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Citation for published version (APA):

Document status and date:
Published: 01/01/1993

Publisher Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
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Download date: 12. Jan. 2021
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Research Report TUE/BDK/LBS/93-28
November, 1993

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This research is sponsored by the Economics Research Foundation, which is part of the Netherlands Organization for Scientific Research (NWO).
A MODEL FOR THE SHORT TERM LOGISTIC SHOP FLOOR
PERFORMANCE EVALUATION AND DIAGNOSIS

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Abstract

The logistic performance of production units varies over time. Queuing models are available
that can be used to calculate the logistic performance on the longer term. These queuing models
however do not account for the performance fluctuations in performances on the short term.
In this paper we present a model to predict the short term performance. The model can also
be used to explain the observed difference between the predicted and actual performance, which
is the basis for a diagnosis. In the model, the possible causes for the performance deviations
are structured beforehand, and are divided into causes that are observable and quantified, and
causes that can not be quantified.

1. Introduction

During the last decade much attention
has been paid to all kinds of performance
measurements. This is illustrated by the large
amount of literature dedicated to this subject
(for example Galbraith et al., 1991, Kaplan,
1990, and Maskell, 1989). Also in industrial
organizations many projects have been
initiated to design and implement
performance measurement systems. We
consider performance measurement as a way
to focus the attention on continuous
improvement. However, measuring is just the
first step in the improvement process (see
figure 1). Having measured the performance,
an evaluation should take place. In this evaluation the measured performance is compared with a performance norm. In case the actual performance deviates from the performance norm, one usually wants to know what the causes are for the performance differences. The search for explanations for the observed deviations will be called the performance diagnosis. The causes that are found are the starting point for actions that have to be taken for performance improvement.

In the literature, performance evaluation and diagnosis seldom are considered as distinct phases in the improvement process; both phases are integrated within the measurement phase. In case the distinction is made, often the meaning of evaluation and diagnosis are substituted. For example Nutt (1993) describes how diagnosis is being used for strategic decisions. But from the context of his paper it is clear that diagnosis has the same meaning as evaluation.

In this paper we propose a model for the performance evaluation and diagnosis of the logistic performance of production units. Here a production unit refers to an autonomous production department, that is a department which on short term is self-contained with respect to the use of its resources, and which is responsible for the production of a specific set of products from a specific set of materials and components (Bertrand et al., 1990). The logistic performance of a production unit is defined as the integrated performance on delivery reliability, throughput, flow time, utilization level, and inventory level (including work in process). Because there are always trade-offs to be made, an optimal logistic performance will never be possible (see for example St. John and Young, 1992, and Durlinger, 1983). Therefore, the interpretation about "good" and "bad" performances will be to a large extent a subjective issue.

In the next section we describe the problems that may occur with evaluation and diagnosis. These problems are the motive for the development of a model for evaluation and diagnosis with regard to production control aspects. In section three we present a model that can be used for evaluation and diagnosis. The parameters that will be used in this model are defined in the same section. In the fourth section we explain how the model should be used for predicting, evaluating, and diagnosing the logistic performance. In the final section some conclusions will be drawn and suggestions for further research will be reached.

2. Problems with respect to evaluation and diagnosis

Consider a production unit that is a part of a chain of production units in an organisation planned and controlled by Materials Requirements Planning (MRP). MRP uses fixed lead times to schedule orders. Each single order has planned arrival and planned completion times for every production unit it comes through. However, all kinds of disturbances may delay or accelerate the progress of single orders. Material shortages and unexpected absenteeism of operator capacity in
a certain measurement period will result in delays in the order progress. On the other hand, the
use of specific priority dispatching rules may result in accelerations of some orders. As a result,
the production unit manager will always be confronted with a set of orders in the shop that is
different from the planned set of orders generated by MRP. This may be a reason that the
expected throughput of the production unit will be different from the real throughput in a certain
measurement period. So, it is difficult for a production unit manager to predict the throughput
for the short term. On the other hand, the explanation of differences between the expected (or
predicted) performance and the actual performance is even more difficult. The production unit
manager usually gives qualitative reasons for the undesirable performance difference. An
instrument for quantifying the possible causes is not available. The logistic department is also
confronted with the deviations in the progress of individual orders. It will be sure that the planned
arrival and completion dates will not be attained for every order, but it is difficult to predict new
arrival and completion dates. Also for the logistic department it is difficult to explain why certain
orders were delayed and other orders accelerated. So, both the production unit manager and the
logistic department do not have an instrument that can predict and explain the short term
performance. In the remainder of this section the problems involved with evaluation and diagnosis
are treated more generally.

