CONSTRANTS EXPERIENCED IN A DIRECT DISTRIBUTION SYSTEM WHEN SAFETY MECHANISMS ARE REMOVED

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ABSTRACT

The aim of this paper is to discuss experiences gained when moving safety stock and other safety mechanisms to a direct distribution system. In order to reduce lead-time, which was about 4 - 5 weeks in the old system, a direct distribution system was implemented. When the safety mechanisms provided in the old system where removed, transport damage, accessory shortages, space problems, and problems with timing of delivery and service technician occurred.

A conclusion drawn from this case is that if material-flow systems are streamlined and lead-times are shortened, a comprehensive analysis has to be carried out to make sure that gains from shortened lead-times do not lead to increased costs because of e.g., customer complaints. As the lead-time decreases in a system, the system becomes more vulnerable to disturbances which, when there are no safety mechanisms to absorb them, can have negative effects. These effects can be difficult to anticipate because the positive effects of the lead-time reduction are emphasized.

The paper is based on a case study carried out at Atlet, a Swedish fork-lift manufacturer.

1. INTRODUCTION

A trend in industry today is to focus on lead-time as a competitive advantage. Short lead-time is seen as a means to gain high market flexibility and a prerequisite for manufacturing to order. By reducing the time in all aspects of the business, it is pos-
Lindau, Woxenius, Lumsden. Constraints experienced in a direct distribution system when safety mechanisms are removed

2. THEORY AND METHODOLOGY

In this paper direct distribution and safety mechanisms are discussed. These two concepts have to be further explained.

Direct physical distribution is when the products are sent directly to the customer from a central plant or warehouse. No intermediate warehouses are used. The aim of this distribution philosophy is to gain shorter lead-time, lower inventory levels and fewer reloading points. However, there is a disadvantage of direct distribution in the

sible to decrease costs, improve quality, and to keep close to the customers (Stalk, 1988). Short lead-time is crucial for business survival (Thomas, 1990).

A reduction of lead-time in a material-flow system results in a number of positive effects, one of which is a faster material flow (See, e.g., Hall, 1983; Schoenberger, 1985; Lubben, 1988; and Hay, 1988). When the speed of the material flow increases, the demands for high precision in the subsystems increase. A delivery that earlier demanded an accuracy of a week or a day, now demands an accuracy of hours. As material-flow systems are adapted to the precision in the subsystems, within acceptable tolerance requirements, even a short delay or stop affects the system's performance. The negative effect of reduced lead-times is that the system's sensitivity to delays, stops and deviations increases. These are often caused by disturbances that frequently occur. Disturbances result in stops and delays that can further result in negative effects, such as poor customer service and increased capital tied up in inventory. To avoid these negative effects, companies protect themselves by different actions, e.g., safety stocks and safety lead-times. A system using such actions absorbs the negative effects caused by a disturbance.

To decrease lead-time and inventory, companies focus on direct distribution. Direct distribution implies that the goods goes are transported straight from the supplier's central warehouse to the customer. In a survey conducted in the United States, it was found that direct distribution increased by 9.4% from 1987 to 1990 (LaLonde & Cooper, 1989). The reasons for implementing direct distribution are, e.g., decreased overhead costs, increased customer service, increased stock turnover, increased flexibility and less transportation damage (Page, 1988).

This paper describes a pilot study performed at a Swedish manufacturing company prior to a full-scale change in distribution strategy from distribution through subsidiaries to direct distribution. The problems experienced and recommendations for how to solve the incurred problems are presented.

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form of losses related to inferior control and timing of delivery and dependencye on transport supplier as well as quality problems discovered directly by the customer. If a product needs more extensive repair work, it has to be sent back to the central warehouse or any other service facilities, incurring additional transport costs. Depending on the transport conditions, transport costs may increase or decrease when direct distribution is implemented.

Safety mechanisms are actions or functions aiming at overall control of the distributed products. This control can be time or quality-related as well as a buffer to absorb unplanned events. Examples are long lead-times, safety stock, fast parallel transport chain, delivery through subsidiary, late assembly (in the distribution channel) and zero variant product.

