Production Systems and Information Engineering
Volume 3 (2006), pp. 97-108

THE TIME FACTORS OF MAINTENANCE LOGISTICS

BÉLA ILLÉS
University of Miskolc, Hungary
Department of Materials Handling and Logistics
altilles@uni-miskolc.hu

[Received November 2005 and accepted May 2006]

Abstract. In the realization of maintenance processes, a vital role is played by logistical activities, i.e. maintenance logistical processes. The way in which the maintenance process is carried out has a basic influence on purchaser satisfaction. Maintenance as an influencing factor of customer satisfaction appears in three basic areas: the production and service process; the maintenance and servicing of the product for the customer; and the administration of maintenance services.

Dominant activities of maintenance logistics are:

- supplying the materials, components, tools and services,
- operating the supply chain of maintenance logistics,
- storage management of the maintenance logistics,
- maintenance inverse logistics.

In the field of maintenance logistics, the time factors and important parameters are explored and mathematically formulated, and the optimal time for starting the maintenance procedure is determined by the transit time.

Keywords: logistics, maintenance logistics, maintenance process, time factor

1. Introduction

For customers expectations the maintenance is an important respect. During the maintenance activity the logistics has got a determined importance [1], [2]. From the total transit time of the maintenance approximately 90% goes on the logistical type activities. The scientific literature does not deal particularly with their topic. In the first step my intention is to compose a model by which the time parameters of the maintenance can be given. After that the specific parameters will be determined on which these time factors are dependent.

The transit time of the maintenance activity is primarily determined by the completion of the maintenance logistical process and by the logistical strategies applied. This transit time has a substantial effect on customer satisfaction. The author investigated which time parameters have an important influence on determining the maintenance transit time.

The basic condition for initiating the maintenance activity is the existence of the following for the item to be maintained:

the necessary type of materials in suitable quality and quality,
the necessary type of parts in suitable quantity and quality,
the necessary type of equipment in suitable quantity and quality,
the services needed for maintenance and the necessary staff.

The assurance of the above conditions is the task of maintenance logistics.

2. Time Factors

For the time parameters of maintenance logistics, two main factors are considered, as can be seen in (2.1):

$$t_a = t_M + t_H \tag{2.1}$$

where

t_M - transit time for the order process of the necessary items, and

t_H - time to fulfilment of order, i.e. the total time of the logistical activities related to the item to be maintained.

The ordering process of the necessary items (materials, parts, equipment, service, staff) can be seen in Figure 1.

3. Process of Order of the Maintenance Necessities

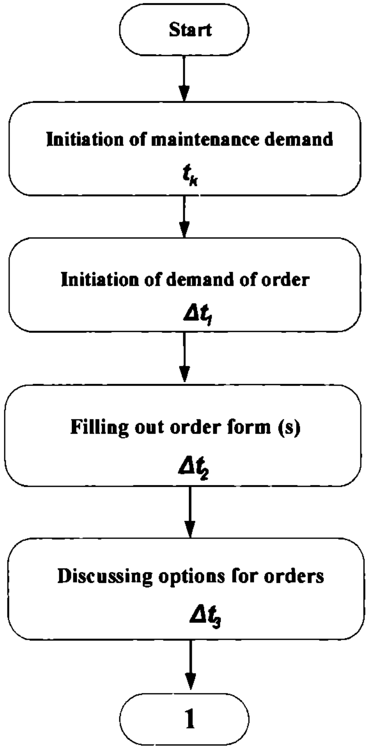
On base of Figure 1 the activities and time necessities of the ordering process are the followings:

failure occurred at a given moment,
after time Δt_1 on ordering demand is occurring for a given constituent,
after Δt_2 time the order has been written,
the order judged by the responsibilities for which Δt_3 is needed,
decision is born about the order is time Δt_4

- if it is negative, then no maintenance activity.

request for price offers to be concerned for which time Δt_5 is needed,
evaluation of the offers, time necessity Δt_6,
necessary time for selection of the optimal price offer is Δt_7,
time necessity for proceeding of the order Δt_8,

– handling time of prove of getting the order is Δt_g.


