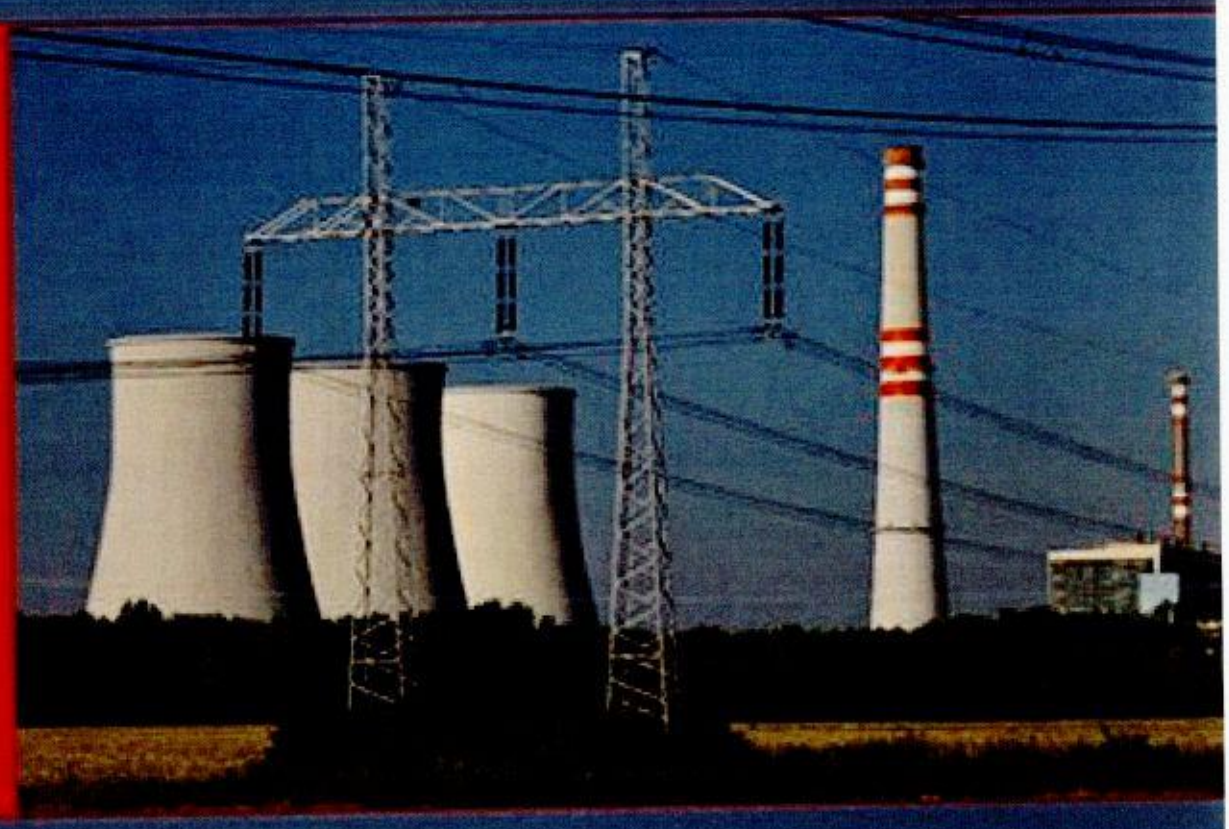

Production Management *and* Engineering Sciences

Editors

Milan Majerník

Naqib Daneshjo

Martin Bosák

CRC Press
Taylor & Francis Group
A BALKEMA BOOK

SCIENTIFIC PUBLICATION OF THE INTERNATIONAL CONFERENCE ON ENGINEERING SCIENCE AND PRODUCTION MANAGEMENT (ESPM 2015), TATRANSKÁ ŠTRBA, HIGH TATRAS MOUNTAINS, SLOVAK REPUBLIC, 16–17 APRIL 2015

Production Management and Engineering Sciences

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Editors

Milan Majerník, Naqib Daneshjo & Martin Bosák

Faculty of Business Economics with Seat in Kosice,
University of Economics in Bratislava, Slovak Republic

