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NOTE

The role of logistics in the materials flow control process

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Frequently, the supply of building materials to the construction site is fraught with difficulties which can have a significant effect on productivity. Major productivity gains are possible, particularly if the building process is planned from a logistics perspective. The concept of logistics was developed initially within the manufacturing industry, and now constitutes an important management tool to ensure an overall strategic perspective on the flow of materials in the production process. This paper contends that logistics are relevant also to the construction industry, and describes the development of a logistics model to manage the flow of materials from suppliers to installation on-site and its application to a Danish house building project. The case study evidence suggests that the primary focus of the logistics concept in construction is to improve coordination and communication between project participants during the design and construction phases, particularly in the materials flow control process. The logistics concept requires accurate scheduling of materials to programmed delivery dates keyed to actual site layout and storage arrangements. The logistics approach also involves a new role for materials suppliers, including early involvement in the design phase and overall responsibility for the flow of information relating to materials.

Keywords: Logistics, materials flow control, house building, Denmark

Introduction

The European Construction Institute Total Productivity Management Report (ECI, 1994) states that: “materials delivery to site is a critical, productivity-related aspect which demands the introduction of a carefully developed system of monitoring and control as early as possible”.

The supply of building materials and components to site is fraught with obstacles which can have a significant effect on levels of productivity. Building materials

often require large storage capacity which rarely is available on site. Storage facilities usually are temporary structures or compounds, and the conditions in which the materials are kept often leads to damage from ingress of weather and movement of people, plant and equipment. Unless stringent quality control systems are followed, materials not meeting specifications may arrive on site and may have to be returned to the fabrication shop or manufacturing works, thus halting production and, in the worst cases, leading to programme delays.

The early and accurate scheduling of materials, planned to a time schedule and keyed to the master plan for site storage of materials is highly desirable (Enshassi, 1996). However, frequently this is impossible because the original details have a limited value, either because they are not complete at the commencement of a contract, or there are considerable variations before the contract has started (Bishop, 1965). The varying workload of the construction industry and its consequential disruptive effect on the materials supply position often create supply bottlenecks which make a planned flow of materials difficult if not impossible. Storage has to be related to the sequence of construction to ensure the minimum of movement and handling.

This paper examines the key issue of material supply logistics, and how it may benefit the construction industry. The first part provides a background to the logistics concept. In the second part an example is given of the application of a logistic model to a Danish house building project. This includes a description of the implementation process, the problems encountered, and the roles of the participants in the application of logistics management.

Definition and scope of logistics

Logistics is a little known term in the construction industry. In the Concise Oxford Dictionary it is defined as: "art of moving, lodging and supplying troops and equipment". As stated, logistics would appear to be limited to the military. It was only with the onset of the industrial revolution that the concept of logistics extended beyond its military context. In business, logistics activities commonly involve movement and storage for the purpose of having the desired object of flow at the right place at the right time. Transport and distribution are cornerstones of logistics and its most visible manifestations (Canadine, 1996).

For the construction industry, logistics comprise planning, organization, coordination, and control of the materials flow from the extraction of raw materials to the incorporation into the finished building (Clausen, 1995). Some may argue that there is little difference between a logistics management system and an integrated materials management system. The former system is the means whereby the needs of customers are satisfied through the coordination of materials and information flows that extend from the market place, through the firm and its operations and beyond that to suppliers. It is broader in scope than the latter, and operates at the strategic level. The scope of logistics spans the organization, from the management of raw materials through to the delivery of the final product.

Materials flow control process: current practice

For most of the materials purchased, the planning of deliveries is undertaken on an ad hoc basis (Clausen, 1995). This can lead to two types of problem. First, some materials may be purchased just before they are required, resulting in delays, and interruptions to the working schedule. Second, other materials are procured in large quantities without complying with production needs on site. This can result in a waste of resources during stocking, handling and transporting. Responsibility for waste concerns all project participants (Enshassi, 1996). It concerns general management as well as site management; any solution to the problem should involve all parties, i.e. those who design the building, those who design the materials and components; and those who specify, describe and account for the work and the suppliers of materials (Loudoun, 1976).