Start
Initiation of maintenance demand
t_k
Initiation of demand of order
Δt_1
Filling out order form (s)
Δt_2
Discussing options for orders
Δt_3
1

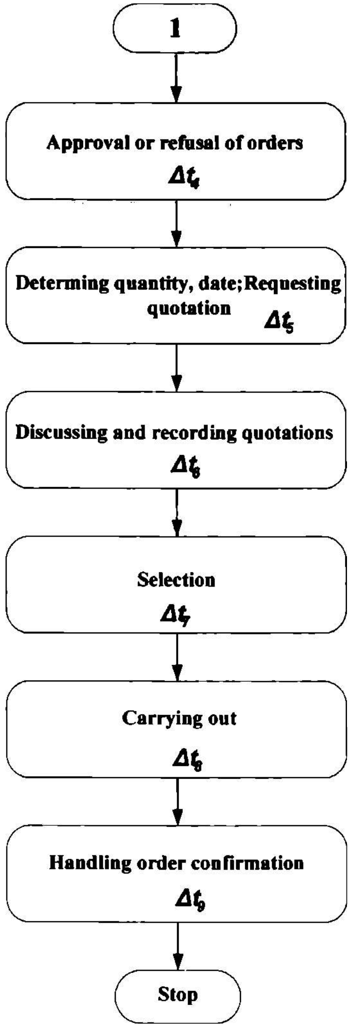


Figure 1. The order process for necessary maintenance items

Transit time of the ordering process of the necessities can be understood on base of

for the materials necessary for the maintenance *(a)*
for the constituents necessary for maintenance *(b)*
for the facilities necessary for the maintenance *(c)*
– for the services necessary for the maintenance *(d)*

$$t_{M\theta}^{i_\theta, j_\theta} = \sum_{k_\theta = 1}^{n_\theta} \Delta t_{k_\theta}^{i_\theta, j_\theta} , \tag{3.1}$$

where:

$$\theta = \{a, b, c, d\}$$

i_θ	identifier of the transporter,
j_θ	identifier of the product or service to be purchased,
k_θ	identifier of the time increment of the ordering process,
n_θ	maximum number of time increment elements taken into account, i.e. the number of activity elements in the order process,
a	index regarding materials,
b	index regarding constituents,
c	index regarding facilities,
d	index regarding services.

By using (3.1) the transit time can be given for the materials, parts, equipment and services which are necessary for the ordering of maintenance. It is advisable to specify the following:

$$t_{M\theta}^{i_\theta,j_\theta} \quad \sum_{k_\theta=1}^{n_\theta} \Delta t_{k_\theta}^{i_\theta,j_\theta} \rightarrow min . \qquad (3.2)$$

4. Logistical Features of Order Fulfilment in Maintenance

In the following section the time factors connected with the fulfilment of the order for the necessary item are investigated. Time factors are related to the place where the needs can be satisfied and to the item needing maintenance, and include:

time for carrying out logistical activities,
waiting time for the necessary equipment.

Types of logistical activities in the field of maintenance logistics can include:

different kind of storage activities,
activities in connection with stores (adding and removing),
activities in connection with breakdown and forming of unit packages,
order picking,
transport,
loading and unloading,
– classification into:

- parts re-usable after overhauling,
- parts for recycling,
- pieces to be treated as waste.

The time factors for order fulfilment of maintenance are given in Figure 2, taking these types of activities into account.

