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CPR a general Cost Performance Ratio in Manufacturing - A KPI for judgement of different technologies and development scenarios

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Abstract

Several parameters and variables affect the production cost and the company competitiveness. The manufacturing part cost is directly influenced by factors related to tools, workpiece materials, equipment, personnel, automation, etc. These factors also have a significant influence on the manufacturing efficiency and performance. The presented model determines the production performance with respect to the actual cost for each factor involved. The CPR relationship sets the cost of a given factor in relation to its production performance. CPR may be used to evaluate or find optimal technical solutions with respect to individual factors.

Keywords: Manufacturing cost; performance ratio; machining; development scenarios; CPR; production system evaluation

1. Introduction

In today´s companies, the production cost has a large impact on the company competitiveness, especially because of the globalized market with effective information flows. The production cost depends on multiple parameters and variables, where several of them are strongly cross-dependent on each other.

This publication addresses production cost and Cost Performance Ratio (CPR). The CPR parameter aims to describe a cost for e.g. a cutting tool, workpiece material, machine units with respect to their performance and to the user value. The presented model, if applied to metal cutting, can identify production cases where the use of more expensive cutting tools may result in lower production costs. The same type of investigation can be made for machine units, where more expensive machines with better performance can result in lower total cost, as compared to less expensive machines with poorer performance. The above mentioned issues are essential when considering manufacturing location decisions and could also be used as a support regarding pricing of products. An example of that is related to a newly developed metal cutting tooling, where the price is related to its performance in comparison with other tools on the market.

Nomenclature

CPR	Cost Performance Ratio
k	part cost
K_0	investment
k_A	tool costs
k_B	material costs
k_{CP}	hourly equipment costs running
k_{CS}	hourly equipment costs downtime
k_D	hourly personnel costs
k_{Ref}	part cost in reference system
k_{ren}	renovation costs
MD	annual market demand
N_0	batch size
n_{MU}	number of parallel machine units
n_{op}	number of personnel connected to the process
q_B	material scrap
q_P	speed loss rate
q_Q	quality loss rate

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q_S	downtime rate
t_0	cycle time
T_p	production time
T_{plan}	planed and paid production
T_{su}	set-up time
U_{RP}	production capacity utilisation (occupancy degree)
κ_{CPR}	CPR index

1.1. Background

The complexity of a production system unfortunately often results in sub-optimisations, resulting in improvements made in one part of the system leading to increased cost in another part. The negative effects can often be related to different production process steps but also within the same processing step, for example cheap cutting tools resulting in longer cycle times.

According to Askin and Subramanian [1] and later on Needly et al. [2], the selection and evaluation of systems and system configurations should be based on economic decisions. Rane et al. [3] state that when improving performance it is helpful to find and develop a relationship between parameters and their corresponding costs. Further Badiru [4] states that decisions based on multivariable analyses, generally are more reliable than decisions made on single factor analysis, suggesting that the decision support for production should involve several parameters and variables.

According to the result from a survey presented in Brierley et al. [6] a majority of the companies partaking considered product cost very important or important for investment in new production processes respectively when deciding a product´s selling price.

The presented model of Cost Performance Ratio (CPR) is a comprehensive economic investment assessment support based on technical production variables and parameters. This type of analysis strengthens the link between technology and economy thus giving a unique approach. The work is based primarily on a previously published generalistic breakdown production part cost-model [5].

1.2. Goals and objectives of the CPR

A CPR index can be used for evaluation of different alternative technical solutions using serval different parameters, as for example batch size N_0, annual market demand MD, cycle time t_0, tool cost k_A, or workpiece material cost k_B with a given producibility or distribution in producibility. The assessment could be relative or absolute in comparison with the current or previously used reference system and may include one or several processing steps. In the assessment, the part cost of different production systems could be presented as functions of different specific production parameters.

When addressing the question of CPR calculation the aspects of company integration are a relevant issue. It concerns vertical, horizontal and cross-functional integration according to Fröberg et al. [7]. This can be exemplified with e.g. the relations between costs and performance for the factor groups (A) Tools, (B) Workpiece material, (C) Processes and equipment, (D) Personnel and organization, (E) Maintenance, (F) Quality assurance and specific factors, and (G) Peripherals, internal material handling and buffers. The relationship between factor groups A, B, and C are exemplified in Fig. 1. In Fig. 1 the process performance and capability are represented by three main parameters: quality rate losses q_Q, downtime rate q_S, and production pace/cycle time t_0. In addition to these three main parameters, environmental and eco-cycle parameters are often used. These additional parameters describe an environmental load by production process with costs related to them in a direct or indirect way. Material scrap (material losses) in the production process q_B, results in a material cost, often caused by factors in the factor group C.

