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Juraj DUBOVEC
University of Žilina, Faculty of management science and informatics
Univerzitná 8215/1, 01026 Žilina, Slovakia
Corresponding author. E-mail: juraj.dubovec@fri.uniza.sk

INFLUENCE OF COMPLEXITY ON THE MARGINAL LOGISTICAL COSTS

Summary. In the article is described the influence of complexity on the logistical operations. Ideal example is the exchange of storage in the system "kanban", which has complexity equal one. Clients directed production increases the consumption of time in logistics within manipulation with critical parts, when the ratio isn't equal to multiple capacity relevant storage. Economical consequence is the increase of costs.

WPŁYW ZŁOŻONOŚCI NA MARGINALNE KOSZTY LOGISTYCZNE

Streszczenie. W artykule opisano wpływ złożoności na działania logistyczne. Idealnym przykładem jest wymiana pamięci w systemie „kanban”, który ma złożoność równą jeden. Centralnie skierowana produkcja zwiększa zużycie czasu w logistyce w ramach manipulacji ważnych elementów, kiedy rotacja nie jest równa wielorakości zdolności właściwego przechowywania. Ekonomiczną konsekwencją jest wzrost kosztów.

1. THEORETICAL INTRODUCTION

The Complexity in the strict sense is determined by the number of elements (exp. components) that exist between elements [4]. It can be internal (from the company's inside), or external (from the market). The number of potential or realized combinations still may not have direct impact on logistical performance, it depends on how many combinations are realized per unit of time and also on the order in which various combinations follow each other on the production line. The design of the line and assembly procedures provides in which part of the line will be the component mounted [2]. With regard to work space limitations and divisions of labor between the assembly plant and the suppliers is decided which aggregates will be pre-mounted in the plant and which in the needed order will be supplied by the suppliers direct on the assembly line and perform sequential picking (commissioning) [1].

In this ideal example the necessary logistic performance to supply the components from the storage to the assembly line can be estimated from the size of production from these parameters:
R – set of components, from which are the cars made,
J_r – type of components $r \in R$,
K_j – capacity of the magazine, in which is the stored part j,
n – number of cars assembled,
n_j – number of cars assembled in which was the type j of the part r used.

Required ideal logistical operation counts, where one operation is picking up the mag from storage, its transport to the assembly line, taking the empty away, its transport to decided place and the return of the manipulating unit to its starting position is:

$$p = \sum_{r \in R} \sum_{j \in J_r} \lceil n_j / K_j \rceil \qquad (1)$$

However, this applies only if the max is transported to the line and will stay there until its fully emptied and then will be changed for a full one (kanban) [3]. This example will be the ideal one.

In cases where the complexity of the production is high, *Jr* contain many types of the parts *r* and cars with identical types of parts do not come on the line in large series, but they're alternating, makes up a situation in which by one tract will have to stay at the same time in the magazine for every type $j \in J_r$ of the mounted part *r*.

Since this is not possible due to work space limitations it is solved in the following way.

The part is allocated for sequential commissioning in places away from the assembly line, or it's commissioned direct on the line [6].

In the first case (sequential commissioning) is competent action for the part *r* requires the same operation count for mag supply as the ideal example.

$$\sum_{j \in J_r} \lceil n_j / K_j \rceil \qquad (2)$$

Additionally it needs $\lceil n / K \rceil$ operations for moving commissioned mag with the *K* capacity from the place of commissioning to the main line and also requires labor which will perform commissioning. By doing so, logistic performance (provision of parts *r* to the assembly line) will become independent on alternating types of parts in sequence on assembled vehicles. [5].

The second case (commissioning direct on the line) will not require additional workspace and labor, but it will rise the count of logistic operations.

For the analysis we´ll define for the part *r:*

p_j – number of removals (supplies for the line) type *j* for period of time

$m_{ji} i = 1, ..., p_j$ –number of removal in the *i* delivery

Then the number of parts type *j* mounted in the vehicles for the period of time:

$$n_j = \sum_{i=1}^{p_j} m_{ji} \qquad (3)$$

$\lceil n_j / K_j \rceil$ defines the minimum count for the delivery of the type *j* for period of time. The number of deliveries, which will be the same as the ideal example. The next model defines the necessary operation count as the ideal example [6].

For the part *r* then total operation count for the period of time will be:

$$\sum_{j \in J_r} \left(p_j - \left\lceil \sum_{i=1}^{p_j} m_{ji} / K_j \right\rceil \right) = \sum_{j \in J_r} p_j - \sum_{j \in J_r} \left\lceil \sum_{i=1}^{p_j} m_{ji} / K_j \right\rceil \qquad (4)$$

2. ESTIMATING THE COMPLEXITY OF THE PRODUCTION

Every type of the part *r* is transported in the magazine with K_j capacity. The production complexity from the looks of one part:

$$\frac{\sum_{j\in J_r}\sum_{i=1}^{q_j}\lceil O_{ji}/K_j\rceil}{\sum_{i=J_r}\left\lceil\sum_{i=1}^{q_j}O_{ji}/K_j\right\rceil} \tag{5}$$

This equals 1 as long as dose levels of types of components equals times the capacity of the magazine, which includes cases when the max capacity is 1. In other examples is more than 1 and grows with the theoretical manipulation counts.

