Determining the Level of Logistics Automation Applicable in a Manufacturing Systems

BUDA Traian
Transilvania University of Brasov, Romania, traian.buda@unitbv.ro
BARBU Magdalena
Transilvania University of Brasov, Romania, magda.n@unitbv.ro
CALEFARIU Gavrilă
Transilvania University of Brasov, Romania, gcalefariu@unitbv.ro
FLORESCU Adriana
Transilvania University of Brasov, Romania, fota.a@unitbv.ro

Abstract
This paper analyzes the economic conditions necessary for logistics automation of manufacturing systems to make effective and consistent with the company's financial strength. Based on the total purchase and operating costs of the logistics system, first thing to do is to determine the prerequisite that need to be fulfilled so automation would lead to lower costs than manual operation. To do this, define the degree of automation of the logistics system and write the formula between this and the total costs. By properly ordering the terms in this relationship, it will establish the necessary condition for introducing automation. If this condition is met, the level of automation will be directly correlated with the level of investment available for this.

Keywords
automation, system manufacturing, logistics

1. Introduction

The benefits and positive implications of automation are demonstrated on all levels, both in terms of productivity and the quality of production and products. To the further expansion of automation in manufacturing and production, to become fully automated has two major limitations: the existence of technical solutions to enable automation and costs of applying those solutions. Therefore, usually in logistics, partial automation solution is applied in most cases.

Moreover, viewed chronologically, the first movements that have been automated are linked with generation surfaces on machines (vending machines) and then those relating to the movement of material. At this time, it is definitively proven that automation of process equipment has favorable effects compared to the manually operated both in terms of productivity and quality, and in terms of processing costs. A recent study conducted by the authors, shows that the share of labor cost using non-automatic technology is averaging 40 ... 60 % and with automated technologies (including CNC) is 10 ... 15%.

In current manufacturing systems, generating movements of technological equipment runs automatically in most cases [2, 6]. In the production of single and small series is also frequent the existence of machines with manual control, or some workstations with manual activities. Even in these cases, it can also be observed that automated generating movements are increasingly present.

However, since the automation of technological equipment is almost a rule; the automation level of a manufacturing system is largely defined by the degree of automation of its logistics system.

From this perspective, manufacturing systems can be:

- Non-automatic: all logistics movements are performed manually or by usage of simple hand-operated means;
- Mechanized: transferring, supply blank, piece in the workstation, catching device, initiating the work cycle, the release of the device and discharge is carried out manually and transport between machines is mechanized: roller conveyor, conveyor belt, chain or other systems carrying blanks between the work stations;

- Semiautomatic (partially automated): only feeding the blank in the workstation, fixing device and cycle initialization are manual, the others steps being automatically executed;
- Automatic: all movements, those inside working cycle and those outside, runs automatically.

For multiple reasons, automation is desired by any manager, but not in all conditions [1, 2, 3, 4, 5, 6]. Assuming that the technical requirements are met (meaning all logistic movements are done using automatic systems), then the economic analysis began. The economic logistic automation outlook is further treated.

2. Determine the Condition Logistic Automation System

Like any activity in the production system, logistics activities contribute with specific costs to the overall manufacturing costs. View over the automation level of logistics system involves solving technical problems, which refers to physical implementation of a fully automated logistics system. Such system, fully automated, usually comes with higher acquisition cost than a logistical system based on manual activities. It should be taken in consideration that even manual logistics systems involve the acquisition of non-automatic equipment, used by human operators to realize the material flow. In other words, both systems the fully automatic logistics and the comprehensive logistics, involving non-automatic acquisition, costs but each of them involving different financial efforts, which are much higher in the case of automated logistics than manual logistics.

Acquisition costs are part of fixed manufacturing costs, which also include the maintenance costs.

To achieve material flow in a manufacturing system, there are different alternatives, usage of either a fully automatically logistic system, or use of a complete manual logistic system, or a hybrid variant, in which the movements are performed partly manually and partly automatically. The question is to identify the conditions in which automation is getting effective and also the affordable level of automation for a manufacturing system.

