12 Transport Planning for Procurement and Distribution

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12.1 Planning Situations

12.1.1 Transport Systems

Transport processes are essential parts of the supply chain. They perform the flow of materials that connects an enterprise with its suppliers and with its customers. The integrated view of transport, production and inventory holding processes is characteristic of the modern SCM concept.

The appropriate structure of a transport system mainly depends on the size of the single shipments: Large shipments can go directly from the source to the destination in full transport units, e.g. as Full Truckload (FTL) or Full Containerload (FCL). Medium sized shipments are consolidated to FTL or FCL shipments in order to increase the efficiency of transportation. A consolidated set of compatible Less-Than Truckload (LTL) or Less-than Containerload (LCL) shipments constitute an aggregate FTL or FCL and will be fulfilled by a single truck or container, respectively on a single combined tour with several pickup and delivery locations. On this combined tour all shippers and receivers of the consolidated shipments are served without any transshipment. Small shipments have to be consolidated in a transport network, where a single shipment is transshipped once or several times

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and the transport is broken at *transshipment points (TPs)*. A particularly effective consolidation of small shipments is achieved by a *logistics service provider (LSP)*, who can combine the transports from many senders in his network, which often has a hub-and-spoke structure.

The consolidation of transport flows decreases the transport cost. As the cost of a single trip of a certain vehicle on a certain route is nearly independent of the load, a high utilization of the loading capacity is advantageous. Moreover, the relative cost per loading capacity decreases with increasing size of the vehicles. But even with a strong consolidation of shipments to full loads, e.g. by an LSP, the smaller shipments cause relatively higher costs, because the consolidation requires detours to different loading places, additional stops and transshipments (see Fleischmann 1998, p. 65).

The following transport processes occur in a supply chain:

- The *procurement of materials and their transportation* from external suppliers or from an own remote factory to a production site
- The *distribution of products* from a factory to the customers.

Note that the transport of materials from factory to factory is part of the distribution function of the supplier as well as part of the procurement function of the receiver. The procurement system as well as the distribution system depend on the type of transported items:

- *Investment goods*, e.g. machines or equipment for industrial customers, are shipped only once or seldom on a certain transport link.
- *Materials for production* are also shipped to industrial customers, but regularly and frequently on the same path.
- *Consumer goods* are shipped to wholesalers or retailers, often in very small order sizes (with an average below 100 kg in some businesses), requiring a consolidation of the transports.

Transport planning is usually the responsibility of the supplier. But there are important exceptions, where the manufacturer has the power to control the transports from his suppliers, e.g. in the automotive industry. In this case, transport planning occurs on the procurement side as well. The transport of materials for production, as far as controlled by the distribution system of the supplier, is mostly done in direct shipments.

An LSP may consolidate the transport flows of several *"shippers"*, operating in separate supply chains, in his own network. Then he is responsible for planning how the transports are executed, i.e. by which vehicles along which routes. However, the decisions on the transport orders, i.e. the quantity, source and destination of every shipment, remain a task (of the APS) of the shipper. Usually, it is not practicable to include the flows of all other shippers of an LSP into the APS. However, the additional flows have an impact on the transport cost and should be taken into account implicitly by appropriate transport cost functions.

Distribution Systems

A typical distribution system of a *consumer goods* manufacturer comprises the flow of many products from several factories to a large number of customers (see

