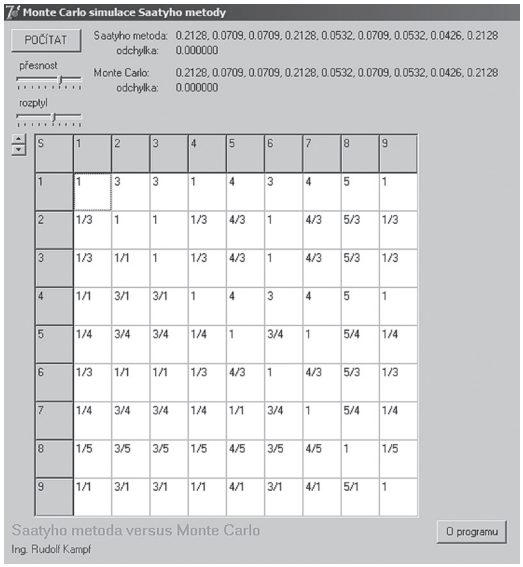


Fig. 2. Simulation of the Saaty method versus Monte Carlo method

ria correctly and, therefore obtains inconsistent results (formula 3.2.5).

Fig. 2 shows the simulated solution of the weight criteria as specified in Table 3 with the use of software programme created by the authors as a part of the solved projects (Kampf 2003).

The calculated (absolute) weight of individual criteria with the use of the Saaty method and Monte Carlo method will be used in the so-called multi-criterion evaluation method WSA (Weighted Sum Approach).

3.3. Selection of the Optimum PLC Location – Multi-Criterion Determination

Method of the Weighted Sum Approach

In real decision making situations it is often necessary to consider several optimum decision affecting criteria (see Table 3). We have specified their weights with the Satty and Monte Carlo methods (Fig. 2). These criteria usually contradict with each other, i.e. the variant that is highly evaluated according to one criterion is not welcome according to another one. The analysis of multi-criterion decision taking solution consists in the solution of mutually contradictive criteria. The actual aim is a choice of one variant that forms the basis for the final decision.

The weighted sum approach method is often mentioned as the WSA method. This method is based on creation of the linear utility function with the limit values of 0 and 1. The worst variant according to a particular criterion results in the utility value 0, while the best variant results in 1. Other variant results are in the values between 0 and 1. Therefore, when applying this method, it is necessary to replace the y_{ij} elements of the input criterion matrix with y'_{ij} values that are going to represent the benefit of X_i variant evaluated according to Y_j criteria. Values y'_{ij} for the maximum criteria can be calculated with the following formula (Jablonský 2001):

$$y'_{ij} = \frac{y_{ij} - D_j}{H_j - D_j}, \tag{3.3.1}$$

where: D_j is the lowest value (the worst one in case of maximization); H_j is the highest value (the best one in case of maximization) of the Y_j criterion. This formula obviously results in 0 in case of the worst criterion value $y'_{ij} = D_j$, whereas in case of the best criterion value $y_{ij} = H_j$ the result equals 1. In case of minimization, the formula needs to be adapted, as follows (Jablonský 2001):