To formulate workable solution that will give a comprehensive formula for the level of automation, an internal logistics system is considered, comprising the entire material flow through the system with a total of N_T movements/manipulation. These movements can be: transport (along the technological path), transfer (perpendicular to the technological route), placing the blank in the workstation, the removal of the finished part, and the orientation of blank along one or more axes etc.

We consider that out of the of N_T movements, logistics system perform, for each unit of product, N_A automatic movements and n_M manual movements. It is defined as the degree of automation G_A, using the formula given below:

$$G_A = \frac{N_A}{N_T}. \tag{1}$$

From this it results:

$$N_M = (1 - G_A) N_T. \tag{2}$$

Use C_{FA} as annual fixed cost of a fully automatic logistics system and C_{FM} as annual fixed cost of a complete manual logistics system. Similarly, C_{EA} and E_{MC} are the averages operating costs for the logistics movement. Operating costs include the average costs of energy consumption and consumables costs, for each logistic movement.

Considering that the annual volume of production is Q, the total annual cost C_T of using logistics system is given by (3):

$$C_T = C_{FA} \cdot G_A + C_{EA} \cdot Q \cdot N_A + C_{FM} \cdot (1 - G_A) + C_{EM} \cdot Q \cdot N_M + S_M N_S. \tag{3}$$

In the relation (3), S_M represents average annual salary of an operator from logistics, and N_S is the number of employees (operators).

Using n_M as average annual standard logistical movements made by an operator, the number N_S of employees is given by the formula:

$$N_S = \frac{Q \cdot N_M}{n_M}. \tag{4}$$

Replacing the expressions (1), (2) and (4) in the formula (3), is obtained:

$$C_T = C_{FA} \cdot G_A + C_{EA} \cdot Q \cdot N_T G_A + C_{FM} \cdot (1 - G_A) + \\ + C_{EM} \cdot Q \cdot N_T (1 - G_A) + S_M \frac{Q \cdot N_T (1 - G_A)}{n_M} \quad . \tag{5}$$

Ordering terms from previous it results:

$$C_T = C_{FM} + C_{EM} \cdot Q \cdot N_T + S_M \frac{Q \cdot N_T}{n_M} + \\ + \left(C_{FA} + C_{EA} \cdot Q \cdot N_T - C_{FM} - C_{EM} \cdot Q \cdot N_T - S_M \frac{Q \cdot N_T}{n_M} \right) G_A. \tag{6}$$

From the relation (6), it is identify that between C_T and G_A there is a linear dependence.

The only possibility that, by increasing the degree of automation, total logistical costs to remain constant or to reduce, is that the slope to be zero or negative, meaning to fulfil the next relationship (7):

$$C_{FA} + C_{EA} \cdot Q \cdot N_T \le C_{FM} + C_{EM} \cdot Q \cdot N_T + S_M \frac{Q \cdot N_T}{n_M}. \tag{7}$$

Hence, in order that automating to be applicable, between the levels of wages of operators combined with acquisition costs and operating cost of the logistics system the following condition must comply:

$$S_M \ge (C_{FA} + C_{EA} \cdot Q \cdot N_T - C_{FM} - C_{EM} \cdot Q \cdot N_T) \frac{n_M}{Q \cdot N_T}. \tag{8}$$

Relationship (8) indicates the limit from which wage or logistic operators' salary level in relation to average, fixed and exploitation costs of logistical system, automatic or manual, leads to a decrease of the total cost for the system in case of automation. If a condition is fulfil (8), then, by the relationship (6), it proves that total costs are reduced if the degree of automation increases. Result by default that the lowest overall costs are obtained when the system is fully automatic, i.e. G_A=1.

