USING THE EOQ PRINCIPLE FOR EFFICIENT VEHICLE UTILIZATION

Michal HUSINEC, Tomáš ŠUBRT, Jiří FEJFAR, Daniel CHAMRADA

Czech University of Life Sciences in Prague, Department of Systems Engineering, Prague, Czech Republic, EU, husinecmt@pef.czu.cz

Abstract

The problem of current freight transport lies in a plenty of smaller shipments that are delivered daily to the same collection points. Consumers and Distribution centers have found the possibility to reduce the amount of money in stock if they order only those goods that they are able to sell in a short time. On the other side, they artificially burden freight and increase the costs associated with transport. Freight transport is therefore affected by some degree of inefficiencies in the area of load. Founding a suitable vehicle to meet the ever-changing demand for capacity would require a greater variability in the fleet. This would significantly increase investment in the fleet. The use of the EOQ (Economic Order Quantity) principle would define the optimal order and thus the efficient utilization of the vehicle in relation to the total transport costs. The analyzed problems are linked to the lack of information in the sector concerned, the limited details and the closed environment for freely available vehicle capacities. The current solution is limited to the solution of individual distribution channels of individual companies requesting services. This article introduces selected economic and mathematical methods in relation to the application for the purpose of determining possible economies of scale and savings from specialization. The essence of the application of economic and mathematical methods is the efficient use of resources and mitigating the negative effects of road transport on the environment.

Keywords: Economic order quantity (EOQ), Transport costs, Warehouse costs, Economies of scales, Economies of specialisation

1. INTRODUCTION

Transport requirements have been growing, with the need generated by modern society and contemporary shopping trends shifting to the sphere of online purchases, when the customer usually expects the shipment to be delivered to his home [11]. Delivery within a minimal timeframe is something expected as a matter of course. With an increased demand for transport capacity, the adverse environmental impact of freight by road is increased, in particular in terms of the volume of pollutants and increased level of noise in urban agglomerations [3], objective of cities is to reduce such adverse influences, which is why low-emission zones are being set up today. Both these adverse influences concern cars with conventional propulsion. That is why an increasing number of carriers are looking for alternatives for sustainable development of transport and distribution of goods with less environmentally burdensome vehicles. One of the solutions is the use of electric cars or cars with a hybrid drive [5]. The acquisition investment, which is higher as compared to conventional cars, leads one to think about efficient use. One of the conditions for increased efficiency is an ideal route driven by the car, but also, in a way, the behavior of the end consumer. As one of the factors for increasing efficiency in the distribution of goods. Our contemporary hurried times offer nearly unlimited possibilities in the delivery of goods and the consumer has quickly got accustomed to maintaining only minimal or no inventory stock, as he expects delivery within a very short period of time, usually within 24 hours of the order being placed. That means that shippers are forced to invest in multiple vehicles of diverse capacity. The final amount of the investment in vehicles for distribution will also bring a change in the behavior of consumers, because carriers will have to reflect higher purchase costs in the final price of the delivery of goods. It is, therefore, possible to expect a potential change in consumer behavior, as higher costs related to more frequent delivery of goods will be offset in the price of the product and the consumer may demand the product at a lower end price. In order to achieve better consumer conduct, thereby achieving greater efficiency of delivery costs, we

