Logistics

LECTURE NOTES*

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Chapter 1

Introduction to logistics systems

Logistics deals with planning and control of material flows and related information, in public and private organizations.

A relevant issue in Logistics is to take decisions (e.g. how and when raw materials should be acquired), by satisfying a given set of constraints (e.g. a budget constraint) while optimizing a certain performance measure (e.g. minimizing the total cost).

Logistics plays a great role in three main contexts:

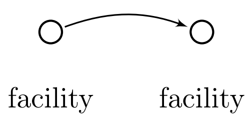
- military context, i.e. supply of troops with food, armaments and troop transportation;
- civil organizations, i.e. production and distribution in firms;
- public organizations, i.e. service management (e.g. garbage collection, mail delivery. . .).

In these notes the emphasis will be on logistics systems which are typical of civil or public organizations, where they have a very significant impact. For example, the total logistics cost incurred by USA organizations in 1997 was higher than the overall USA expenditure in social security, health services and defence.

Specifically, a *logistics system* is made up of a set of "facilities" linked by "transportation services", where:

facilities are sites where materials are processed (produced, stored, sold, consumed. . .); they include manufacturing centres, warehouses, distribution centres (DC), transportation terminals. . . ;

transportation services denote the movement of materials between facilities (using vehicles and equipment), and they are usually depicted as directed arcs:



1.1 Supply chains

The set of facilities and transportation services is called *supply chain*. It models the complex logistics system where raw materials are converted into final products and then distributed to the final users, by considering a business or a service activity context, as indicated before.

Figure 1.1 illustrates a typical supply chain where production and distribution are made up of two stages each.

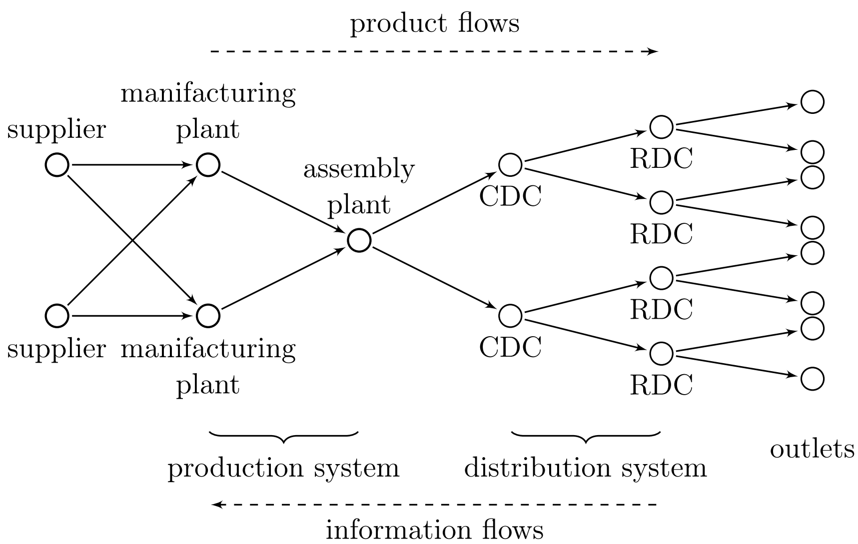


Figure 1.1: A typical two-stage supply chain. CDC: Central Distribution Centres; RDC: Regional Distribution Centres.

This is a very general and abstract representation; usually each facility (○) may comprise devices and subsystems (machines, retrieval systems...), while each transportation link (⟶) may denote a simple transportation line (e.g. a truck line) or a more complex system. In other words, the exact meaning of facility and transportation link does depend on the level of detail we want to address.

The supply chains can be classified according to different criteria.

Push vs. Pull supply chains

pull or make-to-order (MTO): in this kind of supply chains, finished products are manufactured only when customers need them, and so inventories are not maintained;

push or make-to-stock (MTS): in these supply chains, production and distribution decisions are based on forecast; therefore, inventories can be managed;

mixed approaches such as make-to-assembly (MSA) supply chains are also possible, where the final assembly stage is pull based.

