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ASSESSING THE PERMISSIBLE AMOUNT OF CAPITAL INVESTMENTS FOR AN EFFICIENT ASSEMBLY AUTOMATION

Iliya K. Boyadjiev
Ivo K. Malakov
Benko S. Valev
Technical University Sofia
1756 Sofia, 8-Kliment-Ochridski Blv.
Republic of Bulgaria

ABSTRACT

The amount of capital investments is a major factor in the process of creating efficient automated assembly systems. Equivalencies used presently to predict the permissible amount of capital investments on an early stage of the AAS design process do not consider a sequence of factors. Suggested are functional equivalencies, providing-on an early design stage-for a more correct assessment of the capital investment amount, which grants the assembly automation’s efficiency depending on the client’s strategy.

Keywords: *efficiency, automated assembly systems, permissible capital investment*

1. INTRODUCTION

The urge to rise manufacturing efficiency creates a necessity for automation of assembly operations. In the course of developing automated assembly systems the determination of permissible investments becomes highly important. Capital investments are a major decision-making element and fixing the correct investment size is expected to reduce the risk of ineffective decisions. Hence, this is one of the priority tasks on each stage of the automated assembly systems designing process. Usually, the significance of judging the investments amount needed to create the automated assembly systems contradicts the calculation’s accuracy on the separate stages. Assessing the permissible amount of investments on an early automated assembly systems design stage proceeds in a highly ambiguous environment and, consequently, leads to imprecise outcomes when compared to those obtained on later phases. The assessment, though, is important since the permissible investment securing economic efficiency of the automated assembly systems provides the bases for decision-making concerning their building. Taking into account as much as possible of the factors effecting the investment size will improve the accuracy and reduce the risk for automated assembly systems users when they choose to make investments.

In order to determine the permissible amount of capital investments required for building of automated assembly systems it would be appropriate to use the methodology according to [1]. The described approach is based on calculation of the permissible amounts in the case of replacing one assembly worker through adequate automated assembly devices. The investment amount equals the worker’s annual salary multiplied by the number of years of full-scale automated assembly systems performance. This approach, though, could lead to errors in the prognostic estimation and consequently – to serious risks for the investors. The calculation inaccuracies are caused by the fact that the applied methods do not consider a sequence of influencing agents, such as fluctuations in the production program, payments for interest rates, maintenance and service activities, energy, facilities rents, annual inflation rates etc. Known are also equivalencies [2, 3] for evaluating the permissible investment's sum based on the annual expenses for one assembly operator replaced by assembly automation devices, which consider a number of factors. Unfortunately, these equivalencies neglect the changes in spending on material resources and the investment's payback times.

2. DETERMINATION OF THE PERMISSIBLE CAPITAL INVESTMENTS AMOUNT ALLOWING AN EFFICIENT ASSEMBLY AUTOMATION

In order to establish the permissible capital investments, which will guarantee a high economic efficiency of the automated assembly systems functioning, we suggest the usage of following conditions [3, 4, 5]:

$$MK_2 \le MK_1 \tag{1}$$

$$\frac{K_{WB_2} - \theta.K_{WB_1}}{\left(MK_1 - MK_2\right).Q_{J_2} + K_{A_2} - \theta.K_{A_1}} \le N \tag{2}$$

$$K_{WB_2} + MK_2.Q_{J_2}.R \le \theta.K_{WB_1} + MK_1.Q_{J_1}.\theta.R \tag{3}$$

where:

$$K_{WB_1} = K_1.\frac{n_2}{n_1}.(1+a)^{n_2}\,, \quad K_{WB_2} = K_2.(1+a)^{n_2}\,, \quad R = \frac{(1+a)^{n_2} - 1}{a}\,,$$

$$MK_1 = M_1 + \frac{P_1.PK_1 + M_{KH_1}}{Q_1}\,, \quad MK_2 = M_2 + \frac{P_2.PK_2 + M_{KH_2}}{Q_2}$$

MK_1, MK_2 - prime cost, lewa/piece; Q_{J_1}, Q_{J_2} - annual production program, pieces; K_{WB_1}, K_{WB_2} - capital investments under consideration of the "time" factor and adjusted to an equal implementation term, lewa; K_1, K_2 - amount of the lump-sum capital investment, lewa; K_{A_1}, K_{A_2} - annual allowences for depreciation, lewa; M_1, M_2 - spending on materials, lewa/piece; P_1, P_2 - number of workers in one shift, numb.; PK_1, PK_2 - expenditures for the salary (including all allowences) of one worker, lewa/h; Q_1, Q_2 - actual productivity rate, pieces/h; M_{KH_1}, M_{KH_2} - cost price for one machining hour, lewa/h; n_1, n_2 - effective time of usage, years; θ - coefficient of adjustment of the capital investments to equal production programs; R -coefficient of updating (discounting) the production cost prices during the whole automated assembly systems implementation period ; N - time period for the capital investments repaiment,years; a - coefficient of discounting of the capital investments (annual percentage of the national currancy unit devaluation [7], avarage interest rate for long-term credits).

Indecies q and 2 concern the values of the performance features beforem resp. after the implementation of automated assembly systems.

In order to simplify calculations following presumptions are made:

- Capital investments are made in the form of a lump-sum at the beginning of the actual implementation period, while the savings (the difference between the production cost before and after implementing the automated assembly systems) are accounted for towards the end of each year;
- The time related changes in the saving sizes after the automated assembly systems implementation are not accounted for, they are regarded as equally allocated over the whole period;
- Disregarded are the fluctuations in the average annual interest rate as well as the percentage of devaluation of the national currency during the period of the automated assembly systems usage;
- At the end of the automated assembly systems employment period there is no remaining cost [6].