can use the EOQ (Economic Order Quantity) method. It is one of the most broadly discussed models in production logistics [12]. Probably the most well-known adaptation of the formula is the EPQ (Economic Production Quantity) method, which takes into account daily demand of product production. Another well-known modification of the EOQ method is “Japanese production”, a practical approach focused on the order size and time of production or preparation of an order. [7,18,19] introduced principles such as Just-in-time (JIT). An approach which is usually based on the “Pull Production” approach [1,14]. And when the time of preparation is adapted to customer demand. Final products are distributed to customers immediately. But what about cases when order production or preparation cannot respond to customer demand due to longer delivery periods or potential outages in production? Then goods delivery processes should be planned in advance, for example, with the use of “Push Systems” [2,16,19,20]. In this case, however, operative processes, inventory stock of goods, and overall logistical costs will grow. Slower or unbalanced orders bring increased costs into the system on the implementation of repeated orders [4,9,10,15-18,21]. This contribution extends the further potential use of the EOQ principle for determining an optimal order, with a view to cost minimization and increased efficiency in the distribution of goods. With the application of the EOQ method, greater savings can be achieved in the future, based on specialization or economies of scale due to optimized logistical costs. That means that there is an economic effect both on the supplier’s and on the customer’s part. The potential EOQ approach is applied in the practical part to actual distribution data. And it is compared to actual costs of the distribution of goods. An analysis of the costs and benefits of the EOQ method uses the concepts of economic theory for improving the efficiency of distribution shipping. And for a reduction of the adverse impacts that modern methods of transport involve [6]. The objective of the paper is to increase efficiency of the use of car fleets and, with the use of a modified formula for EOQ calculation, to propose changes in the method of distribution used by a specific company in order to save on logistical costs. In the future, the analysis will serve as a basis for investing in vehicles with electric or hybrid drives.

2. METHODS

Economic order quantity is the optimal order quantity that minimizes the total operations logistics costs. Model EOQ is a one of the oldest model. The EOQ models was developer by Ford W. Harris in 1913 [8]. The general formula EOQ:

$$Q^* = \sqrt{\frac{2DK}{h}} \tag{1}$$

Where:

*Q** - optimal order quantity

D - annual demand quantity

K - fixed cost per order, setup cost

h - annual holding cost per unit

The general EOQ formula only applies if demand is constant throughout the year and we expect every future order to be delivered in full. Fixed costs must be entered for each order. The price of the goods purchased is known. The objective of the EOQ model is to minimize aggregate costs of inventory stock and determine the optimal size of an order [13].

In order to be able to apply to EOQ model in a distribution system, we have adapted the general formulation as follows:

$$EOQ^* = \sqrt{\frac{2PD}{C}} \tag{2}$$

Where:

*EOQ** - recommended optimal amount for one delivery

P - costs per order (shipping and costs of assembly)

D - *annual demand quantity*

C - actual storage costs

3. RESULTS

The data presented in this paper is actual data provided by a logistical company in order to optimize the efficiency of distribution directions. Comprehensive data has been obtained from the Logenius internal system. Non-constant shipping costs have been caused by the use of multiple vehicles with diverse capacities. The costs of assembly and storage are constant costs that the company actually bills to its customers.

The distribution area of the Czech Republic was used for the application of EOQ calculation:

- ZIP code from 370 00 to 390 00;
- Monthly delivery;
- Good with a minimum shelf life of 1 year;
- Companies 1-50 are actual customer;

The existing system is based on customer demand: they can order goods on business days and the entire system is limited to orders in a D+24 hours (D = day of the order) regime. This means that delivery must take place within 24 hours of the order being placed. The existing distribution system is burdened by a higher level of inefficiency and individual vehicles are used to approximately 75 %. An adapted EOQ model has been applied with a view to a reduction of costs and increased efficiency of the distribution vehicles. The table below provides a comprehensive overview of individual customers and the actual costs incurred by the logistical company. The costs related to storage, assembly, and preparation of a pallet for distribution are constant. Shipping costs have been influenced by an effort to make maximum use of the fleet for shipment distribution and variability of the vehicles used. That is why those costs are not constant - these are the actual costs based on the category of vehicle. The price of shipment is either from the logistics operator's warehouse to the recipient's warehouse or the sum of combined shipping costs if several vehicles are used. Logistical costs are recalculated in the adapted EOQ model into unit storage costs. The main problem of the sender is to minimize the costs of logistics with a view to order size. On the other hand, there is the recipient's problem as he demands quantities such as to minimize the money invested in stock and to be able to handle uncertain demand. The logistics operator must therefore minimize his own costs of handling the goods with a view to the delivery date. And he must adapt the vehicle to the size of the delivery such as to prevent exceeding maximum vehicle capacity both in terms of space and weight. Hence, fleet variability is key for a logistics operator, as it allows it to minimize its costs and maximize vehicle utilization. The effort to minimize the costs in shipping is influenced by the fact that, following delivery, the vehicle returns empty to the logistics operator's warehouse. MS EXCEL was the software used in the calculation on the EOQ model.