In selecting a method of handling building materials, the materials' characteristics (weight, vulnerability to damage, etc.), the method of packaging, the storage on site, the movement to the workplace and any obstructions, and the plant available and best suited to the task, are all aspects to be considered.

The next few sections describe how the above principles were adopted in the development of a logistics model to manage the flow of materials and general requirements for a house building project in Denmark.¹

Description of the project

The project described in this study relates to the Sophiehaven housing project in Denmark. This comprised the first phase of the construction of 100 two-storey dwellings together with communal facilities. In Denmark, the Ministry of Housing and Building has overall responsibility for the provision of social housing. There are specific rules governing construction costs. In this case, cost could not exceed £100 per square metre.

Both pre-fabricated elements and traditional materials were used in the construction of the buildings. The degree of prefabrication as well as the general standard of the buildings and the quality of the material was typical of social housing in Denmark. The total residential floor area was approximately 4500 square metres and the total contract value was £3.2 million. The programme duration was 11 months.

¹This case study was first reported in Danish; see *Byggelogistik I - materialestyring i byggeprocessen*, Boligministeriet, Bygge-og-Boligstyrelsen, Denmark, 1993.

Tendering procedure and design process

In the case of a publicly funded social housing project it is obligatory to use an open tendering process to ensure the most competitive bids. However, an exemption to this rule was made for the Sophiehaven project. This was because the project was of an experimental nature. Apart from the main contractor, the materials suppliers, and the subcontractors involved in the implementation of the logistics model, in fact all other parties were appointed on a competitive tender basis.

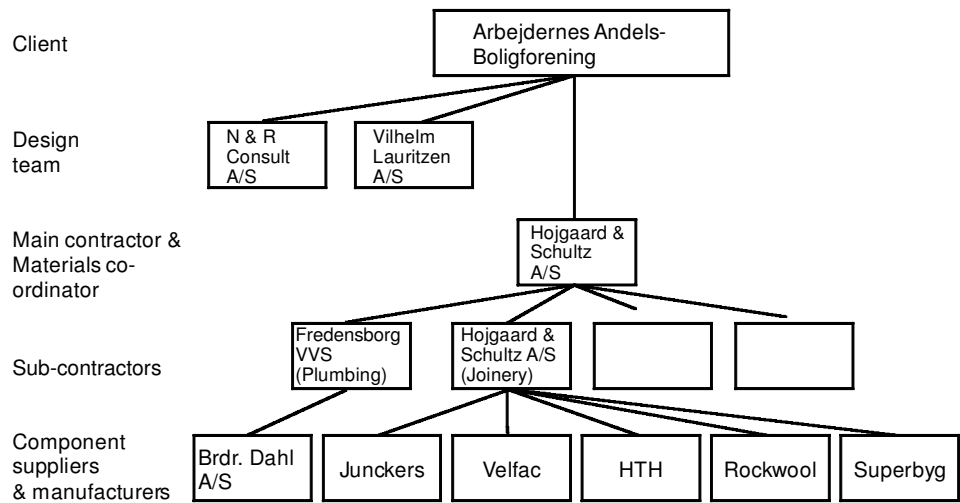
The architect produced the concept design in collaboration with the consulting engineers. Budget costs were produced by the consulting engineers. Working designs were then produced by the architect and the engineers, and to some extent with the main contractor and the subcontractors. The main contractor and the suppliers were involved actively in the planning and design process. The aim was to implement a ‘buildability’ approach during the design phase. Striving for buildability was a vital part of the logistics model. The materials and construction method were chosen/ designed to minimize production, transport and wastage on site. For example, the roof construction was designed to match the standard dimensions of roof insulation material.