CRC Press
Taylor & Francis Group
Boca Raton London New York Leiden

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

A BALKEMA BOOK

Downloaded by [178.40.118.187] at 03:06 06 November 2015

CRC Press/Balkema is an imprint of the Taylor & Francis Group, an informa business

© 2016 Taylor & Francis Group, London, UK

Typeset by V Publishing Solutions Pvt Ltd., Chennai, India
Printed and bound in Great Britain by CPI Group (UK) Ltd, Croydon, CR0 4YY

All rights reserved. No part of this publication or the information contained herein may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, by photocopying, recording or otherwise, without written prior permission from the publisher.

Although all care is taken to ensure integrity and the quality of this publication and the information herein, no responsibility is assumed by the publishers nor the author for any damage to the property or persons as a result of operation or use of this publication and/or the information contained herein.

Scientific publication have been reviewed and approved by two reviewers. The authors are responsible for the content and accuracy of their papers.

Published by: CRC Press/Balkema
P.O. Box 11320, 2301 EH Leiden, The Netherlands
e-mail: Pub.NL@taylorandfrancis.com
www.crcpress.com – www.taylorandfrancis.com

ISBN: 978-1-138-02856-2 (Hbk)
ISBN: 978-1-315-67379-0 (eBook PDF)

Production Management and Engineering Sciences – Majerník, Daneshjo & Bosák (Eds)
© 2016 Taylor & Francis Group, London, ISBN: 978-1-138-02856-2

Contents

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Production Management and Engineering Sciences – Majerník, Daneshjo & Bosák (Eds)
© 2016 Taylor & Francis Group, London, ISBN: 978-1-138-02856-2

Introduction

Sustainable and competitive socio-economic development, either in terms of global or regional and local point of view, is ever more associated with optimizing its material and environmental dimension in the form of "green growth." International calls from this area and the derived strategic development documents of European Union and Slovak republic are focussing on the process of balanced fulfilment of technical, economic, social and environmental objectives. Production management, related technical support sciences and economic practice must respond to these developing trends.

Monography of Production Management and Engineering Sciences composed of monothematic scientific submissions by experts from several countries, describe the status quo and presents the progressive development trends in industrial engineering and integrated quality (technical, environmental, security, economic, social, energetic, ...), as well as in management of sustainable and competitive enterprise production, supported by technical fields such as computer simulation and modelling processes, metrology and testing, authorization and standardization, with focus on implementation of the best techniques and technologies available, Innovation Union and Horizon 2020 included.

Researchers present a case study of experimental research and development of new technology supporting qualitative environmental-safety growth and sustainable development of production management in the field of energetics in Slovakia and European Union.

Editors

Downloaded by [178.40.118.187] at 03:06 06 November 2015

Production Management and Engineering Sciences – Majerník, Daneshjo & Bosák (Eds)
© 2016 Taylor & Francis Group, London, ISBN: 978-1-138-02856-2

Analysis of linear programming utilization in Slovak and foreign industrial plants

L. Veselovská & J. Závadský & Z. Závadská
Matej Bel University, Faculty of Economics, Institute of managerial systems, Poprad, Slovak republic

ABSTRACT: This research paper deals with process optimization via linear programming application. It presents the results of a survey conducted on a sample set consisting of industrial plants operating both in the Slovak republic and abroad. The scientific aims of this research paper is to explore the possibilities of linear programming utilization in process optimization among Slovak and foreign industrial plants and to create foundations for a model of process optimization in selected production company using linear programming methods. The object of this research is the selected production processes and the research subject of this paper is linear programming methods. We tested three related hypotheses in this paper with the most significant benefit being the creation of an image of recent linear programming applications in practice by Slovak industrial plants, mapping its economic benefits, and proposing requirements for a model of process optimization based on a linear programming foundation.