$$y'_{ij} = \frac{H_j - y_{ij}}{H_j - D_j}. \tag{3.3.2}$$

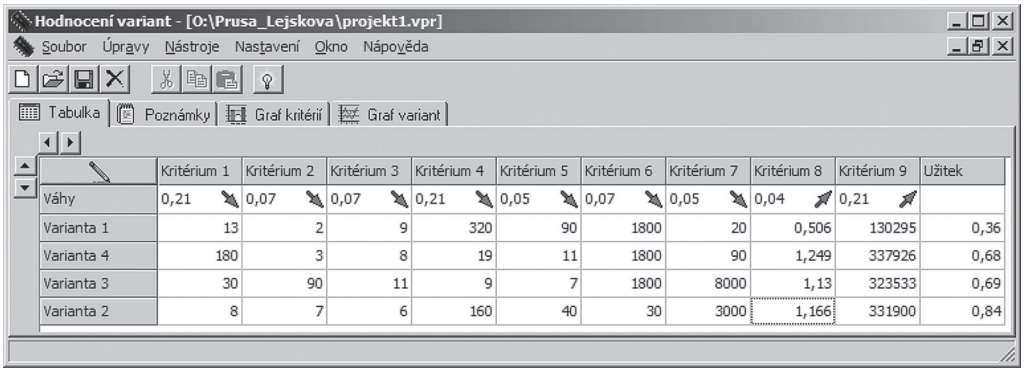
The total benefit of X_i variant can then be calculated as the weighted sum of the partial benefits according to each criterion (Jablonský 2001):

$$u(X_i) = \sum_{j=1}^{k} v_j y_{ij}. \tag{3.3.3}$$

The variants can then be arranged according to the decreasing utility values (X_i).

The mentioned evaluation method can be used in the process of selection of the most suitable variant, considering the existing criteria (Table 3) and their calculated weights (Fig. 2). The criteria (Table 3) specified in the column 'Price for the connection to...', i.e. criteria numbers 1÷7 shall be minimized and the criteria in the part 'Regional characteristics', i.e. criteria numbers 8÷9 shall be maximized.

The choice of the most suitable variant of PLC location according to the particular regions (Pardubice, Central Bohemia, South Moravia, Moravia-Silesia) is shown in Fig. 3.



	Kritérium 1	Kritérium 2	Kritérium 3	Kritérium 4	Kritérium 5	Kritérium 6	Kritérium 7	Kritérium 8	Kritérium 9	Užitek
Váhy	0,21	0,07	0,07	0,21	0,05	0,07	0,05	0,04	0,21	
Varianta 1	13	2	9	320	90	1800	20	0,506	130295	0,36
Varianta 4	180	3	8	19	11	1800	90	1,249	337926	0,68
Varianta 3	30	90	11	9	7	1800	8000	1,13	323533	0,69
Varianta 2	8	7	6	160	40	30	3000	1,166	331900	0,84

Fig. 3. WSA Simulation methods

4. Conclusions

The WSA method (Weighted Sum Approach) which is one of the multi-criterion methods of the project evaluation, proceeding from the Saaty method, has been chosen for the practical part. The Saaty method determined the weight value of each individual criterion and it (Saaty method) was verified by the experimental numerical method Monte Carlo. The WSA method was consequently used for evaluation of the PLC projects considering all individual criteria.

The model example led to the following results (Fig. 4). Regarding the highest value of the linear benefit function, Variant 2 proves to be the best one. It indicates the PLC location in Central Bohemia. Other variants indicate the following positions: Variant 3 – South Moravian region, Variant 4 – Moravian-Silesian region and Variant 1 – PLC location in the Pardubice region.

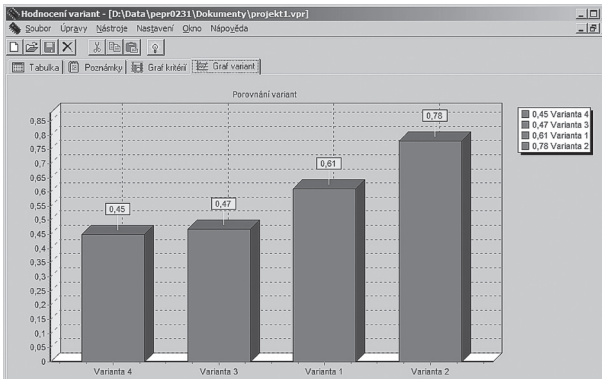


Fig. 4. Evaluation of individual variants

In simulation the authors used the available statistic data. Development in the Moravian-Silesian region will have to be monitored in the future, considering the Hyundai automotive plant that has just been built. With regards to the nascent production of the Hyundai plant and its co-operation with the Kia automotive plant (the Slovak Republic), that is only 70 km away, some changes in the regional economic and social parameters can be expected, as well as rapid increase in the transport requirements. It is very likeable that the results in the evaluated variants of the PLC location will be changed pursuant to the change of these parameters.