The table includes several attributes. Except the variables used in the EOQ formula (and EOQ itself), these are:

- Number of deliveries - the present number of deliveries in a given period;
- Total number of pallets - the number of pallets on which the goods were carried;
- Total numbers of cartons - the number of cartons shipped to the customer;
- Actual transport costs - the sum of shipping costs;
- Storage costs - the costs of storage;
- Assembly costs - costs related to shipment assembly and its preparation for shipping;
- Optimized number of deliveries - the optimized number of deliveries following EOQ application;

- New transport costs - calculation of shipping costs on the basis of the optimization made;
- Saving costs - calculation of saving on costs following optimization.

Table 1 EOQ optimization on the basis of actual data

Company	Number of deliveries	Total number of pallets	Total number of cartons	Actual transport costs	Storage costs	Assembly costs	EOQ	D	P	C	Optimatized number of deliveries	New transport Cost	Saving cost
Company1	1	1	39	1 339,5 CZK	3 092,7 CZK	174,8 CZK	39	39	1 514,3 CZK	79,3 CZK	1	1 339,5 CZK	0,0 CZK
Company2	2	2	89	1 932,0 CZK	7 057,7 CZK	384,8 CZK	51	89	1 158,4 CZK	79,3 CZK	2	1 932,0 CZK	0,0 CZK
Company3	1	3	148	1 530,0 CZK	11 736,4 CZK	583,6 CZK	89	148	2 113,6 CZK	79,3 CZK	1	1 530,0 CZK	0,0 CZK
Company4	4	4	90	2 214,9 CZK	7 137,0 CZK	488,0 CZK	39	90	675,7 CZK	79,3 CZK	2	1 107,5 CZK	1 107,5 CZK
Company5	5	5	250	3 957,8 CZK	19 825,0 CZK	1 050,0 CZK	79	250	1 001,6 CZK	79,3 CZK	3	2 374,7 CZK	1 583,1 CZK
Company6	2	2	79	900,8 CZK	6 264,7 CZK	352,8 CZK	35	79	626,8 CZK	79,3 CZK	2	900,8 CZK	0,0 CZK
Company7	11	11	381	6 852,4 CZK	30 213,3 CZK	1 769,2 CZK	87	381	783,8 CZK	79,3 CZK	4	2 491,8 CZK	4 360,6 CZK
Company8	1	2	64	1 017,9 CZK	5 075,2 CZK	284,8 CZK	46	64	1 302,7 CZK	79,3 CZK	1	1 017,9 CZK	0,0 CZK
Company9	1	1	25	391,9 CZK	1 982,5 CZK	130,0 CZK	18	25	521,9 CZK	79,3 CZK	1	391,9 CZK	0,0 CZK
Company10	2	2	17	1 393,1 CZK	1 348,1 CZK	154,4 CZK	18	17	773,8 CZK	79,3 CZK	1	696,6 CZK	696,6 CZK
Company11	1	1	7	552,4 CZK	555,1 CZK	72,4 CZK	11	7	624,8 CZK	79,3 CZK	1	552,4 CZK	0,0 CZK
Company12	11	20	754	16 411,0 CZK	59 792,2 CZK	3 232,8 CZK	184	754	1 785,8 CZK	79,3 CZK	4	5 967,6 CZK	10 443,4 CZK
Company13	2	2	101	1 551,7 CZK	8 009,3 CZK	423,2 CZK	50	101	987,5 CZK	79,3 CZK	2	1 551,7 CZK	0,0 CZK
Company14	4	10	441	6 567,3 CZK	34 971,3 CZK	1 791,2 CZK	152	441	2 089,6 CZK	79,3 CZK	3	4 925,5 CZK	1 641,8 CZK
Company15	3	4	26	2 848,1 CZK	2 061,8 CZK	263,2 CZK	26	26	1 037,1 CZK	79,3 CZK	1	949,4 CZK	1 898,7 CZK
Company16	2	2	8	1 424,0 CZK	634,4 CZK	125,6 CZK	13	8	774,8 CZK	79,3 CZK	1	712,0 CZK	712,0 CZK
Company17	1	1	5	807,5 CZK	396,5 CZK	66,0 CZK	10	5	873,5 CZK	79,3 CZK	1	807,5 CZK	0,0 CZK
Company18	1	1	67	687,2 CZK	5 313,1 CZK	264,4 CZK	40	67	951,6 CZK	79,3 CZK	1	687,2 CZK	0,0 CZK
Company19	1	1	10	1 312,1 CZK	793,0 CZK	82,0 CZK	19	10	1 394,1 CZK	79,3 CZK	1	1 312,1 CZK	0,0 CZK
Company20	1	1	129	897,6 CZK	10 229,7 CZK	462,8 CZK	67	129	1 360,4 CZK	79,3 CZK	1	897,6 CZK	0,0 CZK
