Logistics performance measurement, evaluation and diagnosis for shop floor control: a research proposal

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Logistics Performance Measurement, Evaluation, and Diagnosis for Shop Floor Control; A Research Proposal

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Research Report TUE/BDK/LBS/92-10
October, 1992

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LOGISTICS PERFORMANCE MEASUREMENT, EVALUATION, AND DIAGNOSIS FOR SHOP FLOOR CONTROL

A research proposal

October 1992

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1. INTRODUCTION
Nowadays a strong competition is going on between manufacturing firms producing comparable goods. In order to survive, the most important goal for these firms is to increase customer satisfaction by improving quality, improving logistics, and reducing costs. All efforts of improving are sensible only if progress is monitored. The use of a performance measurement system has become very popular as a tool of progress monitoring. Performance measurement systems provide management a comparison of actual results with preset targets. After measuring the performance on certain pre-defined aspects, this performance should be evaluated. If the performance is considered to be unsatisfactory, then a diagnosis should take place in order to detect the problem areas and to judge if a better performance could have been established.

This research is restricted to the logistics performance at the shop floor level, and it should give insight in the way how logistics models should or can be used for diagnosis purposes. The practical relevance of this research is to find out which performance level can be reached given the specific characteristics and state of the system that is considered.

First, we will give an overview of relevant literature about performance measurement and diagnosis, followed by an analysis. After that, we define our problem and limit it to some specific situations. Then, we propose the research topics for the next two years, and finally we describe the research methodology that will be followed.

2. LITERATURE STUDY AND ANALYSIS
Performance measurement is a very popular subject for the last decade. In this chapter we will give an overview of the most important literature about this subject. First, we will make some classifications of performance measurement systems to illustrate the different approaches. Second, we will shortly deal with literature about the building and implementation of performance measurement systems. Then, we will give an overview of literature about performance evaluation and diagnosis. To diagnose a performance it is necessary to have some insight in relationships between performance measures. These relationships and the trade-offs that must be made are the subjects of the last but one paragraph of this chapter. In the last paragraph, we will give an analysis of the literature in order to find new research subjects.
2.1 Performance measurement classifications

In literature we can find different types of performance measurement systems. Each performance measurement system takes a different point of view. To see the differences between the performance measurement systems, we have made several classes in which the performance measurement systems can be placed:

- Models that use financial as well as nonfinancial (or physical) measures. These models make a distinction in the dimension of measurement.
- Models that make a distinction between external and internal performance measures. External performance measures can be divided in input measures for evaluating a supplier's performance and output measures for evaluating the performance of the system that is considered to its customers. Internal performance measures are used for controlling internal processes in order to achieve an acceptable output performance.
- Models that use efficiency and effectiveness measures. In these models the efficiency of the appliance of resources is judged. Further, these models qualify to what extent the output targets have been realized.
- Models that distinct measures based on the hierarchical level in an organisation. In these models performance-indicators are derived from performance-indicators on a higher organizational level. In that way, all performance-indicators are derived from the strategic goals of an organization.

It should be noted that with this classification it is possible to classify some literature to more than one classification. On the basis of an organizational chart the classification above is summarized in figure 1. Horizontally (in the direction of the goods flows and monetary flows), each (functional) department/unit can be measured with the help of input-output models or efficiency-effectiveness models. Vertically, performance measurement takes place at a certain hierarchical level. The dimension of measurement that is used, in principle, is independent of the horizontal or vertical division that is made.

FINANCIAL-NONFINANCIAL MODELS

A first division that we consider is the division in models using financial performance indicators (PIs) and nonfinancial PIs. This division is important, because the accounting theory admits to lag behind developments in the area of operational control (Kaplan 1983, 1990). This is one reason for using nonfinancial PIs for operational control instead of financial PIs.
In the past, only financial measurements were used to review an organisation's past performance. But now the insight arises that also nonfinancial measures are important for control purposes. This is especially true for operational levels in organisations. Financial measurements are useful for tactical and strategic decision support purposes, and hardly usable for operational control purposes.