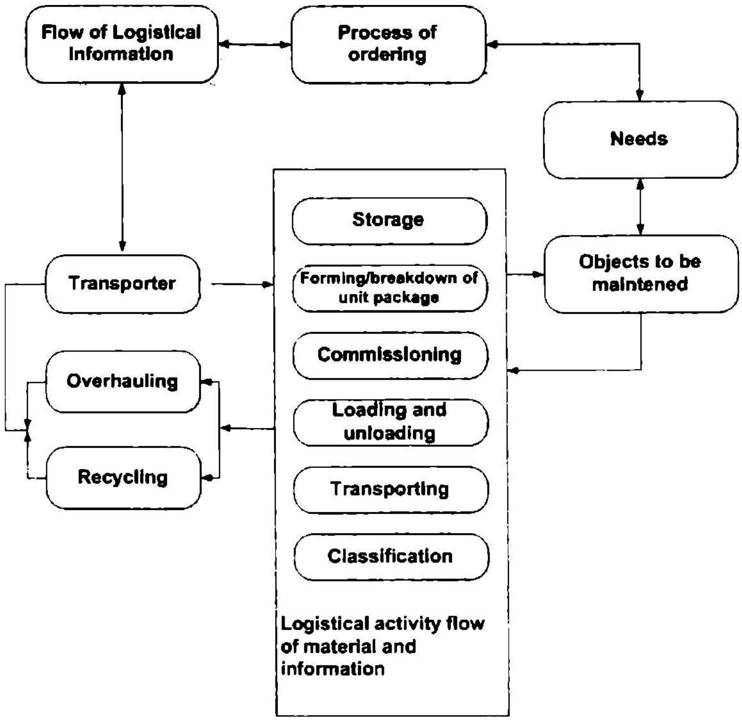


Figure 2. Logistical features of order fulfilment necessary for maintenance

In the system of order fulfilment for maintenance, the delivery of new materials and equipment is always taken into account, because for example necessary materials such as oil or glue cannot be re-used, and equipment needed is considered not to have to be overhauled because of the maintenance demand.

The need for parts can be satisfied from the viewpoint of logistics in three fundamentally different ways:

transport of either new or overhauled parts from the transporter's warehouse,

manufacture of the part, then transport, or

removal of a given part from its original place and its replacement after repair, If the transport is from storage (a new or overhauled part) then the time to fulfilment of the order is:

in the case of parallel activities

$$t_{HR1} = \max_{i_r}\left\{t_{HR1_{i_r}}\right\} \tag{4.1}$$

and in the case of serial activities

$$t_{HR1} = \sum_{i_r=1}^{n_{i_r}} t_{HR1_{i_r}} \tag{4.2}$$

$$t_{HR1_{i_r}} = t_T^{i_r} + t_E^{i_r} + t_K^{i_r} + t_R^{i_r} + t_S^{i_r}, \tag{4.3}$$

where:

t_{HR1}	time for order fulfilment for a given maintenance task in case of delivery from storage,
$t_{HR1}^{i_r}$	time to order fulfilment of a transported part for transporter i_r for the given maintenance activity,
$t_T^{i_r}$	storage time needed in case of supply between transporter i_r and the item to be maintained,
$t_E^{i_r}$	time needed for forming and breaking down unit packages in case of supply between transporter i_r and the item to be maintained,
$t_K^{i_r}$	time needed for order picking in case of supply between transporter i_r and the item to be maintained,
$t_R^{i_r}$	the time needed for loading and unloading in case of supply between transporter i_r and the item to be maintained,
$t_S^{i_r}$	the time needed for transport in case of supply between transporter i_r and the item to be maintained.

The time needed to carry out logistical activities:

$$t_{\theta}^{i_r} = \sum_{j_r=1}^{n_{j_r}^{i_r}} \sum_{\kappa_\beta=1}^{n_{\kappa\beta}^{i_r}(j_r)} t_{\beta_{j,\kappa\beta}}^{i_r}$$
$$i_r = 1,2\ldots n_{i_r} \tag{4.4}$$
$$\beta = \{T, E, K, R, S\},$$

where:

i_r	identifier of the supplier,
n_{i_r}	maximal number of suppliers,
j_r	index regarding necessities,
n_{j_r}	maximal number of necessities,
κ_β	index regarding logistics services,
n_{κ_β}	maximal number of given logistics service,
T	index regarding storage activity,
E	index regarding loading unit formation and disassembling,
K	index regarding order picking,
R	index regarding loading in,
S	index regarding transportation.