Company21	6	6	162	7 510,9 CZK	12 846,6 CZK	818,4 CZK	75	162	1 388,2 CZK	79,3 CZK	2	2 503,6 CZK	5 007,3 CZK
Company22	1	1	39	714,4 CZK	3 092,7 CZK	174,8 CZK	30	39	889,2 CZK	79,3 CZK	1	714,4 CZK	0,0 CZK
Company23	11	17	821	11 770,1 CZK	65 105,3 CZK	3 357,2 CZK	169	821	1 375,2 CZK	79,3 CZK	5	5 350,1 CZK	6 420,1 CZK
Company24	1	1	30	580,9 CZK	2 379,0 CZK	146,0 CZK	23	30	726,9 CZK	79,3 CZK	1	580,9 CZK	0,0 CZK
Company25	1	1	5	510,0 CZK	396,5 CZK	66,0 CZK	9	5	576,0 CZK	79,3 CZK	1	510,0 CZK	0,0 CZK
Company26	2	2	11	3 418,6 CZK	872,3 CZK	135,2 CZK	22	11	1 776,9 CZK	79,3 CZK	1	1 709,3 CZK	1 709,3 CZK
Company27	1	3	191	1 828,9 CZK	15 146,3 CZK	721,2 CZK	111	191	2 550,1 CZK	79,3 CZK	1	1 828,9 CZK	0,0 CZK
Company28	1	1	4	580,9 CZK	317,2 CZK	62,8 CZK	8	4	643,7 CZK	79,3 CZK	1	580,9 CZK	0,0 CZK
Company29	2	2	102	1 487,7 CZK	8 088,6 CZK	426,4 CZK	50	102	957,1 CZK	79,3 CZK	2	1 487,7 CZK	0,0 CZK
Company30	2	2	7	791,7 CZK	555,1 CZK	122,4 CZK	9	7	457,0 CZK	79,3 CZK	1	395,8 CZK	395,8 CZK
Company31	1	1	10	897,6 CZK	793,0 CZK	82,0 CZK	16	10	979,6 CZK	79,3 CZK	1	897,6 CZK	0,0 CZK
Company32	2	2	20	759,2 CZK	1 586,0 CZK	164,0 CZK	15	20	461,6 CZK	79,3 CZK	1	379,6 CZK	379,6 CZK
Company33	4	4	86	3 066,1 CZK	6 819,8 CZK	475,2 CZK	44	86	885,3 CZK	79,3 CZK	2	1 533,1 CZK	1 533,1 CZK
Company34	2	2	8	1 358,5 CZK	634,4 CZK	125,6 CZK	12	8	742,1 CZK	79,3 CZK	1	679,3 CZK	679,3 CZK
Company35	1	1	64	840,8 CZK	5 075,2 CZK	254,8 CZK	42	64	1 095,6 CZK	79,3 CZK	1	840,8 CZK	0,0 CZK
Company36	1	1	67	837,8 CZK	5 313,1 CZK	264,4 CZK	43	67	1 102,2 CZK	79,3 CZK	1	837,8 CZK	0,0 CZK
Company37	1	1	42	654,1 CZK	3 330,6 CZK	184,4 CZK	30	42	838,5 CZK	79,3 CZK	1	654,1 CZK	0,0 CZK
Company38	2	7	3445	4 863,4 CZK	273 188,5 CZK	11 274,0 CZK	837	3445	8 068,7 CZK	79,3 CZK	2	4 863,4 CZK	0,0 CZK
Company39	1	1	15	654,1 CZK	1 189,5 CZK	98,0 CZK	17	15	752,1 CZK	79,3 CZK	1	654,1 CZK	0,0 CZK
Company40	1	1	4	1 313,4 CZK	317,2 CZK	62,8 CZK	12	4	1 376,2 CZK	79,3 CZK	1	1 313,4 CZK	0,0 CZK
Company41	1	1	16	654,1 CZK	1 268,8 CZK	101,2 CZK	17	16	755,3 CZK	79,3 CZK	1	654,1 CZK	0,0 CZK
Company42	3	3	172	1 265,1 CZK	13 639,6 CZK	700,4 CZK	53	172	655,2 CZK	79,3 CZK	3	1 265,1 CZK	0,0 CZK
Company43	2	2	26	2 027,8 CZK	2 061,8 CZK	183,2 CZK	27	26	1 105,5 CZK	79,3 CZK	1	1 013,9 CZK	1 013,9 CZK
Company44	1	1	127	826,5 CZK	10 071,1 CZK	456,4 CZK	64	127	1 282,9 CZK	79,3 CZK	1	826,5 CZK	0,0 CZK
Company45	4	4	153	4 307,1 CZK	12 132,9 CZK	689,6 CZK	69	153	1 249,2 CZK	79,3 CZK	2	2 153,5 CZK	2 153,5 CZK
Company46	1	2	144	3 917,7 CZK	11 419,2 CZK	540,8 CZK	127	144	4 458,5 CZK	79,3 CZK	1	3 917,7 CZK	0,0 CZK
Company47	5	5	195	5 374,1 CZK	15 463,5 CZK	874,0 CZK	78	195	1 249,6 CZK	79,3 CZK	2	2 149,7 CZK	3 224,5 CZK
Company48	1	1	58	1 313,4 CZK	4 599,4 CZK	235,6 CZK	48	58	1 549,0 CZK	79,3 CZK	1	1 313,4 CZK	0,0 CZK
Company49	1	1	9	927,8 CZK	713,7 CZK	78,8 CZK	15	9	1 006,6 CZK	79,3 CZK	1	927,8 CZK	0,0 CZK
Company50	9	9	164	4 471,8 CZK	13 005,2 CZK	974,8 CZK	50	164	605,2 CZK	79,3 CZK	3	1 490,6 CZK	2 981,2 CZK