Theeuwes and Wortmann (1985) are dealing with the integration of production control and budgeting. Traditional budgeting methods can not be used for controlling logistics processes. If budgets are being used by managers, integration of cost control with -relatively- new production control systems like MRP and JIT is necessary. The authors developed a model in which financial values are added to physical units. The resulting "logistics budgets" then, are entirely adjusted to logistics control requirements. A more general description about the integration of production control and budget control can be found in Bertrand et al. (1990, chapter 4).

Van der Veeken (1987) takes the economic performance measurement as a starting-point. The advantage of this measurement method is that it makes different elements comparable in
terms of money. With other measurement methods difficult trade-offs need to be made in deciding which priorities should be set. However, a disadvantage of an economic performance measurement model is that not all elements which show results of effectiveness can be taken into account -such as service performance.

Andersson et al. (1989) conclude there is a measurement gap between engineered measurement (in physical units) and financial measurement. This gap often can be found at the middle management level, where financial ratios are being used for communicating results upwards to higher hierarchical levels in the company, and physical quantities downwards to the operational levels. In an overall measurement model they illustrate some quantifiable aspects of the logistics system. The measures used are both financial and nonfinancial.

McNair et al. (1990) discuss why financial and nonfinancial PIs may not agree. A first reason is that due to volume and mix changes nonfinancial measures -such as flow-time- are improved while financial measures deteriorate. A second important reason is that operational improvements may be benefiting a future financial period. The authors suggest to use activity accounting to overcome these problems; the linkage between financial budgets and operating plans is made by dividing financial measures by operational ones.

Corbey and Jansen (1991a, 1991b) developed a model that links the logistics performance of an organization to the costs that are involved in achieving this performance. The main logistics performance measure is the service-reliability to customers. The physical means that can be used to achieve a certain service-reliability level are: the deployment of capacity, the appliance of work in process, and the appliance of inventories. All these means are measured in monetary terms.

HIERARCHICAL MODELS

Cross and Lynch (1990) have made a "performance pyramid" to show the relationship between objectives and performance measures with the hierarchical level in an organization. The same sort of pyramid can be found in Keegan et al. (1989) (see figure 2), and also Duijker (1990) describes how performance measures on a certain organizational level are related to performance measures on other levels.
Figure 2. The performance pyramid.

Copacino and Rosenfield (1987) direct their attention to the strategic level of an organization. They give a qualitative description of some analytic tools that can be used for strategic logistics planning, like decision-support models, logistics costs analysis, and a cost-service trade off curve.

EFFICIENCY-EFFECTIVENESS MODELS

Another set of performance measurement systems to be found in the literature is a division of systems that use PIs directed at effectiveness and PIs directed at efficiency. In ’t Veld (1983) gives the following definitions to these terms: efficiency = target appliance of resources divided by the realized appliance of resources; effectiveness = realized output divided by the target output.

Azzone et al. (1989) use efficiency indexes and effectiveness indexes in their integrated performance measurement system. They begin with determining the efficiency indexes. From these indexes they are able to derive the effectiveness indexes -also called measures of profitability. Then, the performance measurement model can be used for a "what-if analysis" in order to evaluate the effect of changes in product-mix or in the efficiency and flexibility of the resources.
McKaige (1989) states that being efficient does not ensure survival; effectiveness should come first. Efficiency indicators are only important if the factory is balanced and in synch with market needs. Examples of PIs directed at effectiveness are quality and delivery reliability. Examples of PIs directed at efficiency are machine utilization and material consumption.

Parkan (1991) gives a quantitative method to calculate operational performance measures. This method is meant to show the relative performance of a set of production units based on cost and revenue inefficiencies. The calculation is based on productivity rather than effectiveness, because it compares inputs (like materials, labour, and energy) with outputs (products). All inputs and outputs are transformed into monetary units.

Mentzer and Konrad (1991), finally, state that the total performance is a function of both effectiveness and efficiency. This distinction, however, can hardly be found in their list of measures.