Summarizing the content of (4.4):

$$t_{HR1} = \max_{i_r} \left\{ \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_t=1}^{n_{\kappa_t}(i_r,j_r)} t_{T_{i_r,j_r,\kappa_t}} \quad \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_e=1}^{n_{\kappa_e}(i_r,j_r)} t_{E_{i_r,j_r,\kappa_e}} \right.$$

$$\left. + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_k=1}^{n_{\kappa_k}(i_r,j_r)} t_{K_{i_r,j_r,\kappa_t}} + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_r=1}^{n_{\kappa_r}(i_r,j_r)} t_{R_{i_r,j_r,\kappa_r}} + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_s=1}^{n_{\kappa_s}(i_r,j_r)} t_{S_{i_r,j_r,\kappa_s}} \right\}, \tag{4.5}$$

$$i_r = 1, \ldots n_{ir}.$$

It can be prescribed as an object function that (4.5) should be minimal:

$$t_{HRI} = \max_{i_r} \left\{ \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_t=1}^{n_{\kappa_t}(i_r,j_r)} t_{T_{i_r,j_r,\kappa_t}} + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_e=1}^{n_{\kappa_e}(i_r,j_r)} t_{E_{i_r,j_r,\kappa_e}} + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_k=1}^{n_{\kappa_k}(i_r,j_r)} t_{K_{i_r,j_r,\kappa_t}} + \right.$$

$$\left. + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_r=1}^{n_{\kappa_r}(i_r,j_r)} t_{R_{i_r,j_r,\kappa_r}} + \sum_{j_r=1}^{n_{j_r}(i_r)} \sum_{\kappa_s=1}^{n_{\kappa_s}(i_r,j_r)} t_{S_{i_r,j_r,\kappa_s}} \right\} \to min \tag{4.6}$$

On base (4.6) it can be stated, that the objective function in case of constituent supply from maintenance transport storage is dependent on:

the number of applied transporters $\left(n_{i_r}\right)$,

the number of the type of constituents to be transported $\left(n_{j_r}\right)$,

- on the number of the stockings $\left(n_{\kappa_t}\right)$,
- on the number of the construction and re-assembly of unit consignments $\left(n_{\kappa_r}\right)$,
- on the number of the applied order picked units $\left(n_{\kappa_e}\right)$,
- on the number of applied loadings $\left(n_{\kappa_k}\right)$,

per transporters and type of constituents being involved in the supply.
the time demand for each logistical activity for a given transporter and part.

The actual time needed for logistical activities is composed of two parts:

the actual technological time of the logistical activity,
the waiting times for equipment that is necessary for the given logistical activity and perhaps also the waiting time for the object to be maintained.

Each of the elements in (4.3) can be written as

$$t_\alpha^{i_r,j_r} = t_\alpha^{'i_r,j_r} + t_\alpha^{''i_r,} \tag{4.7}$$

where:

$t_\alpha^{i_r,j_r}$ is the actual time for a given maintenance activity for logistical activity α for product j_r from transporter i_r,

$t_\alpha^{'i_r,}$ is the technological time for a given maintenance activity for logistical activity α for product j_r from transporter i_r,

$t_\alpha^{''i_r,}$ is the waiting time for a given maintenance activity for logistical activity α for product j_r from transporter i_r.

The following equations can be associated with equation (4.6):

$$t_\alpha^{i_r,j_r} = t_\alpha^{'i_r,} + t_\alpha^{''i_r,j_r} \rightarrow min \tag{4.8}$$

that is, if

$$t_\alpha^{''i_r,} \rightarrow 0 \tag{4.9}$$

then

$$t_\alpha^{'i_r,} \rightarrow min \tag{4.10}$$

The basic principles of the optimal selection of the maintenance logistical services, shown in (4.9) and (4.10):

the waiting time for logistical activities should be zero as possible,
the logistical technology time for given constituent and transporter should be minimal.