The assumption of (1), (2) or (3) depends on the home strategy of the automated assembly systems user aimed at an effective assignment and application of the company's resources:

- as long as the cost price is given a priority over the other performance features of the automated assembly systems the determination of the permissible capital investments amount is done in accordance with (1);

- as long as the capital investments reimbursement time is given a priority over the other performance features of the automated assembly systems the determination of the permissible capital investments amount is done in accordance with (2);

- whenever the automated assembly systems are implemented in intermediate Manufacturing processes where the achieved economic efficiency is not in the form of direct profit the determination of the permissible capital investments amount is done on the basis of the total updated expenditures made during the period of the automated assembly systems actual exploitation (3).

The equation for calculation of the automated assembly systems cost price is [7]:

$$M_{KH} = \frac{K_A + K_Z + K_I + K_R + K_E}{s.T_N} , \tag{4}$$

where:

$$K_A = \frac{K_{WB}}{n},\ K_Z = \frac{K_{WB}}{2} z,\ K_I = \frac{K_{WB}}{n} F ,$$

K_A, K_Z, K_I, K_R, K_E -annual expenditures for depreciation allowances, interest rates, maintenance and service activities, energy, facilities rents etc., lewa; s - number of working shifts, numb.; T_N - annual fund of actual working hours in the case of a one-workshift mode, h ; z - annual interest rates; F - coefficient, accounting for the repair and maintenance costs during the exploitation period.

The adequate transforming of (1), (2) and (3) results in the following equivalencies showing how to calculate the permissible amount of capital investments required to build the automated assembly systems according to the respective user's home strategy:

$$K_2 \le \theta.\frac{n_2^{\,2}}{n_1^{\,2}}.\frac{2 + z.n_1 + 2.F_1}{2 + z.n_2 + 2.F_2}.K_1 + \frac{2.n_2.(1+a)^{-n_2}}{2 + z.n_2 + 2.F_2}. \\ .\left[K_{M_1}.\theta.(1-\chi) + K_{R_1}.(\theta-\rho) + K_{E_1}.(\theta-\beta) + K_{P_1}.\sigma.\tau.(\alpha-\lambda.\gamma)\right] \tag{5}$$

$$K_2 \le \theta.\frac{n_2^{\,2}}{n_1^{\,2}}.\frac{2 + z.n_2 + 2.F_2}{2 + z.n_2 + 2.F_1}.K_1 + \frac{2.n_2.N.(1+a)^{-n_2}}{2.n_2 + N.(z.n_2 + 2.F_2)}. \\ .\left[K_{M_1}.\theta.(1-\chi) + K_{R_1}.(\theta-\rho) + K_{E_1}.(\theta-\beta) + K_{P_1}.\sigma.\tau.(\alpha-\lambda.\gamma)\right] \tag{6}$$

$$K_2 \le \theta.\frac{n_2^{\,2}}{n_1^{\,2}}.\frac{2.a.n_1 + (2 + z.n_1 + 2.F_1).[(1+a)^{n_2} - 1]}{2.a.n_2 + (2 + z.n_2 + 2.F_2).[(1+a)^{n_2} - 1]}.K_1 + \\ + \frac{2.n_2.(1+a)^{-n_2}.[(1+a)^{n_2} - 1]}{2.a.n_2 + (2 + z.n_2 + 2.F_2).[(1+a)^{n_2} - 1]}. \\ .\left[K_{M_1}.\theta.(1-\chi) + K_{R_1}.(\theta-\rho) + K_{E_1}.(\theta-\beta) + K_{P_1}.\sigma.\tau.(\alpha-\lambda.\gamma)\right] \tag{7}$$

where:

$\alpha = \frac{Q_2}{Q_1}$ - coefficient, accounting for the rise in the actual productivity of automated assembly systems;

$\beta = \frac{K_{E_2}}{K_{E_1}}$ -- coefficient, accounting for the relative changes in the annual energy expenditures;

$\gamma = \frac{PK_2}{PK_1}$ - - coefficient, accounting for the relative salary increase of the automated assembly systems operator;

$\rho = \frac{K_{R_2}}{K_{R_1}}$ - - coefficient, accounting for the relative decrease in facilities rents expenditures;

$\sigma = \frac{s_2}{s_1}$ - coefficient, accounting for the relative decrease in the number of working shifts;

$\tau = \frac{T_{N_2}}{T_{N_1}}$ - coefficient, accounting for the relative increase in the actual working hours;

$\chi = \frac{M_2}{M_1}$ - coefficient, accounting for the relative fluctuations in materials expenditures;

$\lambda = \frac{P_2}{P_1}$ - coefficient, accounting for the relative decrease in the number of automated assembly systems operators;

K_{M_1}, K_{P_1} - annual expenditures on salaries and materials.

In the displayed equivalencies the permissible investments are determined by way of conveying relative changes in basic automated assembly systems features (actual performance capacity, working facilities, energy costs, number of operators etc.) compared to the situation prior to the systems implementation. The suggested approach considers the actual exploitation duration, the annual interest rates, the reimbursement term as well as a number of further influencing agents.

3. CONCLUSIONS

The present paper offers functional equivalencies serving the purpose of determining the permissible amount of capital investments securing economic cost-effectiveness of automated assembly systems and taking into account the specific strategies of the single users. The equivalencies used on early design stages can support the decision-making concerning any capital investments as well as the preliminary choice of the assembly systems type.

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