INTERNAL-EXTERNAL MODELS

A last division that can be made is that of models using external and internal PIs (see figure 3). The best description of this classification is given by Fortuin (1988). Other authors making the same kind of distinction are Andersson et al. (1989), and Cross and Lynch (1990).

![Figure 3. Internal and external performance measurement.](image-url)
External PIs are meant to measure the performance of suppliers and/or the performance of a department to customers. Suppliers and customers can also be other departments of the same organization. Examples of external PIs are quality of incoming goods and delivery reliability. Internal PIs are being used in a department to monitor the production process in order to influence external PIs related to the customers. Examples of these PIs are machine utilization and flow-times.

OTHER MODELS

Besides the classifications above, many authors only give a list of PIs that are (in their opinion) important for an organization [Mentzer and Konrad (1991), Shapiro (1990), Lippa (1990), Pannesi (1989), Edson (1988), Weston and Brothers (1984)]. The decision which PIs to use for a particular situation is left to the reader.

A completely different model is developed by Pritchard et al. (1988, 1989). Their Productivity Measurement and Enhancement System (ProMES) is an approach to measure the productivity of small groups. The behavioral aspect is the starting point for the system; it assumes that the highest productivity can be achieved by giving group feedback, and by setting goals by the group themselves. Feedback is used to evaluate the performance and to review the goals that were set.

A more general description of performance measurement and related topics (like rules for developing PIs, and implementation) can be found in NEVEM (1984, 1989) and Maskell (1991). Bertrand et al. (1990, chapter 5), finally, give a review of the role of (performance) models. They state that the use of complex performance models is not useful because decision freedom can not be formalized completely.

2.2 Building and implementation of performance measurement systems

The amount of literature about the building and implementation of performance measurement systems as compared to the amount of literature about the use of performance measurement systems is small. Although the steps in building and implementing performance measurement systems are more or less the same as the building and implementing of other kinds of systems, we will shortly deal with some building and implementation models.
Globerson (1985) describes four stages in the development of a performance criteria system:
- choosing the preferred set of PIs;
- measuring the chosen PIs;
- assigning standards to the PIs;
- designing a feedback loop to respond to discrepancies between standards and actual performance.

Much attention in this model is paid to the measuring of the chosen performance criteria.

Pintelon et al. describe five steps to implement a performance measurement system:
- system analysis;
- indicator definition;
- pilot study;
- full-scale implementation;
- decision support system.

Further they give some rules of thumb for defining PIs. As an example they describe the logistics PIs that were used in a logistics performance measurement system for a company producing electronic units.

Copacino and Rosenfield (1987) describe various analytic methods to support strategic planning. The strategic planning is used as a tool to meet customer service requirements, and to support integrated logistics planning. Performance measures are developed as tools for logistics planning. Other related subjects they mention are (i) the substantial impact of logistics costs, (ii) the influence of external measures to logistics, (iii) the complex trade-offs involved in logistics, and (iii) the organizational conflicts that influence logistics.

The NEVEM-workgroup (1989) mention a lot of aspects that are related to PIs and the implementation of a PI-system. Further, this workgroup developed a model (the logistics input-output model; see also NEVEM (1984)) that meets the following requirements:
- it shows the different logistics activities of an organization and their relationships;
- it is possible to look at hierarchical levels separately;
- physical as well as financial measures are used;
- the model can be used for "what-if" analysis.
The logistics input-output model is a combination of a financial model - the Du Pont model - and a logistics model - the logistics process model. The input-output model distinguishes the several functional departments of an organization, and for each department the inputs and outputs have to be described in both financial and physical units. After filling in all inputs and outputs, one is able to analyze the whole organization. If necessary, a department can be split up into several activities, and for each activity the inputs and outputs have to be determined. Thus, for this model financial as well as physical measures are being used to evaluate the performance; aspects like behaviour and timeliness are not a part of this model.

2.3 Performance evaluation and diagnosis

We consider performance evaluation as the comparison of the actual performance with a standard performance. If the actual performance is considered to be unsatisfactory, then causes will be sought to explain the differences between actual and standard performance. This will be called the diagnosis phase. The performance evaluation and diagnosis phases seldom are described as distinct phases; these phases merely are seen as a consequence of the performance measurement phase. In this paragraph we only deal with literature that consider evaluation and diagnosis apart from measurement.