Total production complexity in the relationship with logistics can be written as the sum of complexity through every parts *R*:

$$\sum_{r\in R}\frac{\sum_{j\in J_r}\sum_{i=1}^{q_j}\lceil O_{ji}/K_j\rceil}{\sum_{j\in J_r}\left\lceil\sum_{i=1}^{q_j}O_{ji}/K_j\right\rceil} \tag{6}$$

In real analysis we found that in addition to manufacturing complexity of one vehicle there is also other complexity alternating types of vehicle parts on the line, which doesn’t affect the production but directly affects the intensity of logistic processes resulting in increased demand for logistic workers [6]. The first case the necessity of sequential commissioning and resulting in more consumed labor time. The second case complexity is commissioning direct on the line which is less operations (orders) and thus indirectly on the consumed time.

In the past analysis proposed a method of quantitative evaluation of complexity [4], of the parts flow and was shown that the value of the criterion may help identify critical parts (parts with value more than 1) where it would be possible to reduce consumed labor time either by moving parts commissioned on the line between sequential commissioning parts, or increasing workspace by the line for this critical part.

Minimal contribution to the complexity of logistic activities had parts which complexity was 1. Critical parts with value more than 1 documented the impact of complexity, which significantly affects the logistics performances (some parts valued from 2 to 4) [6].

3. CONCLUSIONS

Results of the analysis of logistics activities shown increasing trend of complexity and the increased demands on operating systems (irregular alternation of different types of the same part in the sequence of vehicles on the line is by logistics non-influence able factor) [1]. Customer production method is causing irreparable complexity, which by limited workspace on the line causes increasing real needed time (we´ve identified group of operations that are increasing the overconsumption time) [6].

Effect of irregular rotation of types by limited logistics workspace by the assembly line is giving us two possible consequences on consumed time in logistics [4]. In the first case are irregular rotations of types forcing to sequential commissioning and this will require labor time of worker who will do this. In the second case are irregular rotations of types require commissioning on the line followed by more orders in comparison with the ideal example (2).

Logistic problem, which results from complexity of ensuring production requirements, we can formulate in three relationships [5]:

• Consumption of time on certain logistics activities (overlaboring) equals complexity of production requirements

$$\Delta VZ = \Delta Tn \tag{7}$$

ΔVZ change in time consumption VZ, ΔTn extra time needed for certain activities. We expect, that *Tn* depends on the complexity.

In this case increasing complexity of production requirements reflected proportionately on the time consumption and operating activities. Situation did not improve or impair.

• The rate of overlaboring (work time consumption on certain operations) is lesser than the change of complexity production requirements

$$\Delta VZ \prec \Delta Tn \quad (8)$$

In this case increasing complexity of production requirements reflected by reducing over-consumption time and logistic operations have improved the situation of efficient procedures

• The rate of overlaboring (work time consumption on certain operations) is higher than the change of complexity production requirements

$$\Delta VZ \succ \Delta Tn \quad (9)$$

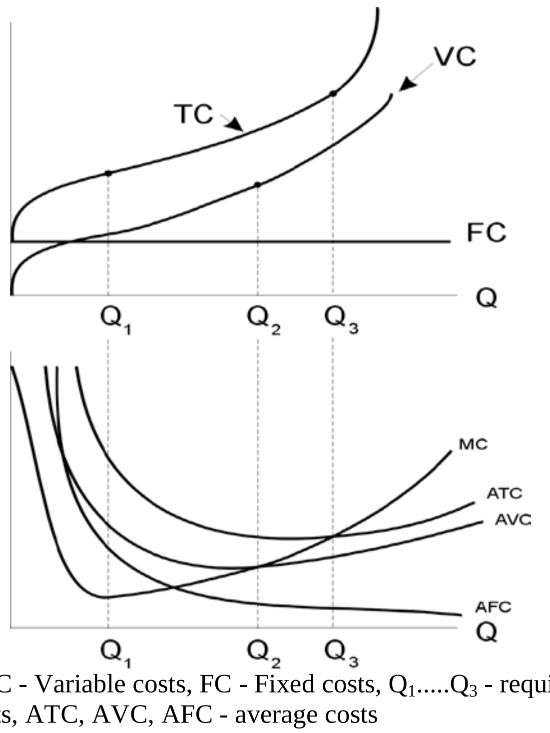
In this case increasing complexity of production requirements reflected by rising over-consumption time and logistic operations have worsened situation by inefficient activities.

All logistics activities have their reflection in the costs and often are those costs non-identifiable by accounting system [4]. The complexity causes increasing *variable costs* (VC). Costs that will change with the level of output (labor costs, energy consumption). *Marginal costs* (MC) are costs needed to secure additional units (requirements)

$$MC = \frac{\Delta TC}{\Delta Q} \quad (10)$$

In where ΔTC means the change of the total costs and ΔQ the change of requirements (complexity). Fixed costs don’t affect the marginal costs. Marginal costs are determined only by variable costs [5].

The changes of complexity (rising) causing that from certain point providing additional requirements causes costs, which doesn’t have direct relationship to the requirements (linear trend), but the marginal costs rising faster. Faster growths in costs are causing coordination and communication problems [3]. Complexity costs can be illustrated by following model – Fig. 1.



TC - company’s Total costs, VC - Variable costs, FC - Fixed costs, Q_1.....Q_3 - requirements for logistic operations, MC - Marginal costs, ATC, AVC, AFC - average costs

Fig. 1. Relationship between the complexity and the costs for logistic operations
Rys. 1. Relacja pomiędzy złożonością i kosztami działań logistycznych

By complexity change from Q1 to Q2 we can see that average costs have downward trend, but marginal costs, in which is also variable factor included are beginning to rise. According to the analysis in real environment, it is clear that logistics activities associated with critical parts (components) have costs beyond the Q2 requirements.

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