The data collection for this study was basically performed by three students writing their master thesis at the Department of Transportation and Logistics at Chalmers University of Technology. Prior to the full-scale change in distribution strategy, a pilot study was performed. It consisted of:

- interviews with Atlet personnel, forwarders and subsidiaries
- field studies at Atlet's plant, primarily at the loading bridge and the finished goods store
- a questionnaire sent to fork-lift receivers at Atlet's subsidiaries

The methods used in the analysis are described as they appear in the text. In the appendix, a weight criterion method for evaluation is described more thoroughly.

3. ATLET - THE CASE STUDY

Atlet AB is a manufacturing company making fork-lifts and other types of materials-handling equipment with annual revenues of 100 Million USD (1992). The head office, R&D and manufacturing are situated in Mölnlycke, Sweden. Atlet has more than 800 employees in approximately 25 countries worldwide. In Europe the main markets are England, Germany and France. In these countries Atlet is represented by subsidiaries and agents that take care of sales and service. The subsidiaries do all the sales work on their market, place the customer order with the plant in Sweden, receive the fork-lifts, do some adjustments such as modifications and repairs of transport damages, deliver the fork-lifts and carry out service.

In Atlet's long-term distribution strategy direct deliveries are considered. In Sweden, Atlet runs direct deliveries today but on foreign markets most fork-lifts pass through
the subsidiaries. In three years time the share of direct delivery to European markets will increase drastically (see table 1).

Table 1. Direct deliveries 1992 and 1995.

<table>
<thead>
<tr>
<th>Market</th>
<th>1992</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>5%</td>
<td>90%</td>
</tr>
<tr>
<td>France</td>
<td>5%</td>
<td>60%</td>
</tr>
<tr>
<td>UK</td>
<td>2%</td>
<td>60%</td>
</tr>
<tr>
<td>Holland</td>
<td>0%</td>
<td>20%</td>
</tr>
<tr>
<td>USA</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

The present distribution strategy, referred to as indirect distribution, i.e., distribution to customer through a subsidiary, is time-consuming. The physical lead-time, measured from when the fork-lift leaves the plant in Sweden to when it is received by the customer, is today approximately 4 weeks.

When the fork-lift leaves the plant it is transported to the subsidiary where some adjustments and repairs of transportation damages are taken care of. As the fork-lift is sold with some accessories, such as battery, battery loading equipment and battery cart, a check is made at the subsidiary that the right fork-lift is delivered with the right accessories. If this is not the case, an order is placed with the plant and the right accessory has to be expedited. When a delivery is complete, i.e., a fork-lift with accessories, it is put in store until final delivery to the customer.

Figure 1. Present distribution strategy.
In the present distribution strategy, the subsidiary is acting as a buffer, i.e., any disturbance (transport damage or shortage of accessories) affecting the material flow from plant to customer is absorbed by the subsidiary. Such a distribution system is robust regarding disturbance sensitivity but at the cost of the physical lead-time, which tends to be very long.

With the new distribution strategy, where fork-lifts are sent directly to the customers, Atlet intends to decrease the physical lead-time between the plant and the customer by 3 - 4 weeks, i.e., the physical lead-time will be only 2 - 3 days.

**Figure 2.** The new distribution strategy.

The questionnaire, mentioned in chapter 2, was send along with 67 fork-lifts distributed during a period in the summer of 1992. As it was considered too risky to involve real customers in the study, the receivers at the subsidiaries acted as customers and filled in the questionnaires. In this paper Leg A in figure 3 is considered comparable with leg C and the findings at the subsidiaries are regarded as made by the customers.

**Figure 3.** Transport legs in Atlet's physical distribution.
The study showed that the physical lead-time could be reduced by 2 - 3 weeks as planned but that the new strategy would not work as well as Atlet had expected. A number of problems not anticipated prior to the pilot study emerged.

4. PROBLEMS EXPERIENCED WHEN CHANGING DISTRIBUTION STRATEGY

Previously, the subsidiaries had taken care of and repaired transport damages and also checked that the right accessories were supplied. If the wrong ones were supplied, the subsidiary arranged for the right accessories to be delivered within the customer lead-time. Information about adjustments and repairs was not always sent to Atlet in Sweden and the scale of the problems was not known at the head office.

The battery accounts for a large portion of the fork-lift, in weight as well as in cost. Due to currency, trade regulation and transport cost factors, the battery is often locally sourced. This was no problem when it was sent to the subsidiary, but with direct deliveries, there is a timing problem.