1 INTRODUCTION

This research paper focuses on process optimization via linear programming application. Linear Programming is a widely recognized method of solving various problems in managerial practice. It is considered a powerful tool for effective achievements. The main purpose of this paper is to explore the possibilities of linear programming utilization in process optimization among Slovak and foreign industrial plants. The research results were achieved through empirical study. Our results provide insights into current applications, which stressed the resulting benefits of a company and these results thus serve as guidelines for future linear programming applications. The results of this research have various implications for process optimization, which we explored further by creating the foundations for a model algorithm based on linear programming.

Our focus is on linear programming as an optimizing method. Sarker & Newton (2008), Buresh-Openheim & Davis & Impagliazzo (2011) and Baker (2011) evaluated the advantages and disadvantages of linear programming utilization and considered the application of these methods for long-term production planning to have a significant advantage as they are relatively accurate. The use of linear programming assumes the creation of the linear objective function, which describes the problem as closely as possible. The variables also enable the close modeling of the company's conditions. One of the main disadvantages of linear programming utilization is the fact that sometimes the linear function may not be the best option for modeling a processes and a situation may arise when company would have to resort to other non-linear methods for operational research. Despite this fact, there are significant advantages for using linear programming utilization in companies as their application can help companies solve many different problems as various authors have found (Vanichchinchai & Igel 2011, Floudas & Lin 2005, Gass 2010, Das 2011, Avis & Umemoto 2003).

2 MOTIVATION FOR THE STUDY

In the 21st century, industrial plants faced severe competition that put severe pressure not only on their quality requirements, but also on their production processes. It is the goal of every company's operations management to ensure the best possible outcome and gain a competitive advantage enabling them to establish a desirable market position. However, it is not a single set of managerial decisions that make this possible. A strive for excellence is a continuous process which does not only involve establishing a good market position, but it also focuses on implementing measures necessary to maintain it. One of the effective ways companies can achieve excellence is through implementing specific measures in order to achieve flexibility and cost minimization of their processes. One of the basic tools is linear programming.

The theoretical aspects of process optimization are broadly covered at various Universities all around the world and that includes application of various optimizing tools including linear programming. Still, there is a question if such methods are currently being applied in businesses and how successful they are. Thus, we consider a closer look at both Slovak reality and the situation abroad to be extremely valuable.

3 RESEARCH METHODOLOGY

The main purpose of this paper is to explore the possibilities of linear programming utilization in process optimization among Slovak and foreign industrial plants. In order to fulfill this goal we use data provided by Slovak companies and foreign compa-

nies via a survey, which was conducted in the period between March 2014 and June 2014. Our research sample file was created as a representative sample of the base file. This file consists of Slovak companies classified by the SK NACE classification as production companies. Moreover, we took into account other criteria, mainly the size of company. We focused our research on medium-sized and large-sized companies, since we assume they had a higher extent of linear programming applications. The decisive criterion was set according to the European Standard No. 96/280/EC. Foreign companies were chosen in accordance with the same criteria in order to achieve the possibilities for cross-country comparisons.

Research was carried out on a set consisting of 1,300 Slovak production companies. The companies were selected randomly and chosen respondents were addressed by email. The questionnaire was fulfilled by 236 Slovak companies, which represents an 18.15% return. In key companies, we used the method of structured interviews with the company's representatives. The overall research sample consisted of 248 Slovak companies. The creation of a sample set of foreign companies was a more complex process. Firstly, we decided which countries we would like to involve in this research. We selected the Czech Republic, Australia, New Zealand, Poland, Germany and Austria. Secondly, we selected those companies in these countries, which met the criteria of our research. Consequently, a similar questionnaire was used to gather data from these companies.

Our questionnaire consisted of 16 questions divided into 3 categories. The first set of questions was focused on exploring various applications of optimizing methods and was completed by all the companies in the survey. The second part of the questionnaire involved questions designed to gain data about linear programming utilization. This section was fulfilled only by companies that currently use these methods or have used them sometime in the past. Lastly, we also added the socio-economic questions created in order to gain data about respondents. We asked companies to provide information about their size (the number of their employees), sector of economy, and regions where they operate.