In common practice, the logistic performance norms that are used for the performance
evaluation are either set intuitively by management (sometimes in consultation with experts or
with the people most involved) or based on historical performances. In most cases the
performance norms are set for a longer period of time. The real performance will always show
fluctuations over the course of time. In a stable environment without any trends, these
fluctuations will move around a certain average performance. It is possible to calculate this
average performance for the long term with queuing models (for example Whitt, 1983, and
Kuehn, 1979). Therefore, these kinds of models are appropriate for norm setting, although it is
seldom the case in common practice.

Because of the natural (or stochastic) fluctuations in performance that usually appear in
production environments, it will not always be possible to achieve the performance norm in each
period; sometimes a better performance can be achieved, and in other times the real performance
will be lower than the performance norm. For operations managers -and also for management that
judges the performance of the production units- it therefore is very important to know which
performance level can be achieved in the short term. If the actual performance is close to the
expected short term performance, then it will not be necessary to conduct a diagnosis, even
though the performance may be far away from the expected long term performance. The short
term norm shows which performance level can be achieved, given the information we have about the factors that influence the short term performance. In other words, the criterion for determining whether a diagnosis should be conducted should be based on the short term norm.

Conducting a diagnosis means that explanations are tried to be found for performance deviations between the actual performance and performance norms. Operations managers often say to know what the causes are for the performance deviations. For themselves, the achieved performance will be understandable enough. In most cases their reasons sound very plausible, so most people can be convinced. However, operations managers hardly ever test their assumptions about the deviations quantitatively. It is very well possible that the assumed causes do not completely explain the observed performance gap. Another possibility is that the performance is quite insensitive for some of the causes they mention. In that case there are other causes that are not detected by the operations managers. The testing of the assumptions about the deviations will form an important part of our model.

Consultants use their experience in finding explanations for performance deviations. Experienced consultants have build up a frame of reference in the course of time. Each new problem they are confronted with is compared to similar problems they have solved in the past. In this way, the frame of reference will be extended continuously. For each class of problems a "standard" solution method will be developed by them. According to Armenakis et al. (1990) it can be very worthwhile to formalise this experience into expert or knowledge based systems. An example of such a knowledge based diagnostic instrument is given by Wiendahl and Ludwig (1990) and Ullmann and Ludwig (1992). A disadvantage of such an expert system is that it must contain many different situations for determining the causes of the problems. For new problems that do not fit in the existing criteria in the expert system, the system is not able to give suggestions for causes for the problems. For that reason we propose another approach.

3. Parameters of a model for evaluation and diagnosis purposes.

In contradistinction to the above approaches, we define beforehand the factors that influence the logistic performance. These factors are: structure of the production unit, policies, state of the shop, work supply, and capacity (figure 2).

By the structure of a production unit, the organic structure is meant. This is the way organisational elements (like workstations and operator pools) perform functions or sets of functions. Also the relationships between the different organisational elements come under this definition.
For some situations, rules are developed that prescribe the kind of decision that should be taken. These formalised rules will be called policies. An example of such a policy is the priority dispatching rule. Policies can be drawn up by operations management themselves (internal policies) as well as by higher management (external policies).

The state of the production unit is described in terms of characteristics of orders that are in the shop (work in process). The main characteristics of an order are: the location of an order together with its operation time for the current workstation, the remaining workstations in the routing, and the operation times at the remaining workstations in the routing. It is also possible to add extra information like sequence dependent setup times and status information about blockages.

Two aspects are of importance concerning the work supply. First, the volume of the work supply. Second, the moment of arrival of the supply. If the work supply arrives at the beginning of a measurement period, another performance will be achieved then if the arrival moments of orders are equally spread over the measurement period.