With direct distribution, the customer was the first to find out about a transport damage or wrong accessory. In the study, the number of complaints was amazingly large, concerning as many as 34% of all shipments.

Table 2. Complaints from the main markets in Europe.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Distributed as:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>40%</td>
<td>Transport damage: 92%</td>
</tr>
<tr>
<td>UK</td>
<td>35%</td>
<td>Accessory shortage: 8%</td>
</tr>
<tr>
<td>France</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Of total:</td>
<td>34%</td>
<td></td>
</tr>
</tbody>
</table>

4.1. Transport damage

The definition of damage is crucial for guarantee claims. In this study, damage is defined as a not accepted deviation in the quality level that needs to be adjusted by Atlet or its subsidiary. This means that damage is no absolute measure. With indirect distribution, the damage level is rather uniform for each market, as the same receivers at the subsidiaries always check the fork-lifts. With direct distribution it is up to the customer to complain and thereby define the deviation as damage.

The acceptance level of Atlet's customers is experienced to have become lower in the last decade. The acceptance levels vary among the three countries in the study.
French customers accept some damage, German customers hardly tolerate any deviations at all in quality and English customers are somewhere inbetween.

Most damage concerns the paint of the forklifts and is as such neither a functional nor a safety problem but is still not accepted by the customer. To repaint a forklift can cost as much as 10% of the sales value and is by us considered as rather unnecessary as a forklift is normally damaged within the first few days of use. A glance at the used forklifts for rent at Atlet, or in any warehouse, confirms this. Still, if the customer demands it, the forklifts must be repainted. It is also a part of Atlet's business strategy to deliver zero-defect forklifts.

The larger forklifts are shipped in closed containers or semi-trailers via Port of Gothenburg. With the closed load units, the point of damage is difficult to locate and, consequently, the damage is difficult to attribute to any particular transportation operator (see Kindred, 1992). In addition, Atlet has no information about damage until the forklifts are delivered to the customer or the subsidiaries. Smaller forklifts are sent on pallets among other goods, but information about damage is not available before delivery.

The main results from the interviews and field studies at Atlet were that several forklifts were damaged before leaving the plant due to careless handling and lack of space in the finished goods store. Further, problems were foreseen, as the number of truck drivers involved in delivering the forklifts would rise from 20 to 50 in a full scale direct distribution system. This would lead to less knowledge of the special handling technique involved as well as less responsibility compared to the truck drivers with experience and personal contacts with Atlet’s personnel.

The questionnaire gave the following statistics concerning damaged forklifts:

<table>
<thead>
<tr>
<th>Fork-lift model</th>
<th>England</th>
<th>Germany</th>
<th>France</th>
<th>Row total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Dam.</td>
<td>Total</td>
<td>Dam.</td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Column total:</td>
<td>31</td>
<td>10</td>
<td>15</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3. Damage statistics for forklift deliveries in the summer of 1992.
The response rate was 74% in total, distributed as 90% for England, 100% for Germany and 50% for France.

The fork-lift models are painted in different combinations of yellow and steel-grey (which is less sensitive to paint damage) and they are of different sizes which gives different transport opportunities; for instance, large fork-lifts must have their masts dismantled. Model A in table 3, a pedestrian controlled pallet truck with no reported damage, is small enough to be placed on a pallet, it has no mast to dismantle and it is painted more grey than other models. Model C, with almost half of the dispatched fork-lifts damaged, is a reach truck with large painted areas.

Experienced causes of damage were:

a) direct contact between fork-lift and container wall
b) fixing ropes were tied to yellow areas without protection
c) the paint was not completely dry before loading
d) reloading during transport
e) cargo not fixed inside the container
f) damage by fixing hooks
g) fork-lifts were not centered and fixed onto the pallet

These problems are present today, but the crucial thing is that the customer will be the one to discover them with direct distribution.