If a part needed for the maintenance activity is supplied by the overhaul of a removed part at a different location, then when determining the time to order fulfilment, the following times should be taken into account:

the time needed for the logistical activity between the object to be maintained and the location of the overhaul $\left(t_B\left(i_r, j_r\right)\right)$,

the actual overhaul time $\left(t_F\left(i_r, j_r\right)\right)$,

In this case the time to order fulfilment is:

$$t_{HR2} = t_{HR1} + t_B\left(i_r j_r\right) + t_F\left(i_r j_r\right). \tag{4.11}$$

If the maintenance activity is proceeded by the manufacture of the necessary part, the total manufacturing time $\left(t_G\left(i_r, j_r\right)\right)$, should be taken into consideration:

$$t_{HR3} = t_{HR1} + t_G\left(i_r j_r\right). \tag{4.12}$$

The necessary times of demand for the materials and equipment can also be written in a similar way to (2.1)

Let us denote, using (1), the points in time related to maintenance activities at which the necessary items are available:

$$t_{a_A} = t_{MA} + t_{HA}; \quad \text{for materials,} \tag{4.13}$$

$$t_{a_R} = t_{MR} + t_{HR}; \quad \text{for parts} \tag{4.14}$$

$$t_{a_E} = t_{ME} + t_{HE}; \quad \text{for equipment} \tag{4.15}$$

t_{a_s} ; the point in time at which the service is available.

Let us denote the point in time when the demand for maintenance is initiated by t_k. Then, a possible point for initiation of maintenance activity for the item to be maintained is:

$$t_{IND} = t_k + max\left\{t_{a_A}; t_{a_R}; t_{a_E}; t_{a_S}\right\} \tag{4.16}$$

On foundation of the time necessity the logistical process model of the maintenance activity has been worked out in the paper. Using the model it turns out,

what kind of time parts are involved by the maintenance logistical activity,

what kind of connection is between the unique time parts and the main logistical parameters,

that different transit times might be occurred on base of the different logistical parameters,

that the determination of the optimal transit time can be done by using a multi-parameter solution mass.

The problem for searching the optimal variation is not be object of this paper, but the time parameters which have to be investigated by which approximately 90% of the total time necessity can be influenced are given.

REFERENCES

[1] KURT, M.: *Tashenbuch Instandhaltungslogistik Qualität steigern.* Carl Hanser Verlag München, Wien, 1999.

[2] MAGGARD, B.,N.: *Instandhaltung, die funktioniert.* Verlag moderne Industrien, Landsberg 1995.

[3] ILLÉS, B.: *Information flow in a logistical system of maintenance*, Gépgyártástechnológia XXXVIII, 6, pp. 55-57, 1998. (in Hungarian)

[4] ILLÉS, B.: *Logistical management of maintenance*, Gépgyártástechnilógia XXXIX, 3, pp. 1-6, 1999. (in Hungarian)

[5] ILLÉS, B.: *Logistical consequences of maintenance activities* LOGINFO, Magyar Logisztikai Egyesület, 2, pp. 19-22, 1999. (in Hungarian)

[6] CSELÉNYI, J., ILLÉS, B., KOTA, L.: *Virtuelle Zentrale zur Disposition der Inspektion räumlich verteilter Objekte,* Magdeburger Schriften zur Logistik, MSL-Heft 1, pp. 61-66, 2002.

[7] ILLÉS, B., CSELÉNYI, J.: *Disposition von Personal, Material und Dienstleistungen bei räumlich verteilten Wartungsobjekten,* Conferencia Ceintifica Internacional de Ingenieria Mecánika, Universidad Central „Marta Abreu“ De Las Villas, Santa Clara (Cuba), COMEC 2004, on CD-ROM, 6 pages.