Schragenheim and Ronen (1991) give a good example of using a diagnosis as a distinct phase in the triplet measurement, evaluation, and diagnosis. In their article they describe a diagnostic tool for shop floor production control: Buffer Management. Buffer Management serves as an alarm system that spots serious and urgent problems, provides control on lead times, and indicates the weak areas, thus prioritizing the necessary improvements in the shop floor. The tool can be used in environments where the drum-buffer-rop method has been implemented. (The drum-buffer-rop method is described by Goldratt and Fox (1986).)

The logistics monetary flow diagnosis, developed by Corbey and Jansen (1991a, 1991b) is a diagnosis that gives a snapshot of the logistics performance and the related deployment of means. The definitions of the monetary flows very closely correspond to the ideas of logistics managers, in contrast to existing cost concepts. Because the "language barrier" between financial controllers and logistics management is abolished with the help of this instrument, negotiations about the necessity to logistics improvements can be clearly conducted.
2.4 Relationships and trade-offs between performance indicators.

It should be clear that some PIs are interrelated; a better performance on a certain PI can lead to a positive or negative influence on other PIs. In case of interactions, often a trade-off needs to be made. No literature is found about trade-offs being made for a whole organization that has to be controlled; the "real world" seems to be too complex for trading off all relationships between measures of different aspects (like economy, logistics, and behaviour). On the other hand, trade-offs between two or three specific measures are easy to find. Some of these trade-offs will be discussed now.

Durlinger (1983) makes researches into the relationship between machine-utilization and flow-time. In two other articles (1985, 1986) he describes which logistics parameters are related to machine-utilization and flow-time. This resulted in an analytic simulation model: the Trade-Off-Module. The model serves logistics decisions that must be made for the long term in showing the expected utilization-rate and mean flow-time for a chosen set of logistics decisions like batch sizes and available capacity.

The trade-off between productivity and flexibility is discussed by Gustavsson (1984) in a qualitative way. He shows what kind of flexibility (demand, product or machinery) should be used in a specific production situation to reach maximum productivity.

A study on trade-offs between productivity, quality, and flexibility is given by Son and Park (1987). They developed an integral manufacturing performance measure by combining a total productivity measure, a total quality measure, and a total flexibility measure. Each measure is represented in monetary terms. Son (1990) worked out these relationships to a tool for a manufacturing accounting system.

Scudder and Hoffmann (1987) simulate the effects of scheduling rules on the cost of work-in-process. Each rule is evaluated on time performance and cost performance. Management has to decide which rule is preferable.

A lot of research is done on the relationships between lot sizes with other variables. For example, a quantitative analysis of the relationship between lot sizes, lead times and in-process inventories is given by Karmarkar (1987), and the relationship between lot sizes and logistics costs is described by Corbey and Jansen (1991a, 1991b).
A different opinion about trade-offs, finally, comes from Ferdows and de Meijer (1990). They postulate that trade-offs can be avoided. To improve total manufacturing capability, management attention and resources should go first toward enhancing quality. Then -while the efforts to enhance quality are further expanded- attention should be paid to improve the dependability of the production system. Then -while efforts on the previous two are further expanded- production flexibility should be improved, and finally, direct attention should be paid to cost efficiency -while all other improvements are further enlarged.

2.5 Literature analysis

In this paragraph we will analyze the literature described in the foregoing paragraph. The analysis is built up of a conclusion followed by an explanation.

A. Most attention is paid to performance measurement, followed by performance evaluation and diagnosis.

In table 1 we made a counting of the literature to illustrate the first conclusion. Literature about evaluation and diagnosis is hardly to find. For a part this is due to the way performance measurement is seen; performance measurement serves as a monitoring system that shows which performance indicators are below the targets, and this implies that performance evaluation is included in performance measurement. This is also the case with performance diagnosis; performance diagnosis in many cases is seen as a part of performance evaluation. So, measurement, evaluation, and diagnosis are narrowly related to each other, but not treated as separated tasks, each with its own approach.