4.2. Accessory shortage

An accessory shortage can result in the customer being unable to use his fork-lift, and such a shortage is therefore very serious. The most common accessory shortage was found to be when the wrong battery was delivered. The main cause of this is poor marking of the battery. As each battery is uniquely matched with a fork-lift, it is given an order number. This order number is connected with the fork-lift and other accessories in the same delivery. When the picking document is generated, the battery belonging to the fork-lift is picked in the central warehouse. The person picking the battery signs the picking document that verifies that the battery has been picked and attached to the delivery. However, the marking of the order number on the battery is of such a poor quality that the person picking the battery sometimes picks the wrong battery. The marking is made when the battery arrives and is made using a piece of tape on which the receiver writes the order number. As the identification of the order number is sometimes difficult, an extra check that the right battery is delivered with the right fork-lift is not done.
Accessory shortage was a small part of the number of customer complaints in the pilot study, but it was normally of a much more serious nature. A shortage or the wrong accessory being delivered results in the customer having to wait for a new accessory to arrive; meanwhile the fork-lift stands still.

### 4.3. Lack of space in finished goods store

As a consequence of eliminating the buffer function at the subsidiaries, the stock of finished fork-lifts increased dramatically, resulting in floor space shortage in the finished goods store at the manufacturing plant. As discussed in section 3.1, this leads to an increase in the number of fork-lifts damaged before delivery.

Previously, the plant could ship the fork-lifts as soon as the delivery was complete, i.e., fork-lift with accessories. There was always a slack between delivery date and due date in the plant, but instead of keeping the fork-lift at the plant it was shipped to the subsidiaries as soon as the delivery was complete. If the fork-lift was stored for an extra week at the subsidiary this caused no real problem. However, a problem occurred when the fork-lifts had to wait for shipment at the plant. As the precision in due dates was slack because the physical lead-time was previously so long, precision in delivery date from the plant to the subsidiary was never considered. As a result of this, the plant had to carry all extra stock being produced earlier than the delivery date. The fork-lifts now have to wait to be delivered.

![Figure 4. New buffer location.](image)

This problem is not crucial today when the number of delivered fork-lifts is low, due to the current recession in Sweden and other markets.
4.4. Timing of delivery and service technician

Another problem concerned the timing of service personnel and the delivery of the fork-lift when it was commissioned at the customer. When the fork-lift is delivered, it has to be commissioned by a service technician. Service technicians are a constrained resource, so the timing of the delivery and the arrival of the technician is crucial. With the direct distribution strategy, the arrival time has become more difficult to predict, which results in the service technicians sometimes having to wait for the fork-lift to arrive. Previously, when the timing of service personnel and the delivery was taken care of by the subsidiary, the timing problem was not as severe. This was basically because the transportation lead-time was more stable, as the distance and possible delays were easier to predict.

5. SUGGESTED SOLUTIONS

When the problem situation has been analyzed, the solutions have to be sought. The active steps have to be made by Atlet, their subsidiaries and the transportation suppliers. In this paper though, some suggestions about how to solve the problems are presented.

5.1. Measure against transport damage

Transport from Atlet to customer is carried out by different carriers. Atlet has no direct control over the transport conditions. There is a legal relationship between Atlet and the transport supplier, regulating deviation in the transport quality. However, the transport conditions is influenced by Atlet in the long run, through its demand for transport services. The conclusion for Atlet is that the best way of preventing transport damage in the short run, is to improve the transport packing.

Torstensson (1990) describes a five-step method for systematic packing design. It is based on research carried out at Michigan State University and the steps are:

1. Characterizing the transport environment
2. Defining the product's resistance to environmental effects
3. Choice of suitable packing materials
4. Design of packing prototype
5. Testing and application for standard approval certificate
This systematic method is useful in the Atlet case, since the key issue is to prevent transport damages. For some of the steps, the weight criterion method for evaluation is considered as a suitable method for Atlet. This method is described in detail in appendix. It is an alternative, or to some extent a complement, to the five-step method and consists of six steps.

In the next section of this paper, an example of the development of transport solution based upon Torstensson's five-step method is described.

**Defining the product's resistance to environmental effects**

In step 1, definition of the evaluation situation, the transport environment is analysed.

For quality products, such as Atlet's fork-lifts, transportation is a hazardous activity. Many environmental threats can cause damage, some of which are listed in table 3 below. Causes marked with bold letters are considered as important in the Atlet case.