The first results of the application of the EOQ method indicated a significant cost saving, and hence, a greater level of freight vehicle utilization. With an optimization of the existing system, the logistical company could reduce its costs while reducing the overall costs it has per customer in the preparation and delivery of the goods. The total saving in the distribution area concerned is shown in the table below.

Table 2 Evaluation of the outcomes of optimization

	Actual	Optimatized
Number of deliveries	129	78
Number of cartons / deliveries (Average)	69	114
Transport costc	124 113,7 CZK	76 172,5 CZK
Saving costs (CZK)		47 941,2 CZK
Saving costs (%)		38,6%

It is evident that a cost-saving of 38.6 % has been achieved. The secondary objective is the reduction of CO2 as an adverse impact of road transport on the environment. Furthermore, EOQ optimization also discovered that selected companies are already optimizing their costs with a view to the quantity of goods ordered. Those companies are marked in the table (**Table 1**).

4. FUTURE RESEARCH

Of vital importance for the correct definition of the issue - construction of the EOQ model and its subsequent modification in road transport - is the set-up of the system such that it would suit all parties involved in the logistical chain. Recently, road transport has been facing a significant reduction in the number of professional drivers and thus the question whether the optimum delivery size, and hence a reduction of the total number of freight vehicles used in the distribution system, may not help address the situation in part. In the future, a greater level of cooperation between logistical operators, owners, and customers purchasing goods can therefore be expected in an effort to optimize costs to the greatest extent possible and to efficiently utilize transport capacity. Hence, the use of the EOQ model or its modification in the optimization of the problem at hand. On the basis of the optimization, distribution of goods at least once a month was ensured, and the possibility of placement in stock by the customer was not examined. That is why, in the future, we would like to examine greater variability of the EOQ model, in order for it to include customer costs prior to final consumption. And the application of a modification of the EOQ model throughout the Czech Republic.