Our sample file of Slovak companies consists of 38.31% large-sized companies with over 251 employees. Nearly two thirds of companies in our sample file have 51 to 250 employees (Table 1).

Table 1. Structure of Slovak sample file based on the size of company

Number of employees	companies	
	no.	%
51 - 250	153	61.69
over 251	95	38.31
Total	248	100.00

Table 2. Structure of sample file based on the sector of economy

Sector of economy	Slovak companies		Foreign companies	
	no.	%	no.	%
Food production	31	12.50	15	15.00
Manufacture (M.) of textiles and clothing	22	8.87	9	9.00
M. of leather	1	0.40	1	1.00
Processing of wood	17	6.85	8	8.00
M. of paper	15	6.05	7	7.00
M. of chemicals	39	15.73	9	9.00
M. of pharmaceutical products	16	6.45	2	2.00
M. of rubber and plastic products	5	2.02	5	5.00
M. of metals	35	14.52	12	12.00
M. of electronic devices	12	4.84	6	6.00
M. of machinery	36	14.52	19	19.00
M. of motor vehicles, trailers and semi-trailers	11	4.44	6	6.00
M. of other transport equipment	8	3.23	1	1.00
Total	248	100.00	100	100.00

The sector structure of research sample is presented in Table 2. For specification of the production sector, we used the Statistical Classification of Economic Activities in the European Community (SK NACE).

With the use of SPSS Statistics and information about the database set, we can verify the representativeness of this sample according to size and based on the data from the Statistical bureau of the Slovak Republic we can describe its character. In 2014, there were 70,370 manufacturing companies in Slovakia. The number of medium–sized companies (based on number of employees) was 1,641 and 627 were large companies. To verify the representativeness of the sample we used the Chi-square test. We set the null hypothesis, which assumes that the sample is representative. The alternative hypothesis is an assumption of non – representativeness of the sample. From a mathematical point of view, the hypothesis is formulated as:

H_0: $F(x) = G(x)$; H_1: $F(x) \neq G(x)$

Statistical testing in SPSS software is based on the following formula (1):

$$X^2 = \sum_{j=1}^{r} \frac{(n_j - m_j)^2}{m_j} \approx X^2_{(r-1)} \qquad (1)$$

where X^2 is Pearson statistics,

r is line,

n is overall frequency in the base set,

m is measured frequency.

Consequently, we find the critical value of $\chi 2$ distribution for *(r-1)* degrees of freedom and selected level of significance α from tables of critical values of the chi square. The Chi square test, however, requires the fulfillment of two conditions:

- no interval should have zero frequency;
- a maximum of 20% confidence intervals should have a frequency of less than 5 as discussed by Maloney & Byard.

The second part of our sample consisted of foreign companies with a focus on neighboring countries as well as New Zealand and Australia. This sample included 100 foreign companies. Figure 1 provides the data about these companies sorted by country.

Consequently, we also sorted these foreign companies by size. We used the same scale as was used with Slovak companies.

© 2016 Taylor & Francis Group, London, ISBN: 978-1-138-02856-2

We can therefore state that 61% of our sampled companies are medium-size and 39% are large-size.

We test one main hypothesis and two related hypotheses in this thesis. In the first hypothesis (H_1) we assume that the majority of selected production companies do not use linear programming. In hypothesis H_2 we assume that companies that use linear programming methods most frequently apply these methods for solving tasks of resource allocation. Hypothesis H_3 tests the assumption that the majority of selected companies, which use linear programming methods, consider the reduction of raw material costs to be the most important economic benefit of linear programming application.