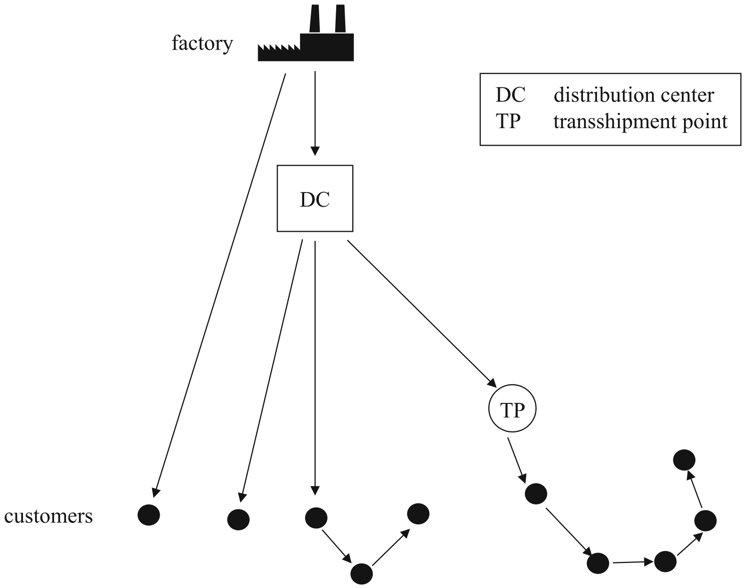


Fig. 12.1 Distribution paths

Fig. 12.1). The consolidated shipment of products to a distribution center (DC) followed by transshipment, deconsolidation and transport of the shipped products to their individual destinations is called pool distribution. Products made to stock are often shipped on forecast by pool distribution. The deliveries of the customer orders may use the following distribution paths:

Shipments may go *directly* from the factory or from a DC to the customer, with a single order. This simplest form of distribution is only efficient for large orders using up the vehicle. Smaller orders can be shipped jointly *in tours* starting from the factory or DC and calling at several customers. A stronger bundling of small shipments is achieved by a joint transport from the DC to a TP and delivery in short distance tours from there. Figure 12.1 illustrates the different distribution paths.

A beneficial concept for the supply of standard materials is the *vendor managed inventory* (VMI), where the supplier decides on time and quantity of the shipments to the customer but has to keep the stock in the customer's warehouse between agreed minimum and maximum levels. In this case, the customer's warehouse has the same function as a DC, so that the planning of VMI supply is similar to the DC replenishment.

Procurement Logistics Systems

If a manufacturer controls the transports of materials from his suppliers, he can use various logistics concepts, which differ in the structure of the transportation network and in the frequency of the shipments. They may occur in parallel for different classes of materials for the same receiving factory. *Cyclical procurement* in intervals of a few days up to weeks permits to bundle the transport flow into larger shipments, but generates cycle stock at the receiving factory. *JIT procurement* with at least daily shipments avoids the inbound material passing through the warehouse. Instead, it can be put on a buffer area for a short time. If the arrivals are even *synchronized with the production sequence*, the material can be put immediately to the production line where it is consumed. The latter case is called *synchronized procurement* or JIS (just in sequence) procurement.

The following transport concepts exist for procurement:

- *Direct transports* from the supplier are suitable for cyclical supply and, if the demand is sufficiently large, also for daily supply. Only if the distance is very short, direct transports may be used for synchronized procurement.
- A *regional LSP* collects the materials in tours from all suppliers in his defined area, consolidates them at a TP and ships them in full trucks to the receiving factory. This concept permits frequent supply, up to daily, even from remote suppliers with low volume. The trunk haulage can also be carried out by rail, if there are suitable connections.
- An *LSP warehouse* close to the receiving factory suits for synchronized procurement: The LSP is responsible for satisfying the short-term calls from the receiver by synchronized shipments. The suppliers have to keep the stock in the warehouse between agreed minimum and maximum levels by appropriate shipments, like in the VMI concept.

Returned empties cause a non-negligible overhead and costs, whose significance is depending on the type of packaging, containers or pallets used for transport. In order to reduce these costs, the return of empties should be consolidated and integrated into the flow of products. In case that the transport of products is outsourced to an LSP, it is favorable to outsource the responsibility and management of empties to the LSP, too.

12.1.2 Interfaces to Other APS Modules

Transport Planning comprises a set of various functions which overlap with other APS modules. It extends from the mid-term aggregate planning of transport processes, which is part of Master Planning, down to the shortest-term planning level: Planning deliveries of known customer orders is the last step of Demand Fulfillment and the release of orders for delivery from stock is part of the ATP function (see Chap. 9).

Transport Planning for Procurement and Distribution is linked to the other modules by the following data flows:

Strategic Network Design (see Chap. 6) provides the structure of the transport network, i.e.

- The locations of factories, suppliers, DCs and TPs
- The transport modes and potential paths
- The allocation of suppliers and customers to areas and of areas to factories, DCs, TPs
- The use of LSPs.