The logistics experiment focused on two specific subcontracts: the joinery subcontract (roof construction, windows, doors, floors, etc.); and the heating and sanitary subcontract (plumbing, etc.). These subcontracts accounted for 30% of the total cost of construc-

tion. The plumbing contractor took no part in the development of the logistics model, but committed himself (during the tendering stage) to using the logistics approach during the construction process. Figure 1 shows the contractual relationship between the parties involved in the logistics experiment.

Development of the logistics model

The logistics model was developed to improve organization on site as well as the construction process as a whole. At an early stage, the project team identified the need to organize the process and to plan the flow of materials from manufacturer to installation on site in a more efficient manner. An important element of the logistics model was the formation of a partnering arrangement between the project participants. The development of the model was inspired by a number of studies undertaken in Sweden (Larsson, 1983). These studies indicated that low levels of productivity were the result of poor planning and logistics: (i) delays on-site, wastage and breakages of materials together with an unnecessary length of time wasted in manufacturers and suppliers workshops were a common experience; (ii) a building site was the worst possible storage facility, but nevertheless very vulnerable construction materials frequently are supplied in full loads exposed to the elements and pilfering; and (iii) materials handling techniques were not taken into account during the design phase.



Note: The joinery contractor is a subsidiary of Hojgaard & Schultz A/S

Figure 1 Contractual relationship between the participants in the logistics experiment

Having identified the problem areas, the project team prepared a detailed plan of action for the construction of the housing. The logistics model would be a materials management tool not only to purchase the right quantity of materials at the lowest price, but also to purchase the necessary services to get them delivered to the right location on site and just-in-time for installation. Deliveries of materials would be overseen by the 'materials coordinator' according to an agreed logistics approach, and suppliers would be responsible for arranging transportation and managing the inventory.

Practical use of the logistics model

The logistics model was developed to improve a number of aspects of the design and construction process. The project team identified several criteria for consideration, including:

- (1) planning of site activities;
- (2) deliveries of materials to site;
- (3) number of changes to the detailed design;
- (4) re-work during the construction stage; and
- (5) site working conditions.

To facilitate improvements during the construction phase of the project a number of practical measures were adopted, including:

- (1) limitation on the transportation of materials within the site boundary;
- (2) avoidance of stocking on site;
- (3) avoidance of wastage of materials;
- (4) avoidance of missing deliveries and returned goods; and
- (5) decrease damage during construction.

The basic components of the logistics model consisted of a number of management tools (see Table 1). Examples of the supply plans and request schedules used during the project are shown in the Appendix.

Planning process

The key individual responsible for materials control during the project was identified as the 'materials coordinator', whose role may be described as follows:

- (1) prepare site plan showing unit delivery locations;
- (2) participate and assist in the definition of units;
- (3) request units on a weekly basis;
- (4) inspect units delivered to site;
- (5) organize the collection and return of reusable materials packaging;

Table 1 Components of logistics management model

Logistics management tool	Description
Materials coordinator	Responsible for managing the logistics model during the construction process
Supply plan	Supply plan indicates the proposed delivery dates of units for the whole project. This plan is specified by the materials coordination in cooperation with each supplier/sub-contractor
Request schedule	A detailed version of the supply plan covering a three week period. The schedule is drawn up by the coordinator in cooperation with each subcontractor
Unloading plans	These plans indicated where daily supplies (units) would be delivered on site
Unit specification	A unit is a package of materials required for one working operation within one craft at one location on the construction site. The whole project was divided into units. The content of each unit was specified by individual subcontractors. A unit plan was specified by the materials supplier in conjunction with the materials coordinator

- (6) organize waste disposal;
- (7) coordinate the use of common materials handling equipment;
- (8) organize weekly meetings to schedule materials deliveries;
- (9) keep in daily contact with materials suppliers and monitor the delivery of sensitive materials;
- (10) evaluate changes in the master schedule and take action if changes in material supply required; and
- (11) ensure that all parties involved make proper use of the logistics concept.