<table>
<thead>
<tr>
<th>Mechanical Static: stacking pressure side compression Dynamic: forces of inertia vibrations shock fatigue wear puncturing</th>
<th>Climatic temperature moisture sunlight atmospheric pressure wind</th>
<th>Chemical chemicals air pollution salt spray water</th>
<th>Biological mould bacteria rodents insects birds</th>
<th>Other dirt sand magnetic fields radioactivity sound waves fire theft</th>
</tr>
</thead>
</table>

Side compression and wear are primarily caused by tightening ropes and objects placed together with the fork-lift while forces of inertia, vibrations, shock and fire originate in the means of transport. Dirt, moisture and water are threats in the whole transport chain, while salt spray only occurs at sea. Theft is mostly a problem for spare part distribution and is as such not discussed further in this paper.

The weight criterion method of evaluation is used to rank the threats to the fork-lifts. The method is described in the appendix and only the weight criterion matrix is shown here.

The chosen criteria are side compression, shocks, wear, moisture, salt spray, water and dirt.
Table 5. Weight criterion matrix, transport damage threats to fork-lifts.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>Corr</th>
<th>P</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0.122</td>
</tr>
<tr>
<td>B</td>
<td>-0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>0.245</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>-1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>12</td>
<td>0.245</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>-4</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>0.143</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>-8</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td>0.061</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-10</td>
<td>0</td>
<td>11</td>
<td>1</td>
<td>0.021</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>-5</td>
<td>13</td>
<td>8</td>
<td>0.163</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Criteria explanation:

A. Side compression  C. Wear  E. Salt spray  G. Dirt
B. Shocks  D. Moisture  F. Water

Σ: 49 1.000

As seen in table 5, shocks and wear are considered as the worst threats to the fork-lifts.

To prevent shocks and wearing, the fork-lifts can be covered by wooden board. Plastic film is used to prevent from moisture, salt spray, water and dirt and wax paper is used against side compression and wearing.

**Choice of suitable packing materials**

The primary disposable packing material for machinery transport is wood. Wood is also used in most pallets. Wood is cheap, protects against some shocks and most wear. It is excellent in preventing paint damage, which is important to Atlet.

Plastic film is used to protect against moisture, salt spray, water and dirt, but also to secure, for instance, boxes onto a pallet. To prevent shocks and wear, the fork-lifts can be covered by wooden board.

Wax paper and cardboard are useful for preventing wear and to some extent also side compression. However, cardboard is useless in a wet environment.

The best suited materials for Atlet are wood in different shapes, plastic film and wax paper. Cardboard is considered too sensitive to water.

**Design of packing prototype**

This packing is not considered as important for other issues than to protect against transport damage and to enable effective handling. As such it is pure transport packing. Aspects such as customer information and packing design for marketing are not treated.
Four different solutions are considered as reasonable:

1. **Loading upon a standardized pallet** is a possible solution for many of the models. All models can be sent in this way, but the pallets have to be specialized for each of the larger models.

2. **Building a wooden crate around the fork-lift loaded upon a pallet** is one way of separating the fork-lifts from other shipments.

3. **Plastic wrapping around the fork-lift upon a pallet** is another way of preventing wear, dirt and water. The plastic film can be attached by heat-shrinking or tape.

4. **Wooden board attached to the fork-lift upon a pallet and plastic wrapping** are another way of preventing transport damage. The wooden board works as a bumper and is effective against shocks and horizontal movements. The plastic wrapping takes care of water and dirt.

The different alternatives can now be evaluated by the weight criterion method. An evaluation matrix is put up:

**Table 6. Evaluation matrix, transport packing alternatives.**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.122</td>
<td>2</td>
<td>0.244</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>0.245</td>
<td>2</td>
<td>0.490</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>0.245</td>
<td>2</td>
<td>0.490</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>0.143</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>0.061</td>
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<tr>
<td>F</td>
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<td>0</td>
<td>1</td>
<td>0.021</td>
</tr>
<tr>
<td>G</td>
<td>0.163</td>
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<td>0.326</td>
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<tr>
<td>Σ</td>
<td>1.00</td>
<td>6</td>
<td>1.224</td>
<td>11</td>
</tr>
</tbody>
</table>

A. Side compression   E. Salt spray   Used scale:
B. Shocks            F. Water           2   The solution alternative fulfills the criteria well
C. Wear              G. Dirt            1   The solution alternative is likely to fulfill the criteria
D. Moisture

As seen in table 6, alternative 4 was considered as best in the evaluation. It is better than alternative 2, which is the most advanced form of packing and as such the most expensive one, regarding materials as well as handling. Alternative 4 is considered less expensive, and was therefore chosen as the basis for building the prototype for further tests.