Master Planning (see Chap. 8) determines

- Aggregate quantities to be shipped on every transport link
- The increase and decrease of seasonal stocks at the factory warehouses and the DCs.

The first point can also be considered as part of mid-term transportation planning. The aggregate transport quantities should not serve as strict instructions to the short-term transport planning in order to keep the latter flexible. The main purpose of that quantity calculation is to provide appropriate resources and capacities and to take the duration of the various transport links into account. However, in case of multiple sourcing — e.g. if a material can be ordered from several suppliers or if a product is produced in several factories or if a customer can be supplied from several DCs — the aggregate quantities reflect the global view of Master Planning. Then they represent important guidelines for short-term transportation which could be used, for instance, as fractions of the demand sourced from different locations.

Also *Demand Planning* (see Chap. 7) provides essential data for transport planning:

- Customer orders to be delivered
- Forecast of demand at the DCs
- Safety stocks at the DCs.

The relationship with *Production Scheduling* (see Chap. 10) is twofold: On the one hand, Transport Planning may determine net requirements, timed at the planned departure of shipments from the factory, as input to Production Scheduling. On the other hand, the latter module provides planned and released production orders as input to Transport Planning for the very short term decisions on the release of shipments.

12.1.3 Planning Tasks and Information Management

As mentioned before, Transport Planning for Procurement and Distribution comprises mid-term and short-term decisions.

Mid-Term Planning Tasks

The *frequency* of regular transports on the same relation is a key cost factor. It is a mid-term decision variable for the DC replenishment on the distribution side and for the supply of materials on the procurement side. The objective is to optimize the trade-off between transport cost and inventory (see Sect. 12.2.1). The resulting frequencies set target values for the short-term decisions on shipment quantities. Moreover, they determine the necessary transport lot-sizing inventory (see Sect. 2.4), which should be a component of the minimum stock level in Master Planning as well as in Production Planning and Scheduling.

The selection of *distribution paths* for the delivery of customer orders usually follows general *rules* fixed by mid-term decisions. They are mostly based on limits for the order size, e.g. orders up to 30 kg by a parcel service, up to 1,000 kg from DC via a TP, up to 3,000 kg directly from DC and larger orders directly from factory.

On the procurement side, the *assignment of material items to the supply concepts* — direct, via regional TP or via LSP warehouse — also has to be fixed on a mid-term basis. As explained in the previous section, these decisions are closely related with the supply frequencies.

The determination of *aggregate transport quantities* on every transport link in the supply chain is an essential mid-term transportation planning task. But this task should be integrated in the Master Planning in order to guarantee a close coordination of the production and transportation flows in the supply chain. Transportation tasks can be executed on own account or by assigning them to LSPs. Outsourcing strategies must be laid down as guidelines for the actual make or buy decisions which will have to be made in short term transportation planning. These strategies must be consistent with the availability of vehicles of an own fleet and with the disposability of LSPs being under contract as carriers. With all carriers and forwarders which are frequently assigned to transportation tasks, contracts specifying the quantity and quality of outsourced transportation services as well as the agreed freight tariffs are fixed in mid-term planning.

The rules for assigning transportation tasks to carriers and the individual tariffs of single carriers may be fixed in a bargaining process with the involved LSPs. But this may alternatively be a result of a combinatorial procurement auction for transport contracts (see Buer and Kopfer 2014; Sheffi 2004), which is based on the bids of carriers for transportation lanes or transports to specific delivery areas.

Short-Term Planning Tasks

Short term transport planning is usually carried out daily with a horizon of 1 day or a few days. This task, which is part of the *Deployment function* (see Sect. 12.2.2), consists of the following decisions:

The *quantities to be shipped* within the current horizon have to be determined, in the distribution system and in the procurement system. These quantities can be influenced by the mid-term decisions on shipment frequencies and aggregate quantities.

The task of *shipment consolidation* is to adjust the sum of the shipment quantities of the various items on the same transport link to FTLs. It is relevant for DC replenishment and the supply of materials.

For the *deliveries to customers*, the quantity is fixed by the customer order, but there may be several *sources* from where to deliver and several *distribution paths*. These choices normally follow the guidelines set by the Master Planning quantities and by the general rules on the distribution paths.