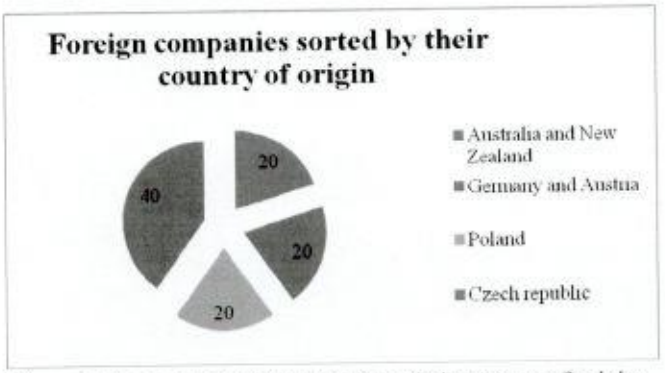

Figure 1. Foreign companies sorted by their country of origin

4 RESEARCH RESULTS

In this part of the paper, we present the results of a survey conducted in order to evaluate the current state of linear programming utilization in process optimization among Slovak and foreign industrial plants. In the first part of the questionnaire, we have obtained information about the optimization of company processes in general, regardless of the used method. We have found that 68.55% of selected production companies are using optimization methods regularly.

The use of the optimization methods is equally divided between positive and negative answer in the subset of Slovak medium–sized companies. In larger companies, we can mostly identify positive answers with 93.68% of them regularly using optimization methods. Only 6 companies with more than 251 employees do not use any optimization methods (6.32%). These findings indicate that the use of optimization methods in industrial production practice is proportionally dependent on the size of the company. If a company applied optimizing methods, we further explored the various aspects of optimization. Firstly, we focused on what types of techniques these companies use with emphasis on linear programming. We found 41.76% of Slovak companies that applied optimizing tools chose linear programming—representing 28.63% of all companies in the Slovak subset. Since this aspect represents the focus of our research, we then look more closely at this aspect under different circumstances. Firstly, we analyzed utilization of linear programming based on the size of companies.

The results of this research showed us that linear programming is mostly used by large-sized companies in Slovakia, 42.11%, compared to only 20.26% of medium–sized companies in process optimization. The difference between large-sized and medium–sized companies in usage of linear programming is rather significant (Table 3).

Table 3. Application of linear programming structured by size of Slovak companies

Application of LP	Yes		No	
	no.	%	no.	%
Medium-sized companies	31	20.26	122	79.74
Large-sized companies	40	42.11	55	57.89
Total	71	28.63	177	71.37

Moreover, we assumed that there is dependence between linear programming application and the size of companies. In order to confirm this assumption we performed the Pearson correlation test. We indeed discovered that there is a medium-strong direct dependence between these two factors. Therefore, our first significant finding is that managers of bigger production companies in Slovakia are more likely to choose linear programming as their optimizing tool.

We achieved similar results in the group of foreign companies. Based on data from the questionnaire survey, we found that 68% of surveyed foreign companies regularly optimize their processes, however only 42.65% of them (29% of all foreign companies) use linear programming as their selected optimization tool. The differentiation of the research sample by country of origin revealed that the rate of linear programming application is particularly higher in companies located in Australia and New Zealand (at 35%). Linear programming is also significantly used in German and Austrian companies (at 30%). Despite the higher rate of linear programming utilization among foreign companies, this rate is substantially lower than a 50% share.

These findings are also related to our hypothesis H_1. Since we found that only 28.63% of Slovak companies use linear programming, the hypothesis was confirmed. Moreover, we used a binomial test to serve as further evidence to this finding. Even though the rate of linear programming utilization was slightly higher in the group of foreign companies, we were unable to reach the rates necessary to disprove our hypothesis.

The following part of the questionnaire involved only companies that used/use linear programming for process optimization. Firstly, we have investigated the most important barriers of linear programming utilization in these companies. Since it was an open question, we got a variety of answers. However, we consider it very interesting that the variability of statements related with this question was not significantly affected by country of origin. We received similar results regardless of location. The most frequent barrier was the size of the company. This barrier was especially important for medium–sized companies (51 to 250 employees). One of the most frequent answers was the inadequacy of linear programming for the needs of the company.