A calculation of the increased demand for space in vehicles for fork-lifts loaded onto pallets, compared to the fork-lift placed directly on the vehicle platform, was per-
formed. Five different pallet dimensions are available at Atlet. These are considered as one-way pallets since they are not of standardized measures. The decrease in space utilization is calculated at 23%.

A problem with loading upon pallets is that some customers lack the proper equipment for unloading this type of shipment. If the unloading is not performed carefully, more damage can be caused than in the transport chain. The solution is to discuss each shipment with the customers.

**Testing and application for standard approval certificate**

A standard approval certificate is not considered as important since the interface to the transportation system is based upon pallets already approved. The interface is standardized fork-lift tunnels.

**Other measures to prevent transport damage**

Some design changes are suggested to decrease transport damage. This is a strategic decision for Atlet, since the design is emphasized and is a part of Atlet's competitive advantage.

The proportions between yellow and steel-grey areas can be maintained, but a thorough analysis of which areas that need grey paint has to be performed. Decorative stripes should not be positioned at tightening points and the best way is perhaps to use other tightening points. The best solution is to locate all ropes or hooks to grey areas with additional padding material.

Special loops and holes for load fixing should be considered.

Other measures suggested are to make masts easier to mount, send carefully prepared instructions to customers and forbid them to touch the shipment until the service technician has arrived.

Further investigations of where in the transport chain damage is caused are suggested. For easier settlement of claims and evaluation of damage, a standard for classifying damage ought to be worked out in cooperation with transport suppliers. Also, negotiating clear rules for responsibility distribution between Atlet's personnel, truck drivers and other transport operators is a natural part of the buying process.

Atlet ought to be consistent when buying transport services. Through own knowledge of the hazards involved, better transport can be demanded. Examples are to keep fork-lifts apart from other (smaller) shipments, center the fork-lifts carefully on the pallets and demand transport without reloading. The number of truck drivers should also be limited, if possible.
The quality check should of course be performed earlier than in the finished goods store and loading ramp. Other obvious precautions are that the paint has to be completely dry and that it should be checked in bright light.

5.2. Measures against accessory shortage

The root cause of the battery shortage (accessory shortage) problem is the deficient marking of the battery and the erratic checking, that the right battery is delivered with the right fork-lift. As the speed of delivery is increased and all the surrounding activities have to adapt, the precision in the battery delivery also has to increase. A solution using bar codes was suggested.

When the battery is delivered from the supplier, he marks the battery with a bar-coded sequence number. This number is nothing but a number that is unique for every battery, even if two batteries have the same performance data. As the battery is unique and a sequence number does not verify what kind of battery it is, the supplier sends a list\(^1\) on which order number and sequence number are matched. This list is keyed into the computer system at the plant, and thereby the sequence number is connected to the order number. When the battery arrives, the bar code is scanned and a stock location is given. In a file, the bar-coded sequence number is matched with the order number, hereby verifying that the battery has arrived and is all right. When the battery is picked, the picking document is marked with a bar code expressing the order number, and the order number on the picking document and the sequence number on the battery are scanned, whereby an automatic check is made that the right battery is delivered with the right fork-lift.

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\(^1\) This list is intended to be sent by EDI in the future.
Figure 5. Automatic accessory checking system.

As this system allows automatic verification of what is being shipped and to whom, no customer complaints have been received after its installation.

5.3. Measures against lack of space in the finished goods store

The lack of space in the finished goods store is not a great problem today, but if production increases, so will this problem. Direct deliveries will move the buffer from the subsidiaries to Atlet's plant.

Possible measures to create more space are better planning and expansion of the store.

5.3. Measures against bad timing of service technician and locally sourced batteries

The service technicians are distributed over the market areas. Their service vehicles are equipped with tools and some spare parts. Since the time planning is inferior with direct distribution, communication between lorry driver and service technician is necessary. However, this is a problem since the driver must stop to call the technician, who in turn must be available at his phone. If this fails, another possibility is to notify the subsidiary.

The locally sourced batteries are supposed to be sent directly to the customer. If the service technician has a workshop and a sufficiently large vehicle, the batteries could
be sent to him. If this is done some days in advance, he can check that it is the right battery for the customer's fork-lift.