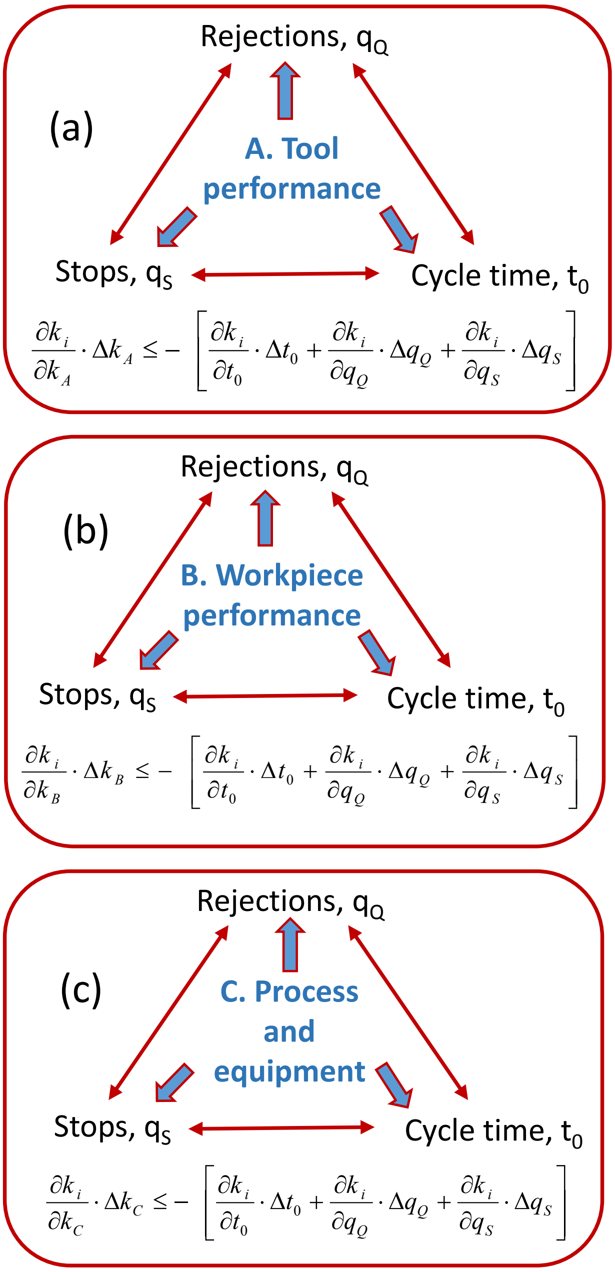

Fig. 1. Examples on relationships for the factor group A (a), B (b) and C (c) and the result parameters of quality rate losses q_Q, downtime rate q_S and cycle time t_0.

The mathematical relations in Fig. 1, require independence between q_Q, q_S and t_0, which rarely is the case. The error of not considering such interdependence is from our experience is less than 5 percent, for small changes in the result parameters. Lager errors may occur in the model in extreme cases for a distribution function, which is described in Ståhl [8]. With use of Monte-Carlo simulations [8], known dependencies of e.g. production pace and quality losses can be handled.

1.3. Delimitations

This paper is only presenting a model for CPR and does not include any case studies. The model has been implemented twice in industry, first for value analysis of metal cutting tooling and second for production system evaluation. Due to confidentiality, none of the two implementations are presented here. Further research has to be conducted regarding error analyses and sensitivity analyses of the accuracy of the input parameters in the model.

2. Breakdown part cost-model

The cost-model used to estimate the CPR is a performance driven process-based breakdown part cost-model and was first published by Ståhl et al. [5] and further developed for simulations by Jönsson et al. [9]. During the last decade, the model have been used in over hundred research publications and master thesis, among others specialized for cost estimation of metal cutting. The equipment cost is based on annuity of equipment investments, floor area used, maintenance and repair cost, and energy cost. The equipment cost is divided on whether the equipment is running or in downtime. Equations for hourly equipment costs can be obtained in [5]. A simplified version of the model is presented in Eq. 1.