The deployment function for products made to stock is closely related to the *ATP function* (see Chap. 9): Customers expect orders to be delivered from stock within a short agreed lead-time, mostly between 24 and 72 h, necessary for order picking, loading and transportation. If the incoming orders of the current day in total exceed the available stock of a certain item, the orders cannot be released according to the standard rules. Instead, some of the following measures have to be decided on:

- Shipping some orders from an alternative source
- Substituting the item by an available product, if the customer accepts it

- Reducing the quantities for DC replenishment which are in competition with the customer orders to be shipped from factory
- Reducing some customer orders in size, delaying or canceling them: This most undesired decision is usually not completely avoidable. Even if it is only necessary for a very small percentage of all orders, the concerned orders must be selected carefully.

If several LSPs are involved in fulfilling the transportation tasks it has to be decided which task will be assigned to which carrier. Due to the agreements made in the mid-term planning, the selection of a carrier may be uniquely determined by the characteristics of the task. Otherwise, this selection process is performed considering cost minimization aspects. The payment of freight charges is calculated by applying the tariffs which have been specified and agreed on during mid-term planning. Most tariffs take into account the compatibility of different shipments and thus offer the possibility of reducing the freight charge by an optimization process which is based on bundling compatible shipments to complex orders. This refers to assembling several LTL shipments to an FTL shipment as well as combining several FTL shipments to a chain of consecutive transportation tasks.

For all own vehicles used for transport fulfillment and in case that the payment to carriers is based on the characteristics of the outsourced tours, the tasks of operational transportation planning has to be done. This refers to the construction, routing and scheduling of the following tours:

- Short distance tours for delivering small orders from a TP in smaller vans
- The trunk haulage from the factory to the DCs, from DCs to TPs and the direct delivery tours from a factory or a DC to customers.

Information Management

Information Management is based on the above planning tasks. It provides and integrates all relevant data which are necessary for the control and fulfillment of the previously planned transportation tasks as well as all data which is needed for the tasks following the factual transportation fulfillment. For shipments on the procurement side, a notification for the supplier should be automatically generated. Concurrently, a transportation order for a LSP should be created and a corresponding announcement for the incoming goods department should be induced. The potential bundling of the created transportation order with other (more or less compatible) transportation orders as well as the choice of the LSP depend on the rules which have been fixed in mid-term planning and on the decision made in short-term planning. A well-functioning Information Management enables to guarantee the consistency of the information which has been sent to the suppliers, the LSP and the incoming goods department. Additionally, all returning information must be checked and reconciled, e.g., the advance shipping notification made by the supplier, the carriage documents, the information on the handling of empties, and the acknowledgment of receipt made by the incoming goods department of the factory. After successful electronic reconsolidation, the freight can be calculated according to the specifications of mid-term planning and the decisions during short term planning. Finally, a credit advice for the carrier can be generated automatically.

For transportation processes on the distribution side, similar support for the generation of documents and the integration of information is needed. Based on the short-time planning for shipments, the following information and documents are generated: the notifications of dispatch which are sent to receivers, the bordereaux (loading lists) and loading plans for the vehicles, accompanying documents as e.g. freight documents and tour schedules, as well as prepared documents for the proof of delivery. After the reconsolidation of all outgoing and returning documents, the freight calculation and payment to the LSP can be initiated.

12.2 Planning Approaches

12.2.1 Transport and Inventory

Transport planning has a strong impact on the inventory in the supply chain. It directly creates transport lot-sizing stock and transit stock and influences the necessary safety stock. The lot-sizing stock results from the decision on the transport frequencies. Unfortunately, the present APS do not (yet) support the optimization of mid-term transport planning with regard to inventory. Nevertheless, this section presents some generic planning models, since the resulting frequencies and inventories are also important data for other APS modules. When setting these data, the following relationships should be taken into account. A review of combined transportation and inventory planning is given by Bertazzi and Speranza (2000).