REFERENCES

[1] Abdulmalek, F. A., and J. Rajgopal. Analyzing the Benefits of Lean Manufacturing and Value Stream Mapping via Simulation: A Process Sector Case Study. *International Journal of Production Economics.* 2007. vol. 107, pp. 223-236.

[2] Aigbedo, H. *Some Structural Properties for the Just-in-Time Level Schedule Problem*. Production Planning & Control. 2000. p 357-362.

[3] Cattaruzza, D. et al. Vehicle routing problems for city logistics, *EURO Journal on Transportation and Logistics*. Springer Berlin Heidelberg. 2017.vol 6, pp. 51-79. DOI: 10.1007/s13676-014-0074-0.

[4] Demeter, K., and Z. Matyusz. The Impact of Lean Practices on Inventory Turnover. *International Journal of Production Economics*. 2011. vol 133 (1). pp 154-163.

[5] Grauers, A. et al. WHY ELECTROMOBILITY AND WHAT IS IT?. [viewed 2019-10-25]. Available at: http://publications.lib.chalmers.se/records/fulltext/211430/local_211430.pdf.

[6] Graham, D. J. and Gibbons, S. Quantifying Wider Economic Impacts of agglomeration for transport appraisal. *Existing evidence and future directions*. 2019. DOI: 10.1016/j.ecotra.2019.100121.

[7] Hall, R. W. *Driving the Productivity Machine: Production Planning and Control in Japan. Las Vegas*, American Production, Inventory Control Society.1981.

[8] Harris, F.W. *What quantity to make at once*, The Library of Factory Management, Vol. V. Operation and Costs. A.W. Shaw Company, Chicago.1915. pp. 47-52.

[9] Chiarini, A. *Waste Savings in Patient Transportation inside Large Hospitals Using Lean Thinking Tools and Logistic Solutions*. Leadership in Health Services 2013. pp 356-367.

[10] Chiarini, A. Relationships between Total Quality Management and Six Sigma inside European Manufacturing Companies: A Dedicated Survey. *International Journal of Productivity and Quality Management*. 2013. vol 2. pp 179-194.

[11] Juřičková, E., Adu, M. and Ing, K. ECONOMICS AND MANAGEMENT OF ENTERPRISES. On-line shopping behaviour in the Czech Republic under the digital transformation of economy. *Economic Annals-XXI*. 2017. 165(165), pp. 119-1235. DOI: 10.21003/ea.V165-24.

[12] Khan, M., M. Y. Jaber, A. L. Guiffrida, and S. Zolfaghari. A Review of the Extensions of a Modified EOQ Model for Imperfect Quality Items. *International Journal of Production Economics*. 2011. vol. 132 (1). pp 1-12.

[13] Kundu, K. and Staudacher, A. P. *Investigation of Effectiveness of Order Review and Release Models in Make to Order Supply Chain*. DOI: 10.1051/0.

[14] Lu, J. C., T. Yang, and C. Y. Wang. A Lean Pull System Design Analysed by Value Stream Mapping and Multiple Criteria Decision-Making Method under Demand Uncertainty. *International Journal of Computer Integrated Manufacturing*. 2011. vol. 24 (3). pp 211-228.

[15] Monden, Y. *Toyota Production System: An Integrated Approach to Just-in-Time*. New York. CRC Press. 2011.

[16] Ohno, T. *How the Toyota Production System Was Created*. Japanese Economy. 1982. pp 83-101.

[17] Porteus, E. L. *Investing in Reduced Setups in the EOQ Model*. Management Science. 1985. pp 998-1010.

[18] Schonberger, R. *Japanese Manufacturing Techniques*. New York The Free Press. 1982.

[19] Shingo, S. *Non-Stock Production: The Shingo System of Continuous Improvement*. Cambridge MA Productivity Press.1988.

[20] Spearman, M. L., and M. A. Zazanis. Push and Pull Production Systems: Issues and Comparisons. *Operations Research*. 1992. vol. 40 (3). pp 521-532.

[21] Ulutas, B. An Application of SMED Methodology. *World Academy of Science, Engineering and Technology*. 2011. vol.5 (7). pp 63-66.