$$\begin{aligned} k = {} & \frac{k_A}{N_0}\left(\frac{N_0}{(1-q_Q)}\right)_A + \frac{k_B}{N_0}\left(\frac{N_0}{(1-q_Q)(1-q_B)}\right)_B + \\ & + \frac{k_{CP}}{60N_0}\left(\frac{N_0 \cdot t_0}{(1-q_Q)(1-q_P)}\right)_{C1} + \\ & + \frac{k_{CS}}{60N_0}\left(\frac{N_0 \cdot t_0}{(1-q_Q)(1-q_P)} \cdot \frac{q_S}{(1-q_S)} + T_{su} + \frac{1-U_{RP}}{U_{RP}} T_b\right)_{C2} + \\ & + \frac{k_D}{60N_0}\left(\frac{N_0 \cdot t_0}{(1-q_Q)(1-q_P)(1-q_S)} + T_{su} + \frac{1-U_{RP}}{U_{RP}} T_b\right)_D + \\ & + k_E + k_F + k_G \end{aligned} \tag{1}$$

The annual and demanded production time to produce MD number of parts is estimated with the use of Eq. 2.

$$T_p = \frac{T_{su} \cdot MD}{N_0} + \frac{MD \cdot t_0}{(1-q_Q)(1-q_S)(1-q_P)} \tag{2}$$

The utilization U_{RP} of the production system with regards to the reduced production can be estimated according to Eq. 3, using required number of parallel machine units, n_{MU}. Where, the mathematical function "trunc" gives the integer part of the current quota and T_{plan} is the planned production time.

$$U_{RP} = \frac{T_p}{T_{plan}\left[1 + trunc\left(\frac{T_p}{T_{plan}}\right)\right]} \tag{3}$$

The required number of parallel machine units, n_{MU} is estimated according to Eq. 4.

$$n_{MU} = 1 + trunc\left(\frac{T_p}{T_{plan}}\right) \tag{4}$$

3. The definition of a CRP

As mentioned before, the CPR can be absolute or relative in comparison to a current or given reference system. Depending on the area of application, several different CPR versions can be formulated. The CRPs can be organized with respect to whether all costs in the cost equation are known (Category I) or the cost information is incomplete (Category II). The two categories can be described as follows:

(I) The ratio between the estimated part cost of the reference system and the new system for evaluation gives CPR. The estimated ratio can be a function of one or several production parameter or variables. Interesting parameters could be yearly demand (MD) and batch size (N_0).

(II) The CPR is related to a reference system, where the ratio between the studied parameters for the reference system and the investigated system is calculated based on a cost neutral relation with respect to the estimated part cost. Different systems and configurations have different performance and capability related to the different factor groups and the CPR is used to find the maximal possible investment, giving an equal or lower part cost compared to the reference system. Examples of issues for respective factor group could be:

A. What is the maximal cost of the new tooling system (k_A)?
B. What is the maximal cost of the new workpiece material (k_B)?
C. What is the maximum investment (K_0) in the new equipment or the maximum hourly equipment cost (k_C)?
D. What is the maximum cost of an enhanced personnel and organization change ($n_{op} \cdot k_D$)?
E. What is the maximum cost of a new maintenance strategy (k_E)?
F. What is the maximum cost of a new or altered quality assurance system (k_F)?
G. What is the maximum cost of handling system and buffer stock (k_G) giving a lower or equal part cost compared to the reference system?

In category I all costs are known. In the analysis, only costs directly related to a specific product or product group are included, overhead and indirect cost are excluded.

The definition of a category I CPR can be estimated as:

$$\kappa_{CPR}(MD) = \frac{k_{Ref}(MD)}{k_i(MD)}, \tag{5}$$

where k_{Ref} is the part cost of the reference system and k_i is the estimated part cost of the production system i = 1, 2,...N. For values of $\kappa_{CPR} > 1.0$ a production system with a lower part cost is obtained and for values < 1.0 the opposite. In Eq. 5, the annual market demand (MD) has been used as an example of a parameter/variable. Other possible variables are technical life of equipment and the cost of capital.

Fig. 2 presents the production cost of one reference system and three optional developments of the system resulting in different performance. In the current case, the hourly equipment cost k_C differs between the system and correspond to from 1000 [SEK/h] for the reference system to 1500 [SEK/h] for system 2 and 3 because of the different required investment levels. In Fig. 3 the different input parameters are presented. In system 1 a slightly lower personnel cost is obtained due to different system configuration.