Single Link, Single Product

The simplest case is a transportation process linking a production process of a certain product at location A with a consumption process at location B. Both production and demand are continuous with a steady rate. In this case, the optimal transportation scheme consists in regular shipments of the same quantity. Figure 12.2 depicts the cumulative curves of production, departure from A, arrival in B and consumption. The vertical distances between these curves represent the development of the stock in A, in transit and in B. With the notations

p	production rate (units per day)
$d = p$	demand rate
Q	maximum load per shipment
L	transport lead-time
t	cycle time
$q = d \cdot t$	shipment quantity
h	inventory holding cost (per unit and day)
$T(q)$	cost of a shipment of quantity $q \leq Q$

the following relationships are obvious: The average transit stock is $L \cdot d$. As it does not depend on the transport schedule, it can be neglected in transport planning, as

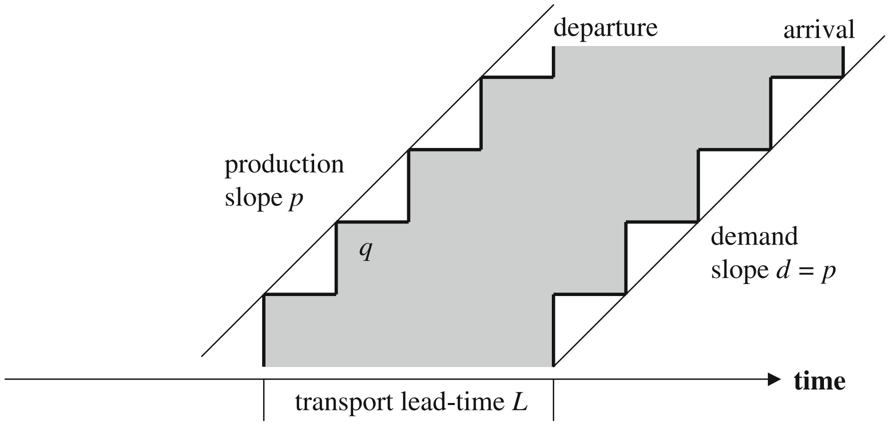


Fig. 12.2 Cumulative production, departure, arrival and demand

long as the transportation time is fixed. Therefore, $L = 0$ can be assumed in the following. The total cost per day due to transportation is

$$hq + T(q)d/q. \tag{12.1}$$

As the transport cost usually shows economies of scale, i.e. $T(q)/q$ is decreasing with increasing q, there is a tradeoff between inventory and transport cost which can be optimized by the choice of q. If $T(q) = F$ is fixed for $0 < q \leq Q$, i.e. the shipment is exclusive for the quantity q, the optimal q is obtained from the usual EOQ formula (see Silver et al. 1998, Chap. 5.2) with two modifications: The factor $\frac{1}{2}$ of the holding cost h is missing and q must not exceed Q, i.e.

$$q^* = min(Q, \sqrt{Fd/h}). \tag{12.2}$$

However, in most cases, the transportation costs are dominant, so that the transport in full loads $q^* = Q$ is optimal.

It follows from Fig. 12.2 that Production Planning must consider the demand in B shifted by the time $L + q^*/d$ or, equivalently, guarantee a minimum stock of $Ld + q^*$.

Single Link, Several Products

Now, several products i are produced in A and consumed in B, each with a steady rate d_i and holding cost h_i. If the transport cost F per shipment is fixed again, it is optimal to ship always all products together, i.e. with a common cycle time t and quantities $q_i = d_i t$ (see Fleischmann 2000). The optimal cycle time is

$$t^* = min(Q/\sum_i d_i, \sqrt{F/\sum_i h_i d_i}). \tag{12.3}$$

Even if demand fluctuates, it is optimal, at a certain shipment, to ship all products with positive net demand in the following cycle. Rules for determining shipment quantities in this case are discussed in Sect. 12.2.2.

General Case

The above assumption of steady demand may be realistic in case of consumer goods, whereas the consumption of materials in production and the output from production mostly take place in lots. In this case, it has to be decided whether the production lots and the transport lots should be synchronized or scheduled independently (see Hall 1996). Synchronization of transports and the consumption of materials is the basic idea of JIT procurement. Synchronization of production and distribution is the rule in a make-to-order or assemble-to-order situation. Production to stock is by its nature not synchronized with the shipments of customer orders.