The whole project was divided into units. The content of each unit was specified by individual subcontractors, and unit plans by the materials suppliers in conjunction with the coordinator. Each unit was specified in the supply plan by a number, by its contents, by its supplier and by the subcontractor at the receiving end. The contents of each unit were specified by a catalogue number and by type of material. The unit plan stated the time required for delivery, the method of transportation and equipment required for delivery, and details of packaging. The supply plan included a

description of the units and details of their proposed delivery date. This allowed suppliers to place orders with manufacturers at an early stage. Because the amount of storage space required was reduced, suppliers were able to pack units into ready-to-use packages in accordance with the unit plans. The suppliers had details of the orders in advance of delivery. The units, however, were not delivered to site until they were requested by the materials coordinator. This was undertaken two weeks before the scheduled time of delivery or on the actual day of delivery if amendments were made to the project schedule. The logistics model allowed the coordinator to change the supply plan according to progress on site.

Materials flow control process

During the construction phase, weekly material control meetings were held between the site management team, the suppliers and the materials coordinator. During these meetings weekly forecasts were broken down to identify daily material requirements according to the material plan. This was undertaken to identify the precise requirements two weeks in advance, and whether corrective action would be necessary in the third week. The request schedule was therefore a sliding window in the supply plan, where material supplies three weeks in advance were identified, supplies two weeks ahead were probable and supplies in the coming week were requested. The request schedules were supplemented by unloading plans indicating where daily supplies would be delivered on site. This allowed the supplier to load units into the containers ready for delivery, and in the correct sequence. At the same time, equipment required for unloading was identified as were details of any special conditions on site on that particular day.

Overall assessment of project

Compared with a traditional approach to design and construction, cost savings were made throughout the duration of the Sophiehaven project. Table 2 shows the effect of logistics planning on total construction costs. In spite of the extra costs associated with the logistics concept, including additional administration and the use of a telescopic handler, total savings amounted to 5% of construction costs. Savings were achieved through a reduction in materials wastage and breakages and early completion of the project. These calculations were undertaken by the Danish Building Research Institute (SBI). The method of data collection is described below.

Table 2 Effects of logistics planning on total construction costs

	Cost savings (%)	Extra cost incurred (%)
Reduction in wastage and breakages	3	
Reduction in working days	5	
Materials coordinator		1
Telescopic handler hire		1.5
Administration		0.5
Subtotal (%)	8	
Total cost saving (%)	5	

The materials coordinator kept a diary throughout the duration of the project. This included a record of all deliveries to site categorized by subcontractor. The key element of the evaluation process was the registration of all unforeseen incidents relating to material deliveries. This information was collected by the coordinator.

The incident record was divided into two categories; whoever was responsible for an incident, and any action that had to be taken, and by whom. The costs of each incident were calculated by the coordinator in conjunction with subcontractors and suppliers. In total, 251 incidents were registered (in a 9 month period). This covered approximately 45% of all deliveries to site. 144 of these incidents led to additional costs for the parties concerned.

Approximately 45% of the incidents were attributed to the failure of suppliers (e.g. defects or absence of materials in units), and 30% to the main contractor and subcontractor (e.g. insufficient specification of materials/units).

Opinions on the use of the logistics approach varied from one party to another, but generally were favourable. Subcontractors expressed their approval for logistics planning, even though they felt that the materials co-ordinator was an unnecessary link between the subcontractor and the materials supplier. The subcontractors were used to having direct contacts with suppliers: without this contact they had to change their working practices towards a more planned and less ad hoc approach.

Although subcontractors and craftsmen expressed their approval for logistics planning, the suppliers of basic materials (i.e. insulation materials and bricks) were more critical of the approach. One reason given was the need to increase the number of deliveries to the site due to the types of unit and the just-in-time requirement. All parties found the unit plans and delivery plans very useful, but emphasized that these

management tools should be kept as simple as possible and user-friendly.