The net available capacity is an important factor for the performance that is or can be realised. This holds for machine-capacity as well as for operator-capacity. Multi-skillness of capacity types should also be taken into consideration.

4. The use of the model for the prediction and explanation of the logistic performance

In the foregoing section we described the factors that influence the logistic performance of a production unit. We are now interested in the explanation of the performance that is achieved. In figure 3 the model for this explanation is depicted.
Estimations of the input

PREDICTING MODEL

Predicted performance

PERFORMANCE DEVIATION

Real performance that is achieved

Actual input

Revised input values

PREDICTING MODEL

Post predicted performance

Performance deviation caused by variations in the fulfillment of policies or unformalised decisions

Figure 3. Model of the prediction and explanation of the short term logistic performance.

As is said before, an explanation will not be necessary when it is demonstrated that there is only a little difference between the actual performance and the short term performance that could be achieved. Therefore, we first have to predict which short term performance level can be realised. The main difference between short term and long term prediction is that the first one should be state-dependent. For long term predictions, the actual state of the shop is not taken into account because it will have no or only a very small influence on the long term performance. This is the reason that most queuing models are state-independent. By doing state-dependent predictions we affirm that it is logical that fluctuations in the logistic performance appear. These fluctuations mainly appear due to the changes in the work supply and changes in the available capacity.

The short term predictions show which performance is possible to achieve. The input factors for the predictions are the ones we mentioned before: structure of the shop, policies, work supply, state of the shop, and available capacity. The structure and state of a production unit can easily be observed and are objective input-data. The policies that are being used can be ascertained by interviews or by observation. These policies are considered to be objective input-data too. For the work supply and available capacity only estimations can be given. These factors are very sensitive for changes in the short term. Examples of such changes are rush orders that
suddenly have to be released, unexpected machine breakdowns, and unexpected absence of operators. With all these (fixed or estimated) input-data we now predict which performance level can be achieved.

The prediction of the logistic performance can be restricted to the prediction of the throughput of the production unit and the completion times of orders. From the throughput prediction, it is easy to derive predictions about utilization levels. Predictions of the delivery reliability and mean flow time can be derived from the prediction of the completion dates. In highly utilized production units the throughput mainly depends on the available capacity. On the other hand, the completion dates of orders mainly depend on the state of the shop and the priority dispatching rule that is being used. The predicting rules should take into account these relationships.

At the end of a measurement period, the predicted performance will be compared with the measured (or actual) performance. It is very unlikely that both performances will be equal. Therefore, the observed deviation should be explained. Thereby we assume that no measurement mistakes have been made. A part of the observed deviation can be explained by a so called post prediction. This post prediction is the same prediction as is done at the beginning of the measurement period, but the estimations about capacity and work supply are replaced by the real available capacity and the real work supply. A requirement for this post prediction is that the original input-data have been stored.

The next step is that the post prediction is compared to the real performance. It is possible that there still is a performance deviation. There are only two possibilities left that may cause this deviation. The first possibility is that the policies are not completely fulfilled. For example, operators were expected to process orders in sequence of the arrival moment (first in first out), but the real sequence resembled a random order. The second possibility is that some decisions are made, that were not captured by the policies. In this case, someone is confronted with an unexpected situation for which no formalised rule was available. In figure 4 we illustrate the different comparisons between the performances.

4. Conclusions and further research

The proposed model, including some general state-dependent predicting rules, enables us to quantify some possible causes of observed performance deviations. By defining only a limited number of factors that influence the logistic performance, the analyses in the diagnosis phase can be restricted. The strength of our approach is that the observed performance deviation will be explained by all factors that can be quantified. A possible remaining part of the deviation can only
be caused by factors that are directed at the behaviour of people in the production unit. The modelling of this deviant behaviour is not a part of our research. However, it is interesting to know why people show this deviant behaviour. Empirical research will be the only way to investigate this.

Empirical research is further needed to validate the model. The validation of the predicting rules (and extensions of them) can be carried out by simulation experiments. However, simulation experiments are not sufficient for validating the explanation instrument. By simulation only the controllable aspects can be tested. For that reason, empirical tests of the prediction and explanation instrument are needed. Empirical research provides extra information about the causes of performance deviations. This extra information can be used for improvements in the proposed model.

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