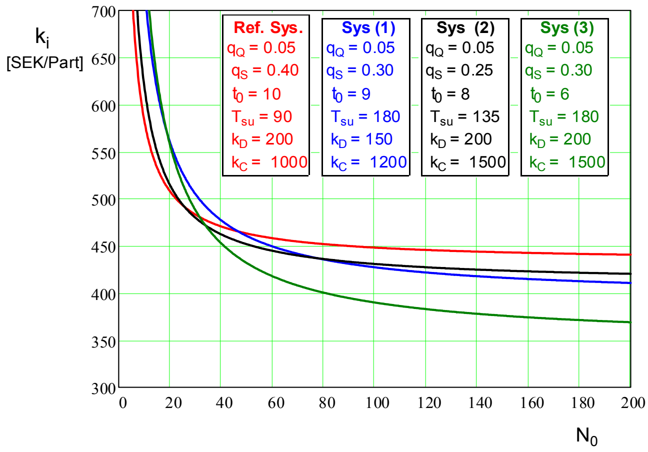

Fig. 2. Example of the part cost [SEK/part] for a current reference system and three alternative developments of the production system, which results in different performance and production costs as a function of the batch size N_0. In the example the system is considered to be fully occupied $U_{RP} = 1.0$.

In the diagram in Fig. 2, it is seen that the reference system (red) is competitive when the batch size is smaller, $N_0 < 20$. For batch sizes larger than 30, system 3 shows the best potential. It is also possible to make this conclusion from Fig. 3, where CPR (κ_{CPR}) for these four system is presented. All values of the CPR above 1.0 correspond to a better alternative than the reference system, which in Fig. 3 is represented by the horizontal line.

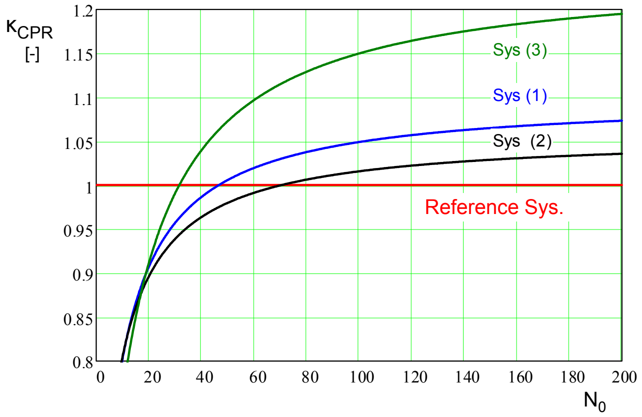

Fig. 3. Examples of CPR (κ_{CPR}) of a current production system (Reference Sys.) and three alternative system developments, as function of the batch N_0, using full occupancy, $U_{RP} = 1.0$.

Important to notice is that the result from the investigation above is strongly dependent of the market demand and the efficiency improvements made on the system. Especially, if the improvements results in lowered cycle time (t_0), thus affecting the occupancy degree of the equipment. It is also important to emphasise that there is a correlation between optimal economic order quantity (EOQ) and fluctuations in market demands.

When selecting development options, assessment regarding set-up time (T_{su}) and associated ramp-up costs (q_S, q_Q, q_P) for respective batch have to be made in comparison to the reduced cycle time t_0. To gain optimal processing time the batch size has to be regulated and to handle the variation in the market demand some stock leading to storage cost and tied capital is necessary.

In category II all cost associated to the reference system are known. The reference system is preferably an established and currently used system that to some extent or overall is challenged by a new technology which is deemed as a potential solutions for cost efficiency. The CPR is then used to investigate cost neutral alternative within the factor groups A-G according to above given list. If the obtained CPR value is larger than 1.0 the cost of the part produced in the alternative system is lower than in the reference system. If CPR<1.0 the reference system still is the best alternative from an economic perspective. Category II CPR is best suited for evaluation of smaller and specific changes in the system connected to one of the factor groups, for example purchase of cutting tools, workpiece material, cutting fluids, or peripheral equipment, etc.

A general CPR for category II can be estimated according to Eq. 6. Where κ_{jCPR} is the general CPR for one of the input parameters in the factor group j = A-G, and as a function of a parameter/variable z and for the new alternative system i.

$$\kappa_{jCPR}(z) = \frac{k_{jRef}(z)}{k_{ji}(z)} \tag{6}$$

In general the cost related to a factor group j = A-G and a system i can be estimated as given in Eq. 7. In this case all costs related to the reference system (k_{Ref}) have to be known, such as the cost of the specific investigated factor group k_j, which could e.g. be tool cost k_A or equipment cost k_C. The cost k_{ji} is dependent on the parameters/variables that control the part cost and hence include the performance according to equation 1.

$$k_{ji} = \left[k_{Ref}\left(k_j = k_{jRef}\right) - k_i\left(k_{ji} = 0\right)\right] \tag{7}$$

In Fig. 4, representation of k_{ji} is made with the use of k_{Ai} and k_{Bi}. The CPR according to Eq. 6 can be estimated from the values found in Fig. 4.