But shipments from a factory to remote DCs or to VMI customers can be synchronized with production to stock. However, in case of many items produced cyclically on common lines and distributed to several destinations, the synchronization may become very difficult or impractical.

Transportation and Safety Stocks

In a distribution system for products made to stock, the safety stocks that are necessary for guaranteeing a certain service level, depend on the strategy of the transports between the factory and the DCs (see Silver et al. 1998, Chap. 12.4): In a strong *push system* any production lot is distributed immediately to the DCs. A modification consists in retaining some central safety stock at the factory warehouse which is distributed in case of imminent stock-out at some DC. In a *pull system*, transports are triggered by the local stock at every DC, when it reaches a defined reorder point. In a push system, global information on the demand and stock situation at every DC is required for the central control. But also in a pull system, global information can improve the central allocation of stock in case of a bottleneck. In an APS, such global information should be available for the whole supply chain.

The push system corresponds to the case of synchronized production and distribution and thus requires less cycle stock, but in general higher total safety stock or more cross-shipments between the DCs. The local safety stock at a DC has to cover the local demand uncertainty during the transport lead-time, the total system safety stock has to cover the total demand uncertainty during the production lead-time and production cycle time. In a consumer goods distribution system, the transport cycle time is usually very short, as a DC is usually replenished daily, but the production cycle time may last weeks to months, if many products share a production line. Therefore, the system safety stock calculation should be based on a periodic review model with the review period equal to the production cycle.

12.2.2 Deployment

The general task of deployment is to match the short-term demand with the available and expected stock for the next day or few days. As the *source locations* (factories, suppliers), where stock is available, are in general different from the demand locations (DCs, customers), it has to be decided how much to ship from which source location to which demand location. In the case of a single product, this is a simple network flow problem. In the case of several products and restricted transport capacity, it becomes a special LP problem, which is in fact an extract from the Master Planning LP for the entire supply chain (see Chap. 8), restricted to transport processes and to a shorter horizon. It is therefore easy to integrate into an APS as it is offered by most APS vendors.

Delivering Known Customer Orders

In a make-to-order situation, the completion of the orders in due time is the responsibility of production planning and scheduling. Deployment can only deal with completed orders ready for delivery, and the shipment size is fixed by the customer order.

In a make-to-stock situation, many customer orders may compete for the same stock. If the stock at every source is sufficient for the normal allocation of orders, again, all order quantities can be released for delivery.

Otherwise, ATP decisions about measures against shortage have to be taken as explained in Sect. 12.1.3. If there are several sources with sufficient stock in total, reallocations can be made, either by transshipments from source to source or by directly reallocating certain customer orders from their normal source to an exceptional one. The latter measure is both faster and cheaper, in particular if customers are selected near the border between the delivery areas of the concerned sources. While this is difficult in conventional distribution systems with local control within the areas, it is no problem in an APS with global information and central control of deployment.

The optimal combination of the measures against shortage for all customers competing for the stock of a certain product can be determined with the above network flow model, with the following interpretation (see Fleischmann and Meyr 2003):

- Every customer j is modeled as a demand location.
- Besides real locations with available stock, the source "locations" i include other potential measures, in particular a "source" with unlimited availability that stands for reducing or canceling orders.
- The cost c_{ij} includes penalties for delaying, reducing or canceling a customer order, depending on the priority of the customer.

Replenishment of DCs and Procurement

Shipment quantities for replenishment and procurement are not determined by customer orders but have to be derived from Demand Planning. Moreover, the calculation requires the prior specification of a certain *transport cycle time* (or of the transport frequency) for every relation, as explained in Sect. 12.2.1. The *net demand* for a shipment is then

$$
\begin{aligned}
d^N \quad = \quad & \text{demand forecast at the destination} \\
& \text{during the following transport cycle and the transport lead-time} \\
+ \quad & \text{safety stock for the destination} \\
./. \quad & \text{available stock at the destination.}
\end{aligned}
$$

In a *pull system* the shipment quantity is set equal to d^N, if there is sufficient stock at the source *for all destinations*. The quantities may be modified by a shipment consolidation procedure, as explained below. If the stock at the source is not sufficient, it is allocated to the destinations using a *"Fair Shares" rule* which takes into account the demand and stock situation of every destination and therefore requires global information and central control (see Silver et al. 1998, Chap. 12.4.3). The basic idea of fair shares is to balance the stock at various demand locations so that the expected service level until the arrival of a new supply at the source (e.g. by a production lot) is equal at all locations. If the local stocks are included into the allocation procedure, it may result that, for some destination, the allocation is lower than the available stock, indicating that stock has to be transferred by lateral transshipments.