<table>
<thead>
<tr>
<th>Main subject</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance measurement</td>
<td>19</td>
</tr>
<tr>
<td>Performance evaluation</td>
<td>8</td>
</tr>
<tr>
<td>Performance diagnosis</td>
<td>2</td>
</tr>
</tbody>
</table>

B. Most performance measurement and evaluation models are directed at more than one aspect.

If we consider the four most commonly used aspects (finance, quality, logistics, and behaviour),
we see that most performance measurement/evaluation models use a combination of all the aspects with a preference for the combinations with finance, quality and logistics. So, it is evident that one realizes that there are trade-offs that must be made between different aspects.

C. There are no objective norms/targets for evaluation.

The setting of targets for performance evaluation is done in several ways. In practice, we see that targets are:

- based on historical data;
- set by conferring between management and working groups;
- "randomly" chosen by management.

It is interesting to notice that targets are not based on objective norms that are based on theoretical results.

D. There is no diagnosis methodology.

We have seen that there are different methodologies to build and implement a performance/evaluation model. For performance diagnosis however, such a methodology does not exist.

3. PROBLEM AND RESEARCH DEFINITION

Our view of the connection between performance measurement, evaluation, and diagnosis can be seen in figure 4 (next page).

- After each (periodic) measurement on pre-defined indicators, an evaluation takes place: the actual performance is compared with the targets. If the performance deviates from the targets, action should be taken. To undertake the proper actions, the causes that resulted in a low performance have to be identified. The identification of the causes is done in a diagnosis phase. When the causes are identified, one should be able to deduce the appropriate actions that should be taken to improve the total performance. The focus of our research will be at the diagnosis phase. This phase is still an area that gets little attention, as we concluded in the foregoing chapter.

In organizations often the question arises: how good is our performance? The general approach to get an answer is to compare the performance achieved with a target or the
performance of a comparable unit. With this approach one shall only react to negative deviations between actual performance and a standard. This does not mean, however, that in case of a performance that is better than the target, this performance is the maximum that could have been achieved. Suppose, for example, that a company obtained a delivery reliability of 95% according to the latest monthly report. The target for the company is set at 90%. In this case no action will be taken; everything looks all right. But it is possible that the delivery reliability could have been 98% if one had taken specific actions. The example above shows the basic problem on which our research wants to give an answer: what is the maximum performance that can be achieved? (A related problem is the problem of target setting; what are correct targets, and how can they be obtained?) With this the practical relevance of our research has been made clear.

We assume that it is possible to determine an objective maximum attainable performance with the help of theoretical models. In literature we saw that for performance measurement in most cases a combination of at least two aspects (such as the combination quality and logistics) were considered. We consider the following aspects:

- finance/economy;
- quantity;
- timeliness;

Figure 4. Relationship between performance measurement, evaluation, and diagnosis.
The quantity and timeliness aspect together form the logistics aspect. With our research we want to take this logistics aspect as the starting point for performance measurement, evaluation and diagnosis. This means that we want the logistics aspect to be controlled. As a consequence only logistics performance measures will be looked at, such as mean flow time, work in process, and utilization rate. It should be noted that some logistics performance measures are strongly related to economic measures. For example, work in process can be translated into money, and utilization rate is also used as a financial performance indicator. (Note: in most cases the utilization rate for financial control is different from the utilization rate for logistics control.) The theoretical logistics models we want to use for our research, are quantitative models (eg. based on queueing theories and inventory control theories) that can predict (or explain) the logistics performance. This prediction or explanation of the logistics performance will be based on a "normal" appliance of resources. A goal of this research is to get more insight in the relationship between the amount of resources/means and the logistics performance. In this way we link the aspects economy, quantity, and timeliness. The other two aspects do not form subjects for this research; people are expected to show a behaviour that is almost independent of the circumstances, and the quality aspect is considered to be a characteristic of the logistics aspect in delivering the right products at the right time on the right place.