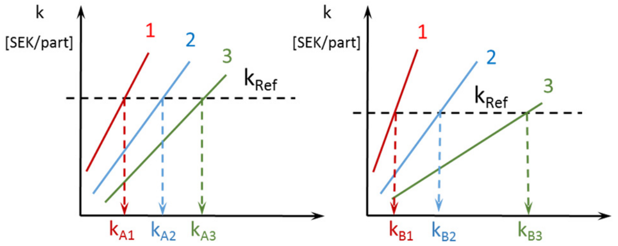

Fig. 4. Part cost [SEK/part] as a function of the neutral cutting tool (left) and work material (right) cost, where the production part cost for the reference system corresponds to k_{Ref}.

4. Application and examples of use of CPR

In this section, examples of application areas are presented. The first, related to category I CPR is a comparison of three new equipment concepts with a reference system. The last two examples are related to category II CPR, the first investigating the maximum cost neutral investments level of equipment with respect to performance and the second maximum cycle time in relation to the investment level K_0. In all three cases, the reference system use well-established and known technologies.

4.1. Example of a direct part cost related CPR of category I.

The example concerns the mass production of an electrical needle in four diversified production systems, where one of the systems act as a reference. The reference system is in use today and is challenged by the three other alternative systems. The current study has been performed to find new possibilities for strengthened competitiveness on a global market.

All investigated systems include several alike parallel machine units. Number of machine units (n_{MU}) is dependent on cycle time (t_0), annual planned production time (T_{plan}), losses (q_i) and yearly demand (MD) of the actual product. This is exemplified in Fig. 5. In the assessment, no concern is given to the synergy effects of operation, neither maintenance is taken into consideration. In this concern, only system 2 is sensitive to such influence, as it involves only two machines to manufacture 20,000,0000 products on an annual basis.

The reference system consists of older equipment with a relative long cycle time t_0, while the maintenance and repair costs increase on a yearly basis as the equipment ages. In relation to the other more modern systems, the reference system has a low cost connected to the investment.

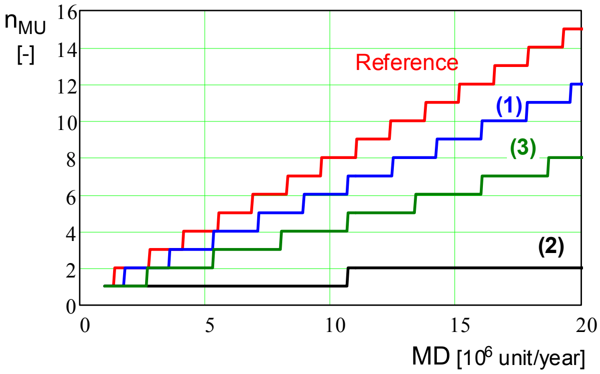

Fig. 5. Number of machine units n_{MU} required to satisfy a given yearly demand MD for each of the studied production system.

System (1) is modernised version of the reference system. The cost related to needed investments is moderate and the cycle time relatively low, but not considerably lower than the reference system. However, the system have lower maintenance costs and better quality output.

System (2) is made of specialized machines with extreme performance giving very low cycle time, while the cost of investment is high. This system will be very sensitive to the fluctuations in demand, which is illustrated in Fig. 7. The production cost will increase radically with low occupancy, which is illustrated in Fig. 8. Hence, when using full capacity (MD = $10.7 \cdot 10^6$ products) the lowest production cost is achieved, including all systems investigated, illustrated in Fig. 7.

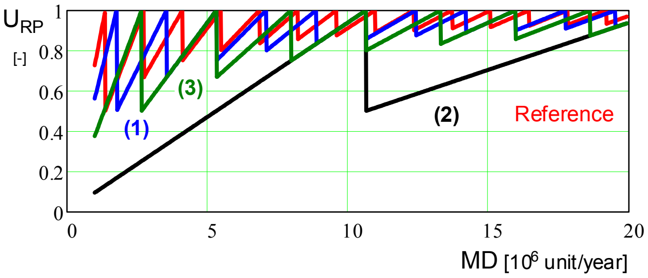

Fig. 6. The utilization rate U_{RP} for the studied system and as a function of assumed yearly demand MD.