Distribution Requirements Planning (DRP) (see Silver et al. 1998, Chap. 15.6) can be used to propagate the net demand upstream in a network, if every node is supplied by a fixed single source. It is an extension of the MRP demand calculation to the distribution network and permits, like MRP, to consider time-phased dynamic demands and lead times from node to node.

In a *push distribution*, every supply arriving in the source is immediately distributed to the destinations according to fair shares. In case of short transport lead-times and long supply cycles for the source, it is advantageous to retain some central safety stock at the source which is distributed later according to updated fair shares.

In the case of shortage, the determination of the DC replenishment quantities can also be integrated in the network flow model, together with the deliveries of customer orders, where a DC appears as demand location with the above net demand.

Shipment Consolidation

The previous calculations of shipment quantities are carried out separately for every product. They do not consider joint shipments of many products in appropriate transport units (e.g. whole pallets). This is the task of shipment consolidation which starts from those shipment quantities and fits them to FTL or FCL sizes. As far as the quantities represent net demand, they can only be increased, but in general, the demand calculation can specify minimum quantities below the proposed quantities. An upper bound is given by the stock which is ready for shipment. Shipment consolidation comprises the following steps:

- Round up or down the shipment quantity of every product to whole transport units (e.g. pallets)
- Adjust the size of the joint shipment, i.e. the sum of the single product quantities, to a full vehicle capacity, where the vehicle is eventually selected from a given fleet.

Both steps have to consider the minimum quantities and the available stock, the second step should try, within these bounds, to balance the percentages of increase (or decrease) over the products.

Vehicle Scheduling

As explained in the previous section, vehicle scheduling is mostly the task of an LSP and has only a limited importance for advanced planning. Therefore, and in view of the huge body of literature on vehicle scheduling, this subject is not dealt with here. Instead, the reader is referred to the survey by Cordeau et al. (2006).

12.2.3 APS Modules

There is no standard structure of the APS modules for Transport Planning. In any APS, these tasks are covered by several modules or by multi-functional modules, but with different allocations within the SCP-matrix. In the following, essential features of these modules are explained regarding the planning tasks of Sect. 12.1.3. This Section is based on information from JDA Software Group Inc. (2014), Oracle (2014) and SAP (2014).

Mid-Term Planning

The optimization of *transport frequencies* (see Sect. 12.2.1) w. r. t. transport and inventory costs is not supported. The same is true for establishing *rules on the use of distribution paths* and for *assigning materials to supply concepts*. However, the effect of such tactical decisions can be studied by means of analytical modules.

The integration of *Distribution Planning* in the Master Planning function is standard in all APS. Thus, using the LP solver or heuristic algorithms of Master Planning, aggregate quantities can be determined for every transport link in the supply network.

Short-Term Planning

For the short-term *deployment*, the APS provide the same modules as for Distribution Planning, used with a shorter horizon and more detailed demand information. Alternatively, there are special heuristics for calculating deployment quantities following a push or pull strategy, but restricted to the case, where every order has a specified single source. They work in two steps: First, a DRP calculation is performed upstream, starting from the net demand at the demand locations. If the available stock is not sufficient at some location, then fair share rules are applied downstream in a second step. The fair share rules are rather simple, e.g. the inventory is distributed proportionally to the demand or such that the same proportion of the target stock level at every location results. They do not consider service levels. The DRP calculation may differentiate several types of demand: customer orders, forecasts, safety stock replenishment and pre-built stock. Then, the allocation of tight inventory proceeds in this order and fair shares are only applied within one type of demand. Some APS include a more sophisticated allocation algorithm for insufficient inventory that runs after the normal deployment algorithm (LP or heuristics) and allocates the resulting inventory to the customer orders and forecast. It may consider multiple sources and track the effects of reallocations along the supply network.