Note

The article is published within the solution of the research proposal VZ-MSM 0021627505 'Transport systems theory'.

References

Bruinsma, F.; Gorter, C.; Nijkamp, P. 2000. Multimodal infrastructure, transport networks and the international relocation of firms, *Transportation Planning and Technology* 23(3): 259–281. doi:10.1080/03081060008717652

Buková, B.; Dvořáková, E. 2007. Logistické centrum Zwardoň, in *Proceedings of the International Conference "Outsourcing dopravně - logistických procesů a prostorová lokalizace veřejných logistických center"*, 26–33 (in Czech).

Buková, B.; Ondráš, L. 2010. The role of innovations in transport companies, *LOGI – Scientific Journal on Transport and Logistics* (2): 14–22. Available from Internet: <http://logi.upce.cz/issues/2010-02/bukova-ondras.pdf>.

Cempírek, V.; Kampf, R. 2005. *Logistika*. Pardubice: Institut Jana Pernera. 108 p. (in Czech).

Fabian, F.; Kluiber, Z. 1998. *Metoda Monte Carlo*. Praha: Prospektrum. 148 p. (in Czech).

Gašparík, J.; Lendel, V. 2010. Process portal for railway sector, *LOGI – Scientific Journal on Transport and Logistics* (1): 33–43. Available from Internet: <http://logi.upce.cz/issues/2010-01/gasparik-lendel.pdf>.

Hesse, M.; Rodrigue, J.-P. 2004. The transport geography of logistics and freight distribution, *Journal of Transport Geography* 12(3): 171–184. doi:10.1016/j.jtrangeo.2003.12.004

Jablonský, J. 2001. *Operační výzkum*. Praha: Vysoká škola ekonomická v Praze. 305 p. (in Czech).

Jablonský, J. 2002. *Operační výzkum, kvantitativní modely pro ekonomické rozhodování*. Praha: Professional Publishing, 323 p. (in Czech).

Janeček, M. 2010. The highway to progres, *PPP Journal* 69. Available from Internet: <http://www.publicservice.co.uk/article.asp?publication=ThePPPJournal&id=446&content_name=European Transport&article=14797>.

Johnson, R. M. 1976. Beyond conjoint measurement: a method of pairwise trade-off analysis, *Advances in Consumer Research* 3: 353–358.

Kampf, R. 2003. *Transport Network Development Conception Methodology*. University of Pardubice. Research project for the Ministry of Transport of the Czech Republic acted as an opponent by Development of Management Theories. Žilina University, 7 July 2003 (in Czech).

Kampf, R.; Roudná, J. 2010. Slept analysis of logistics centers' operating in Czech Republic, *LOGI – Scientific Journal on Transport and Logistics* (1): 79–85. Available from Internet: <http://logi.upce.cz/issues/2010-01/kampf-roudna.pdf>.

Knyvienė, I.; Girdzijauskas, S.; Grundey, D. 2010. Market capacity from the viewpoint of logistic analysis, *Technological and Economic Development of Economy* 16(4): 690–702. doi:10.3846/tede.2010.42

Montague, S. 2002. Transport's public private history, *BBC News*, 6 February 2002. Available from Internet: <http://news.bbc.co.uk/2/hi/in_depth/business/2001/ppp/1507970.stm>.

Průša, P.; Babić, D. 2007. Information support for logistic centers network, in *Proceedings of the International Conference "Infotrans 2007"*, 239–242.

Průša, P.; Kampf, R. 2007. Problematika veřejných logistických center v České republice, in *Proceedings of the International Conference "Aktuální problémy v dopravě 2007"*, 99–102 (in Czech).

Průša, P. 2008. *Logistic Centres*. Brno: Tribun EU. 158 p.