6. CONCLUSIONS

A conclusion drawn from this case study is that when material-flow systems are streamlined and lead-times are shortened, a comprehensive analysis has to be carried out to make sure that gains from shortened lead-times do not lead to increased costs because of, e.g., customer complaints. As the lead-time decreases in a system, it becomes more vulnerable to disturbances which, when there are no safety mechanisms to absorb them, can have negative effects. These effects can be difficult to anticipate because the positive effects of the lead-time reduction are emphasized. A thorough analysis has to be carried out before a change is undertaken in the physical distribution. Customer confidence once lost is hard to regain!

REFERENCES


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APPENDIX

**Weight criterion method for evaluation**

This method can be used in an evaluation of solution alternatives according to a number of criteria. The purpose of the method is to force the analyst to perform a thorough comparison in order to assess the alternatives objectively. It is best suited when the number of criteria is large and there is no obvious relative importance between them. The method is described step by step:

1. The first step is to define the conditions of the evaluation situation. This should be thoroughly done every time, since it is a common mistake to use old references that do not fit the actual problem.

2. The next thing to do is to make a list of criteria. Criteria are classified as demands or wishes. Demands have to be fulfilled and do not have to be weighted. Cost is not used as a criterion in the first steps of the method.

4. This is the crucial step in the method. The requirement criteria are weighted against each other in order to decide how important the different criteria are. The criteria are coded with letters and are compared in pairs. A matrix is designed:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Corr</th>
<th>P_i</th>
<th>k_i (P_i/ΣP_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-0</td>
<td>2 (AB)</td>
<td>2 (AC)</td>
<td>0 (..)</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0.24</td>
</tr>
<tr>
<td>B</td>
<td>-2</td>
<td>2 (..)</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>-4</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>-1</td>
<td>2 (DE)</td>
<td>7</td>
<td>8</td>
<td>0.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>-4</td>
<td>9</td>
<td>5</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Σ</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Text and numbers in **bold** print refer to the original form; other numbers are part of the example.

If criterion A is more important than B, the number 2 is put in the cell AB. If they are equal in importance, the number 1 is put in the cell. If B is more important than A, the number 0 is put in the cell. All cells in the matrix are filled out using the same procedure. A correction factor, corr, with odd numbers is put in a column.

Every column is summed up and the plus sign of the sum is changed to a minus sign. The rows, including corr, are then summed up with their proper signs giving the row sums. The P_i-column is added up and the sum shall equal the squared number of criteria. The weight factor, k_i, can now be calculated as k_i = P_i/Σ P_i. The sum of all k_i:s, Σ k_i, will equal 1.00 if the matrix is properly filled out.
5. A list of solution alternatives that satisfy the demands is generated. A new matrix is used to evaluate the alternatives:

Table 8. Evaluation matrix, example.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k_i$</td>
<td>fulfill</td>
<td>$k_i$*fulfillment</td>
</tr>
<tr>
<td>A</td>
<td>0.24</td>
<td>3</td>
<td>0.72</td>
</tr>
<tr>
<td>B</td>
<td>0.20</td>
<td>2</td>
<td>0.40</td>
</tr>
<tr>
<td>C</td>
<td>0.04</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>D</td>
<td>0.32</td>
<td>2</td>
<td>0.64</td>
</tr>
<tr>
<td>E</td>
<td>0.20</td>
<td>1</td>
<td>0.20</td>
</tr>
<tr>
<td>Σ</td>
<td>1.00</td>
<td>10</td>
<td>2.04</td>
</tr>
</tbody>
</table>

The alternatives are evaluated according to the degree of fulfillment against each criterion. The scale used in this example is:

3  The solution alternative fulfills the criterion well
2  The solution alternative is likely to fulfill the criterion
1  The solution alternative is not likely to fulfill the criterion

The scale can be altered to obtain greater detail in the evaluation. The $k_i$*fulfillment of the alternatives is calculated and the columns are summed up. Note that alternatives 1 and 2 have the same product rating even though number 2 has more points.

6. At this stage it becomes clear how well the alternatives satisfy the criteria and hereby also the probability of solving the problem at hand. In this last step, the cost of each alternative is estimated. The final decision is based on the $k_i$*fulfillment-rate and the cost of the different solutions. A ratio can be calculated but the decision is not necessarily the most cost-efficient one, other aspects being likely to influence the choice.