Shipment consolidation is supported in all APS of the above vendors by particular modules or submodules running after the deployment. For every shipment they perform

- Rounding procedures to multiples of transport units for single items
- Building shipments containing several items.

At least the first step considers the effects of quantity changes on the planned inventories. Sometimes the two functions are split: The first one runs after the Deployment, the second one is done by a separate shipment consolidation module.

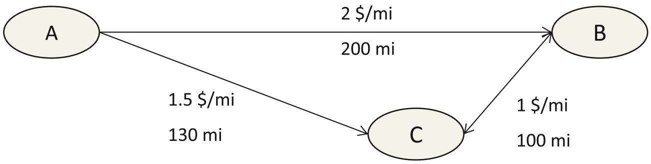
All APS of above vendors perform a detailed planning of the single shipments and aim at an efficient consolidation of the shipments and an optimal use of capacities. They can be used to plan for an own fleet as well as for subcontracting scenarios. From planning perspective they adopt primarily the view of an LSP:

- Input data are shipments (customer orders) with given origin and destination, quantities and (requested) dates/times.
- The paths of shipments through consolidation points (TPs and hubs) and the routes of the vehicles are planned.
- The use of various carriers is controlled.
- Various transport tariffs of the carriers and for billing the customers can be considered.

In contrast, a manufacturer deals with customer orders that specify only quantity and destination, but leave the source location open. For DC replenishment shipments, even the quantity is open. These decisions are typically not in scope of the shipment consolidation modules.

As planning for shipment consolidation comes very close to physical execution of transports, optimization based on real (carrier) costs is aimed for. While real freight rates are usually composed of many items (e.g. base fees, handling fees, fuel surcharges, tolls) based on a multitude of dimensions (e.g. distance based, weight based, volume based, stop based) considering real costs in vehicle scheduling and routing algorithms is not an option, but surrogate costs are used here. However, the final carrier selection decision can be based on real freight rates.

Vehicle scheduling and routing algorithms in standard APS have reached a state to obtain good solutions for most practical transportation planning scenarios. They even cater for different flavors of cost structures e.g. the calculation methods of distance based cost for road transports. While in the North American market this cost is usually calculated destination based, in most other parts of the world, it is calculated route based (see Fig. 12.3).



Destination based cost:

Transport Order (A➔B➔C) = Distance (A➔B➔C) * Cost (A➔C) = 300 * 1.5 = 450 $

Transport Order (A➔C➔B) = Distance (A➔C➔B) * Cost (A➔B) = 230 * 2 = 460 $

Route based cost:

Transport Order (A➔B➔C) = Distance (A➔B) * Cost (A➔B) + Distance (B➔C) * Cost (B➔C) = 200 * 2 + 100 * 1 = 500 $

Transport Order (A➔C➔B) = Distance (A➔C) * Cost (A➔C) + Distance (C➔B) * Cost (C➔B) = 130 * 1.5 + 100 * 1 = 295 $

Fig. 12.3 Destination based vs. route based distance cost calculation

Information Management

Several aspects of Information Management in the area of transportation can be in scope of APS modules. The first one is related to logistics information and deals with either the provisioning of data to vendors (inbound transportation planning) or customers (outbound transportation planning). Provided data ranges from advance shipping notification to goods receipt or proof of delivery documents. While this type of information deals with the goods itself, the second aspect is more related to the transport and deals with the information that is exchanged between shippers and LSPs. Subcontracting transport orders to carriers and their confirmation are usually exchanged electronically. Even auctioning mechanisms (tender to several carriers) are offered by APS or marketplaces like Transporeon can be integrated.

Another aspect of Information Management is the integration of financial flows. With transportation management software being able to even optimize carrier selection based on real freight rates, the calculated numbers based on midterm negotiated tariffs, can be used to substantially gain efficiency in the freight accounting processes. With accurate logistical information being available, freight costs are calculated directly and self-billing schemes allow to send carriers a credit note for their services.

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