Involvement in the logistics concept was purely voluntary. Several subcontractors opted out of the process from the outset of the project. This led to a number of problems during the construction phase. For example, when the master mason purchased a large quantity of insulation materials it was delivered in bulk and off-loaded in a careless manner very close to scaffolding where the work was in progress. This caused a considerable amount of disruption on site. Furthermore, although an initial saving was made by buying insulation materials in bulk, this was offset by losses due to wastage.

The Sophiehaven project illustrates indirectly what appears to be a common but also problematic procurement strategy. Subcontractors traditionally acquire materials and components from manufacturers and suppliers at the lowest possible price, without careful consideration of the costs associated with handling and production on site; any savings made initially may be offset by additional work during the construction process. Therefore, any alternative strategy must be based on a holistic view of procurement and the planning and control of materials deliveries. The development of logistics planning is an on-going process. All parties (in the Sophiehaven project) recognized that the logistics model would need further refinement, but that this should also be an inclusive process: the involvement of all subcontractors is vital for the further development of the model.

Conclusion

This paper has described the logistics concept and development of a logistics model to manage the flow of materials from manufacturer to installation on site, including its application to a house building project in Denmark. The advantages of using logistics management on the Sophiehaven project were recognized by all participants. The requirements for a high quality product and for overall savings were provided by a process of planning site activities based on a strategy to ensure that materials were handled, transported and stocked as little as possible. This led to overall savings of 5% when compared with a similar traditional project. This success was based not only on an integrative approach to materials control, but also on the 'new' (non-traditional) roles adopted by the participants during the design and construction phases of the project.

The primary focus of the logistics concept in construction is to improve coordination and commu-

nication between project participants during the design and construction phases, particularly in the materials flow control process.

The case study evidence suggests that the focal points of logistics are the interfaces between the parties, exchange of information, and development across project organizational boundaries based on 'partnering-type' arrangements. Effective materials flow control demands the concerted and coordinated action of numerous parties performing a variety of functions within the construction industry.

Any strategies for effective materials control must involve those who design the building, those who design the materials and components, and those who specify, describe and account for the work. Materials control based on the logistics concept must start at the design stage. Designs should allow for the effective handling and convenient manoeuvring of materials and components of preferred size during construction. The logistics concept requires accurate scheduling of materials to programmed delivery dates keyed to actual site layout and storage arrangements. The findings also suggest that materials procurement must specify the quality, quantity and the timing of the delivery of materials precisely.

The logistics approach involves a new role for the materials suppliers, including early involvement in the design phase and overall responsibility for the flow of information relating to materials. Communications between materials suppliers and recipients should be such that details regarding transportation, eventual site location, order of delivery, labelling and packaging sizes should be available to all those involved.

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Appendix

Supply plan no.1

Page : 1

Revision:

Materials supplier: Brdr.Dahl

Trade : Heating and sanitation

Building no. : All

Contractor : Fredensborg VVS

Project : Sophie haven

Time/amount

Planning period: Week 30-37

Unit no.	Week 30	Week 31	Week 32	Week 33	Week 34	Week 35	Week 36	Week 37
VK001	1						2	
VK002						1		
VK003					1			
VK004				1				
VK005	1			1	1			

Figure A1 Supply plan

Request schedule no: 2						Page : 1						
						Revision :						
Materials supplier: Brdr.Dahl												
Trade		: Heating and Sanitation										
Building no.		: All										
Contractor		: Fredensborg VVS										
Project : Sophie Haven						Planning period : Week 33-34						
Time/amount		Request					Briefing					
		Week 33					Week 34					
Unit no.	Description	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri	Wk 35
VK002	Water and heating (I)											1
VK004	Water in channel								1			
VK005	Water and heating (II)		1									
VK006	Water and heating (III)		1						1			
Delivery/transportation: Truck												
Unloading method:												
Packing:												
Supplementary												
Information :												

Figure A2 Request schedule

Examples above are of a typical supply plan (Figure A1) and a typical request schedule (Figure A2) used in the Sophiehaven project.