System (3) is composed of specialized machine units and is closest related to system (2). Both cycle time (t_0) and investments (K_0) are moderate.

An important issue to arise is the capability to assess the yearly demand of the needle. In the study it was found that system (2) and (3) would be hard to occupy with other products if there was a decrease in demand, due to the direct specialization of this type of machinery. System (2) would be highly sensitive to reduced production, while system (3) better would cope with the decrease in demand.

In Table 1, the nine most important parameters for each of the four systems are presented. In total over 20 parameters and variables are included in the analysis based on the breakdown cost per part approach presented in Fig. 7 and Fig 8.

There are three reasons for the discontinuously behaviour of the curves showed in the figures.

1) When there is an increase in the demand, an additional equipment is required, thus giving higher capacity, yet resulting in a lower utilization rate. The phenomena is especially apparent in Fig. 6 and Fig. 7 for system (2) where the production cost doubles when a second machine unit is added and occupancy degree is reduced to half. With the increased number of machine units such effect will decrease with the increased demand.

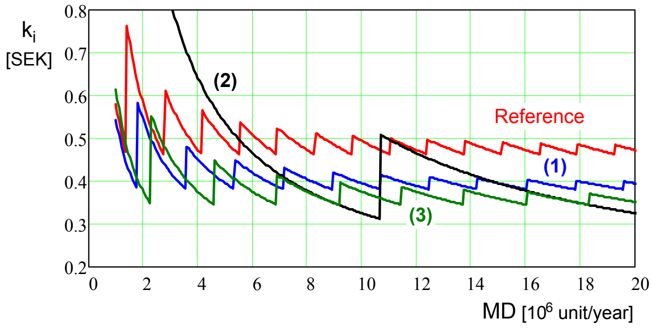

Fig. 7. Example of estimated part cost k_i [SEK], for the reference system (red) and the three new alternative production system 1 (blue), 2 (black), and 3 (green) as a function of the yearly demand MD.

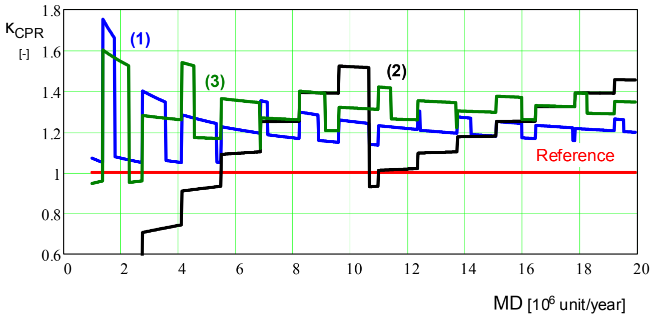

Fig. 8. Examples of estimated CPR (κ_{CPR}) for each of the studied systems, reference system (red), 1 (blue), 2 (black), and 3 (green) as a function of the yearly demand MD.

Table 1. Important data for each of the system used in the analyses.

	Description	Unit	Ref.	Sys (1)	Sys (2)	Sys (3)
k_{ren}	Renovation costs	[-]	0.5	0.1	0.1	0.1
K_{ph}	Dynamic costs per hour	[SEK/h]	20	30	80	40
q_Q	Quality losses, rejection rate	[-]	0.06	0.03	0.03	0.03
q_B	Material losses	[-]	0.05	0.05	0.03	0.15
q_S	Downtime, disturbances	[-]	0.20	0.10	0.10	0.10
K_0	Investment/unit	[MSEK]	0.20	1.5	10	2.5
t_0	Cycle time	[s]	12	9	1.5	7
$n_{op}\cdot k_D$	Personnel costs	[SEK/h]	280	280	280	280
T_{plan}	Working hours per year	[h]	6100	5100	5100	5100

2) Due to the needs of equipment renovation occurring after a certain number of production hours the cost of the equipment will also increase stepwise.

3) The CPR is based on two discontinuous functions, and when they are divided with each other it results in an even more discontinuous function having higher frequency than the two functions involved. The increase in frequency of the function for the CPR can be observed in Fig. 8. The behaviour of the cost functions, when compared to Fig. 7, has higher frequency.