Degree of vertical integration and third-party logistics

- *vertically integrated*: in this case all the supply chain components belong to a single firm (quite rare);
- supply chains are operated by several *independent companies* (more frequent).

In the second case, the relationship among companies can be:

- *transaction based* and *function specific*;
- *strategic alliance*; examples are given by:
  - third-party logistics (3PL): an outside company performs all or part of a product distribution;
  - vendor-managed resupply.

The main logistics activities and the related decision problems will be addressed in the rest of the notes.

1.2 Logistics managerial issues

When devising a logistics strategy and taking decisions, managers typically try to achieve a compromise among three main objectives:

1. *capital reduction*: to reduce as much as possible the level of investment in the logistics system (logistics network, equipment. . .);
2. *cost reduction*: to minimize the total cost associated with operating the supply chain (inventory management, transportation. . .);
3. *service level improvement*: this is also a relevant objective, since the level of logistics service influences customer satisfaction, which in turn has impact on revenues; often it is expressed via the *order-cycle-time*, i.e. the elapsed time between the instant an order (or a service request) is issued and the instant foods are received (or service is provided).

Since the three objectives may be contrasting, often a customer service level is set (first phase), then logistics decisions are taken so as to meet that service level at a minimum (capital and operating) cost.

1.3 Decisions in logistics systems

Several decisions have to be taken in logistics systems, both at the design and at the operating level. Examples are:

- location problems: should new facilities (e.g. CDC, RDC...) be opened? what are their best configuration, size and location?
- production problems: how should production be planned?
- inventory problems: when and how should each stocking point be resupplied?
- transportation problems: what is the best fleet size? how should vehicles be routed?

Logistics decisions are traditionally classified as follows, according to the considered planning horizon:

- *strategic* decisions: they have long-lasting effects (many years), and include logistics system design and acquisition of costly resources (facility location, capacity sizing, plant layout, fleet sizing); they often use forecasts based on aggregate data;
- *tactical* decisions: these decisions are made on a medium-term basis (e.g. monthly); they include production and distribution planning, inventory management, storage allocation, transportation mode selection...; they often use forecasts based on disaggregate data;
- *operational* decisions: in this case, decisions are made on a daily basis or in real-time; they include shipment and vehicle dispatching, vehicle routing and scheduling, and are based on very detailed data.

1.3.1 Methods for making decisions

How can we take logistics decisions?

Quantitative analysis is essential for intelligent logistics decision making. Operations Research offers many support methods for taking decisions in Logistics. Three basic methods are:

1. *Benchmarking*: this method is helpful when a logistics system already exists, and one wants to compare its performance to a "best practice" standard, i.e. the one of an industry leader in logistics operations; the most popular method is based on the Supply Chain Operations References (SCOR) model, using several performance indicators.

2. *Simulation*: this methodology is helpful to answer a number of "what-if" questions regarding different alternatives to the existing system, by considering the dynamics of the system (e.g. what is the average order retrieval time if we use a certain policy storage rather than the existing one); however, this approach may be time consuming and heavy in case of a large number of alternatives.

3. *Optimization*: some logistics decision problems can sometimes be formulated as mathematical optimization models. This is the approach which will be pursued in these notes. Optimization models include:

   - *Linear Programming* (LP) models
   - *Network Flow* models;

   these are "easy" problems, i.e. solvable in polynomial time. However, most logistics problems can be formulated only in terms of

   - *Mixed–Integer Linear Problems* (MILP)
   - *Nonlinear Problems* (NLP);

   they can be difficult to optimize, since *NP*-hard. This has motivated the development of heuristic approaches, in order to find good but not necessarily optimal solutions.

In any case, modeling logistics problems in terms of LPs and MILPs is very important, both to use suitable solvers to get solutions (for "easy" problems or "difficult" ones of reasonable size), or as a starting point to design exact and/or heuristic approaches for "difficult" problems. This is the subject of these Logistics notes, with focus on network flow, LP and MILP formulations to state and solve Logistics decisions problems.

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Textbooks

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