This barrier is also related to the use of other optimization methods, especially if the company is satisfied with the achieved results of the optimization process. The lack of knowledge of linear programming by managers and subsequent distrust of these methods and achieved results were also problematic. Managers tend to use other, better-known or previous optimization method. One of the barriers of the linear programming application was the price of the software. The most problematic and hardest barrier to remove was the satisfaction of the managers with the achieved results. That is why managers pay less attention to optimization, which can consequently cause stagnation and an inevitable reduction in quality of manufactured products. These facts can cause the reduction of competitiveness as well. In practice, this fact seems to be a problem of many managers who prefer short-term positive results to sustainable future competitiveness. Inattentive long-term vision is a serious obstacle to the application of linear programming in companies both in Slovakia and abroad.

We also explored the various possible applications of linear programming. Various types of production processed were selected as provided options. Our goal was to find out which are the most common applications to the analyzed methods. Table 5 provided this information gave us an accurate image. Therefore, we also include those possibilities that were not selected. The percentage provides information about how many of all companies in the sample file choose that particular application (Table 4).

Table 4. Application of linear programming on different types of production processes structured by the location of company

Optimized process	Slovak companies		Foreign companies	
	no.	%	no.	%
resource allocation	31	43.66	13	44.83
creating production plans	30	42.25	14	48.28
creating cutting plans	39	54.93	18	62.07
personnel management	7	9.86	1	3.45
mixture preparation	8	11.27	3	10.34
waste management	1	1.41	2	6.90
distribution plans	14	19.72	5	17.24
financial management	8	11.27	1	3.45
supply-chain manage.	0	0.00	1	3.45

Another significant factor we wanted to explore was the linear programming applications in terms of the sector of economy in which company operates. We discovered that linear programming is mostly used by companies manufacturing chemicals and chemical products with resource allocation (27.66% Slovak companies). These companies often use linear programming also to create their production plan (23.4% Slovak companies). However, these companies also apply optimization to other processes. We marked the highest diversification of results in the group of these companies, e.g. the highest amount of different applications. Our findings also indicate that Slovak companies processing wood and manufacturing products made of wood and cork often apply linear programming to create their cutting plans. We also find that no production company in our sample file applied these methods to supply chain optimization. This application can bring company many benefits and as such, we consider this area to be a gap to be fulfilled in the future.

The results in the group of foreign companies were similar. The most common application of linear programming is also in the process of creating cutting plans. The biggest difference was in the rate of financial management use of linear programming application as it was significantly lower among foreign companies. These findings served as a foundation for verification of hypothesis H_2. We were unable to confirm this hypothesis despite the fact that resource allocation is a significant linear programming application. However, linear programming is not commonly applied in this process optimization, either in Slovakia or abroad.

One of the last questions included in the questionnaire was focused on analyzing the economic benefits of linear programming application in the management of industrial companies. The most general advantages are involved with various types of cost reductions. We explored the opinions of corresponding managers of companies on this subject (Table 5).

Table 5. Cost reduction structured by areas in the company

Type of cost reduction	Slovak companies		Foreign companies	
	no.	%	no.	%
r. of raw material costs	41	57.75	22	75.86
r. of labour costs	23	32.39	6	20.69
r. of overheads	23	32.39	9	31.03
r. of administrative costs	0	0.00	1	3.45
r. of selling expenses	15	21.13	4	13.79

According to the data presented in this table, we can state that the most significant benefit of linear programming application is the reduction of raw material costs in both Slovak and foreign companies. Medium-sized Slovak companies consider reduction of labour costs and reduction of production overheads as important advantages of linear programming application. On the other hand, reduction of administrative costs is not perceived as a significant benefit by any Slovak company. Moreover, only one foreign company considers it important. We also looked at these benefits dependent on the sector of economy where the company operates. According to provided data, emphasis can be placed on the fact that reduction of raw material costs is perceived as a significant benefit by companies from all economic sectors that used linear programming in optimization. These finding allowed us to confirm hypothesis H_3.

5 DISCUSSION AND CONCLUSION

This research paper focuses on application of linear programming in practice. The scientific aim of this research paper was to explore the possibilities of linear programming utilization in process optimization among Slovak and foreign industrial plants and to create a model of process optimization in selected production company using these methods. Based on the survey analysis, we can conclude that this objective was fulfilled.