In the beginning of chapter two, we distinguished several classes of performance measurement systems. One of these classes consisted of systems that made a distinction in hierarchical level. Our opinion is that it is necessary to make this distinction, because every organizational level needs its own specific information. We consider three levels at which performance measurement can take place: (i) the total organisation, (ii) the shop floor level, and (iii) the working unit or cell level (see figure 5).

For this research, we made the choice to consider the shop floor level. Examples of shop floor levels are: a turnery, an automobile assembly line, an assembly line of printed circuit boards, a packing department of snacks, a stockpoint of pharmaceutical products, and a central stockpoint of iron. Often, at this shop floor level we can observe the "measurement gap" that was defined by Andersson et al. (1989). The shop floor management in most cases have a budget and their performance will be judged by the top management level by financial measures. On the other hand, a shop floor's logistics performance is determined partly by the
The physical characteristics of the shop, namely the characteristics of the working units or cells. The logistics shop floor control is only possible with logistics measures. Thus, with this research we also get more insight in the measurement gap.

So far, we restricted the research to the shop floor level and to theories that can predict the logistics performance at this level. Most theoretical models predict performances that can be reached in the long term. The current state is of no importance for these models, because at the long term the impact of the state will diminish. Thus, the state for this kind of models is considered to be stable. At the operational shop floor level, however, a stable situation does not exist. Shop floor managers always are busy to solve ad hoc problems that possibly are the cause of an unsatisfactory performance, and they always make attempts to get a good judgement on the next periodic report. Because of all operational problems that arise every day, the long term models are of no use because the actual situation on the shop floor is neglected. If, for example, the delivery reliability of a shop was far below the target because their inventory of finished goods has decreased strongly, the delivery reliability for the next period will also be unsatisfactory due to an aftereffect. The delivery reliability for the next period can only be predicted with (short term) models that use the actual situation (in the example: a low inventory level) as input data.

Summarized, we restrict the research to:
- the logistics aspect;
4. RESEARCH TOPICS AND METHODOLOGY

In the foregoing chapter we described the problem and defined the scope of the research. In this chapter we formulate the research topics for the next two years. After formulating and discussing these topics, a plan is proposed for the research's methodology.

4.1 Research topics

Based on the literature analysis and the problem and research definition, we distinct two research topics.

1. What is the ability to use logistics theories for diagnosis purposes at the shop floor level?

   Our hypothesis is that logistics models can predict (or explain) the logistic performance of a shop floor well. This means that we expect that it is possible to calculate a maximum attainable performance with those theoretical models. If this hypothesis is confirmed, then it must also be possible to determine the causes which resulted in a deviant performance of the calculated maximum performance. We then can say that the logistics model that is used has got a diagnostic ability.

   Based on the examples of shop floors on chapter three, we distinguish four different kinds of control situations: a) a job shop, b) a flow shop, c) an industrial stockpoint, and d) a commercial stockpoint. Each control situation will have its own set of theories that can predict the performance. For example, theories for job shops shall be based on queueing theories, while theories for an industrial stockpoint shall be based on inventory control theories. Because each control situation will have its own set of theories, we expect that the usability of logistics theories for diagnosis purposes will be dependent on the control situation in which the theory is used.

2. Develop a diagnosis methodology for shop floor control.

   This methodology should of course also make a distinction in the control situations mentioned above. The diagnosis methodology should meet some requirements:

   a. It has to identify the logistics policies that caused a difference between the realized and theoretically maximum logistics performance. We define a logistics policy as a course of action in which a limited number of logistics decisions can
be taken. Examples of logistics policies can be found in table 2.

b. The methodology should be used by someone who has knowledge about the interactions/trade-offs between logistics policies. The output of the diagnosis are the policies that led to a lower performance. The user should know in what direction a policy should be changed in order to get a higher performance.

c. The methodology has to be directed at short term performances (of about one month).

Table 2. Logistics policies and logistics decisions.