4.2. Examples of performance and value-based analysis of category II CPR

Assuming that the investment K_0 from previous example are unknown, the maximum investment for each alternative can be put in relation to the cycle time of the system in question. The neutral part cost from the reference system gives 0.47 SEK/part at MD = 20,000,000 part/year, as exemplified in Fig. 9.

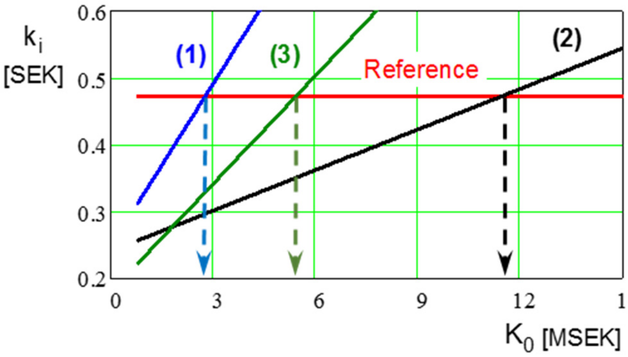

Fig. 9. The cost neutral investment level K_0 [MSEK] in relation to the reference system (red) with respect to the performance to each of the systems, 1 (blue, 2.8 MSEK), 2 (black, 11.5 MSEK), and 3 (green, 5.4 MSEK) for assumed yearly demand MD = 20,000,000 parts/year.

In Fig. 10 the level of investment K_0 is assumed as a fixed given value on which the cycle time resulting in a neutral cost in relation to the reference system is estimated. All cycle times lower than the cost neutral cycle time will result in a lower production part cost, than the one in reference system.

In Fig. 11 the CPR (κ_{t0CPR}) is a function of the cycle time t_0. The values of CPR for each of the systems is given on the y-axis, the horizontal line in the figure shows the CPR for each of the systems assumed t_0. If the cycle times can be reduced, then the value of the CPR will increase and result in a lower part cost.

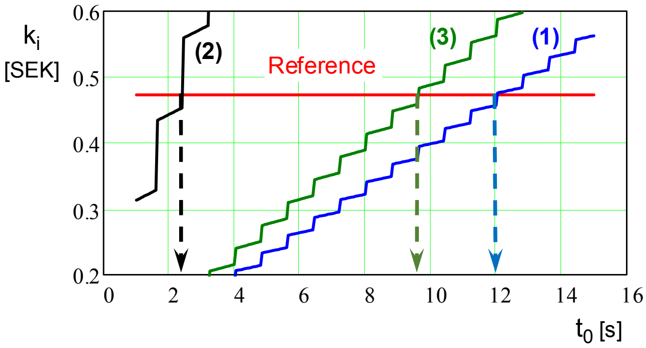

Fig. 10. The cost neutral cycle time t_0 [s] in relation to the reference system (red) with respect to a given investment level for the studied production systems, 1 (blue, 12.05 s), 2 (black, 2.45 s), and 3 (green, 9.65 s) for assumed yearly demand MD = 20,000,000 parts/year.

If the parameters and variables used for analysis of the production cost and the CPR are also affecting the production capacity, then the equipment utilization will also be affected similarly to the number of needed machine units n_{MU}. This is exemplified in Fig. 12.

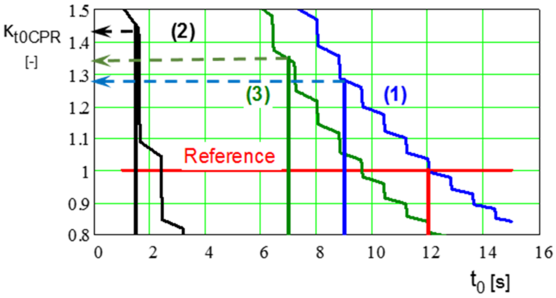

Fig. 11. CPR (κ_{t0CPR}) concerning the cycle time t_0 [s] in relation to the reference system (red) for a given investment level K_0 for the studied production systems with t_{0Ref} = 12 s, System 1 (blue, 9 s), System 2 (black, 1.5 s), and System 3 (green, 9 s) (vertical lines).

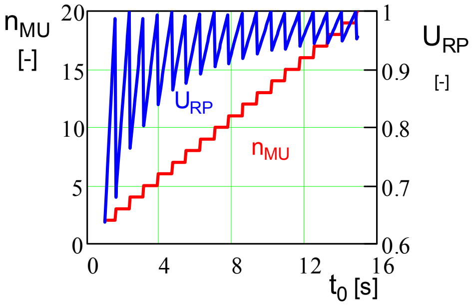

Fig. 12. Behaviour of the production capacity utilization U_{RP} and the number of used production units n_{MU} as a function of the cycle time t_0, for a given yearly demand MD.