We found that according to the provided data, nearly a third of medium-sized companies choose linear programming as their optimizing tool. We therefore concluded that the size of company is an important factor of linear programming application. The extent of utilization was significantly higher in the group of large-sized companies.

© 2016 Taylor & Francis Group, London, ISBN: 978-1-138-02856-2

Moreover, we explored various aspects of practical applications of linear programming in terms of the size of company and the sector of the economy where company operates both in Slovakia and abroad. Consequently, we assessed perceived advantages of linear programming applications. Our focus included various types of cost reductions. In terms of our contribution and originality, we consider this to be the most significant aspect of this paper. The value of this article lies mainly in providing a detailed insight into the extent of linear programming applications in managerial practice of Slovak production companies and indications for possible differences in comparison to companies operating abroad. Since our sample file of foreign companies was rather small, we used data provided by them only as outline for comparison and for assessing possible differences. These findings can serve as a foundation for further, more extended research.

Based on the information concluded from the conducted research we can assess not only the present situation of linear programming application in practice, but we can also predict basic trends for the future. Methods of linear programming are broadly covered as topics of education at universities all around the world. However, we found less than a third of Slovak production companies utilize these methods. This is merely a problem of perception of managers since they perceive their company to be "good enough". Therefore, such managers do not feel the need to seek the best optimization methods. Another both current and future problem involves perception. Many managers consider linear programming to be a set of very simple methods and in their opinion; linear programming is not suitable and instead favor other method. This problem is sometimes caused by personal characteristics of managers, especially factors concerning risk avoidance. In general, when manager do not thoroughly know linear programming, the person usually chooses other – more commonly known optimizing techniques. Academic experts clearly consider these methods suitable for practical applications whereas managers of production companies tend to favor other optimization methods. Overall, linear programming is simultaneously a very useful optimizing tool and a highly underestimated one.

Moreover, these findings served as a foundation for creating a model algorithm of selected process optimization. All of the above findings took into account the essential required basis and these guidelines provided some necessary information and helped us set:

- the objective of model algorithm – the specification of type of cost reduction that would make this model algorithm more suitable for practical needs in company and that would make its application more beneficial;
- the requirement of flexibility – implementation of various measures designed to increase flexibility of particular operations;
- the orientation of the model – since supply chain optimization is absolutely absent among linear programming applications in Slovakia, we decided not to model only the production process itself, but the whole logistics process from receiving of an order, the creation of products, and their final delivery to the customer;
- the types of secondary tasks this model algorithm needs to focus on – since linear programming is most commonly apply towards creating cutting plans and resource allocation, these problems had to be addressed (if applicable) to our model algorithm.

REFERENCES

Avis, D. & Umemoto, J. 2003. Stronger linear programming relaxations of max-cut. *Mathematical Programming* 97(3): 451-469.

Baker, K.R. (1st ed.) 2011. *Optimization modeling with Spreadsheets*. Hoboken: Wiley.

Buresh-Oppenheim, J. & Davis, S. & Impagliazzo, R. 2011. A Stronger Model of Dynamic Programming Algorithms. *Algorithmica* 60(4): 938-968.

Das, K. 2011. Integrating effective flexibility measures into a strategic supply chain planning model. *European Journal of Operational Research* 211(1) 170-183.

Floudas, C.A. & Lin, X. 2005. Mixed Integer Linear Programming in Process Scheduling: Modeling, Algorithms, and Applications. *Annals of Operations Research* 139(1): 131-162.

Gass, S.I. (1st ed.) 2010. *Linear Programming: Methods and Applications*. New York: Dover Publications.

Maloney, T. & Byard, K. (1st ed.) 2013. *Quantitative Methods for Business*. Auckland: Pearson New Zealand Publishing.

Sarker, R.A. & Newton, C.S. (1st ed.) 2008.*Optimization Modelling: A Practical Approach*. Sydney : CRC Press.

Vanichchinchai, A. & Igel, B. 2011.The impact of total quality management on supply chain management and firm's supply performance. *International Journal of Production Research* 49(11): 3405–3424.