3. Setting the Level of Automation of Logistics System

Degree of automation is limited by the level of investment for development or replacement existing logistic system. The value of investments and depreciation period determine the fixed costs (depreciation plus the maintenance costs). Relationship (8) is giving the rule that automation would lead to a decrease in costs, but does not provide information relating to the degree of automation of logistics system. It should be seen from a different perspective. Achieving full automation can only be made if an undertaking has the investment funds needed $C_{FA}T_A$, where T_A is the time for the depreciation of logistical systems automatic. In the case fully automatic logistics these investment costs are significant. Therefore, because of the investment costs in manual logistical systems $C_{FM}T_M$ (where T_M is the time for the depreciation of logistical means manual) are much smaller, in most cases it is decided to use a partly automatic logistic system. Degree of automation will be dictated by the level of investment that company will be disallowed to get involved in logistical systems.

Considering that the undertaking has the fund V_I for investment in internal logistics, it may write formula:

$$V_I = C_{FA} T_A G_A + C_{FM} T_M (1 - G_A). \tag{9}$$

The resulting degree of automation of logistics system, which the company can get to a certain volume of investments:

$$G_A = \frac{V_I - C_{FM} T_M}{C_{FA} T_A - C_{FM} T_M}. \tag{10}$$

By applying previous procedure shall indicate the proportion of optimal movements performed automatically and those to be carried out manually. A resource to minimize the actual costs is that of the choice of the best practical solutions for automation, and by appropriate selection of the equipment by the analysis of offers for market.

4. Number of Employees for Handling

Number of employees needed for materials handling is determined by the degree of automation equipment and handling rate movements. In principle, the number of employees is equal to the number of non-automated equipment, but bear in mind the following two factors:

- the possibility that handling equipment can be driven by the operator of machine tools (e.g. Crane pivoting movements transfer). The solution is usable if the frequency of movements is relatively small, meaning that the operating time on machine is relative high;
- the possibility that the same operator to serve successively more logistics equipment (e.g. same operator using forklifts/tow tractors carrying a container with small pieces and same operator is using a crane, controlled from the ground, to transfers it to a hopper of an installation of automatic feed).

Allocation of staff for handling material based on the above mentioned factors should not affect the continuity of the manufacturing process. It is desirable that the manufacturing equipment have the highest possible degree of use. This is reflected in all cases in the level of efficiency and profitability for industrial activities

5. Conclusions

This paper provides a tool that can determine two important aspects of logistics automation systems. The first issue concerns the answer to "What is the condition for automation?". The answer to this question is given by the condition (8). The second aims at answering the question "What is the level of automation?" And the answer is given by (10).

Relations have been written for previous average values of the parameters. These give precise results if the differences between the average and the minimum or maximum costs of logistics movements are not too high. If there are big differences between them (e.g. greater than 50%), then the system is decomposed into logistic subsystems, based on cost criteria (complexity) and relationships (8) and (10) apply for each subsystem.

Practically, quantitative method is being applied from the entire logistics system and going up to the workplace level. In the last case it will work with actual values of fixed and operating costs.

Acknowledgements

This paper is supported by the Sectorial Operational Programme Human Resources Development (SOPHRD), ID134378 financed from the European Social Fund and by the Romanian Government.

References

1. Boian, N. (2010): *Economic performance of small and medium enterprises (SME)*. RECENT, ISSN 1582-0246, vol. 11, no. 3(30), p. 166-172
2. Calefariu, G., Barbu, M. (2011): *Sisteme de producţie. Teorie şi aplicaţii*. Editura Lux Libris, ISBN 978-973-131-112-8, Braşov, Romania (in Romanian)
3. Găvruş, Cristina (2013): *Economic Efficiency of Using Rapid Prototyping Technology*. Applied Mechanics and Materials, vol. 371, p. 210-214, DOI: 10.4028/www.scientific.net/AMM.371.210
4. Gheorghe, C. (2013): *Opportunities to Reduce Operating Expenses in Industrial Enterprises*. Proceedings in Manufacturing Systems, ISSN 2067-9238, vol. 8, Issue 3, p. 135-140
5. Zandin, K.B. (2001): *Maynard's Industrial Engineering Handbook*. Fifth Edition, McGraw-Hill, ISBN 9780070411029
6. Tempelmaier, H., Kuhn, H. (1993): *Flexible Manufacturing Systems. Decision Support for Design and Operation*. John Wiley & Sons, ISBN 978-0-471-30721-1

Received in October 2015