6. Discussion and conclusions

A CPR is used to assess improvements in current production systems. It is done by comparing different alternative systems with the current one in use, but also for comparison of organizational solutions. The primary use is to assess alternative technologies and production systems with high complexity. The CPR creates the relationship between the performance and costs of alternative technologies to produce a given part or a product. This enables comparison of different scenarios based on their competitiveness. The CPR value above 1.0 results in enhanced competitiveness in relation to the reference system. It is envisaged that a CPR, for conventional technologies, will be within the range 1.0-1.5, thus giving maximum 50 % improvements in regards to the production cost. Disruptive changes of technology could result in higher values of the CPR.

Improvements can be applied to the entire system or delimited parts. In this paper two different categories of CPR have been identified: Category I, where all costs and performance are known, and Category II where a parameter has to meet specific demands in a given solution to result in enhanced competitiveness. This analysis can be made based on the defined factor groups A-G, which have a considerable influence on the production system performance and the related costs.

As in many other contexts, it is essential that the input information to the models is reliable and correct [10]. This paper has identified the most important parameters for system evaluation, both for short and long-term perspectives. If the demand is large enough for one product to be produced in one system, resulting in no change over time, the improvements can be aimed towards shorter cycle times, reduced scarp rate, downtime, and quality losses. The yearly demand is affecting the number of changeovers in the system between products, but it is also indicates in how many years the investment can be divided on. The part cost is highly depended on yearly demand and number of year the parts have on the market, as it is the base on what investments and cost of renovation is dived on. This issue has a considerable uncertainty. Because the price, demand, quality, etc. are not deterministic entities [11], further research has to be conducted regarding error analyses and sensitivity analyses of the accuracy of the input parameters using with the use of statistical distributions.

Based on the CPR, it is reasonable to assume that if there is a shortage in knowledge and documented experience of the company's current production system, the company miss necessary references to evaluate performance of other systems. The concept of CPR and cost breakdown approach can also be applicable when making decision on production location/relocation and make or buy evaluations.

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References

[1] R.G. Askin, S.P. Subramanian, A cost-based heuristic for group technology configuration, Int. J. Prod. Res. 25 (1987) 101–113.
[2] K.L. Needy, R.E. Billo, R. Colosimo Warner, A COST-MODEL FOR THE EVALUATION OF ALTERNATIVE CELLULAR MANUFACTURING CONFIGURATIONS, Comput. Ind. Engng. 34 (1998) 119–134.
[3] A.B. Rane, V.K. Sunnapwar, S.M. Khot, Cost-model for improved vehicle assembly line perfromance, Int. J. Simul. Process Model. 12 (2017) 111–123.
[4] A.B. Badiru, Manufacturing Cost Estimation: A Multivariate Learning Curve Approach, J. Manuf. Syst. . 10 (1991).
[5] J.-E. Ståhl, C. Andersson, M. Jönsson, A basic economic model for judging production development, in: 1th Swedish Prod. Symp., 2007.
[6] J.A. Brierley, C.J. Cowton, C. Drury, A NOTE ON THE IMPORTANCE OF PRODUCT COSTS IN DECISION-MAKING, Adv. Manag. Account. 15 (2006) 249–265.
[7] P. Fröberg, D. Carlsson, J.-E. Ståhl, How to improve cooperation within and across organizational dimensions using Company Integration, in: 7th Swedish Prod. Symp., 2016.
[8] J.-E. Ståhl, Development of Manufacturing Systems – The link between technology and economics, Lund University, Lund Sweden, 2016.
[9] M. Jönsson, C. Andersson, J.-E. Ståhl, A General Economic Model for Manufacturing Cost Simulation, in: Proc. 41st CIRP Conf. Manuf. Syst., Springer London, London, 2008: pp. 33–38. doi:10.1007/978-1-84800-267-8_7.
[10] R. Cooper, R.S. Kaplan, Measure Costs Right: Make the Right Decisians, Harv. Bus. Rev. 66 (1988) 96–103.
[11] S.W. Wallace, Decision Making Under Uncertainty: Is Sensitivity Analysis of Any Use?, Oper. Res. 48 (2000). doi:10.1287/opre.48.1.20.12441.