<table>
<thead>
<tr>
<th>Logistics policies</th>
<th>Logistics decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequencing-rules</td>
<td>Choice of work out of a queue</td>
</tr>
<tr>
<td>Lot-sizing rules</td>
<td>Choice of batching orders</td>
</tr>
<tr>
<td>Rules for capacity allocation</td>
<td>Operator capacity allocation</td>
</tr>
<tr>
<td></td>
<td>Machine capacity allocation</td>
</tr>
<tr>
<td></td>
<td>Maintenance capacity allocation</td>
</tr>
<tr>
<td>Ordering rules</td>
<td>When to order and how much</td>
</tr>
<tr>
<td>Order release rules</td>
<td>Order release decision</td>
</tr>
<tr>
<td>Rules for contracting out</td>
<td>Decision to contract out</td>
</tr>
<tr>
<td>Rules for overtime work</td>
<td>Decision to work overtime</td>
</tr>
<tr>
<td>Rules for determining delivery dates</td>
<td>Calculation of internal delivery dates</td>
</tr>
<tr>
<td></td>
<td>Calculation of external delivery dates</td>
</tr>
</tbody>
</table>

4.2 Research methodology

The research will be started with some case studies in order to find the similarities and differences between real and theoretical logistics performances. For each control situation at least one case study should be made. The first step in these cases is to describe all the possible relevant characteristics for the logistics performance of a shop floor in terms of shop floor
characteristics (such as: number of work stations, number of machines, and distribution of processing times), and product characteristics (such as lot-sizes, routings, and order quantities). After collecting the relevant characteristics, these data are put in a model that can predict the logistics performance on pre-defined criteria. This predicted performance should then be compared with the real performance achieved by the shop floor. Then, the differences and similarities are going to be analyzed. This analysis will result in two sets of conclusions. The first set of conclusions is made for the case itself; these conclusions in fact are advices to get a better performance. This set of conclusions is of no direct importance for this research. The other set of conclusions is based on the usability of the theoretical models for the specific cases. These conclusions support the answer on the first research topic. An additional result of the analysis is that more insight will be gained into relationships and trade-offs between logistics variables. A problem that will arise in all cases is to find a proper theoretical logistics model by which the logistics performance will be predicted.

If the models appear to be usable for situations with the same characteristics as the specific cases, then the next step is to find out if the theoretical models can also be used for more general situations. This means that the sensitiveness for another filling up of the characteristics should be tested. For example, when a certain model assumes that arrival times have a Poisson distribution, it can be tested what the differences in performance are when these arrival times have a negative exponential distribution. The theoretical model in this example is tested for the sensitivity of the distribution of arrival times. The testing of the sensitiveness of the models can be done by (computer) simulations. If the results of the simulations show that the models are also to use in situations with slightly different characteristics without making large prediction errors, the application area of the models is broadened. Eventually, these models are then tested in other cases to validate the use of the models in the new application area.

The result so far will be a set of theoretical models that can predict the logistics performance on the short term for a specific application area. The next step is to develop a diagnosis methodology. This methodology will consist of a number of actions that must be taken to search causes for an unsatisfactory performance. One of these actions shall be the use of the theoretical models. The input of these models will then consist of the real characteristics of the past period that is reviewed, and not the expected characteristics as was the case when the performance was predicted.
Two approaches can be followed to build a diagnosis methodology. The first approach is to develop separate methodologies for each control situation we distinguished. When the methodology for the first control situation is developed, the methodologies for the other control situations can be deduced from the first one. The second approach is to develop just one methodology that can be used for all control situations. This second approach is more elegant, but it will probably be more time-consuming to develop it. It assumes for instance that all theoretical models we want to consider for the different control situations must be a part of the methodology. Another disadvantage of this second approach is that every time only a part of the methodology is used (namely for just one control situation at a time). Thus, every time only one theoretical model will be used, and not all the methodology steps will be passed through. Our choice therefore is to start with developing a diagnosis methodology for one control situation. After developing this diagnosis methodology, it should be tested in practice. If this test leads to a positive result, the methodologies for the other control situations shall be deduced from the validated one. A test in practice for the other methodologies then will be the final step of the research.
REFERENCES


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