# CONSTRUCTION MATERIALS SUPPLY LOGISTICS

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Materials supply logistics plays a significant part in meeting the project delivery goals of cost, quality and time. Customer service is the key element that holds together all supply logistics activities, thus, the effectiveness in selecting suppliers should begin with evaluating characteristics that are deemed necessary for a supplier to provide a pre-requisite level of customer service. Such factors, or enablers, provide indications as to whether a given supplier will be able to meet key materials delivery objectives. This paper provides a review of problems besetting the supply of construction materials as identified in current literature. Opportunities presented by the introduction of information and communication technologies for improving the materials management process have been examined. A logistics perspective of construction materials management has been adopted. The analytic hierarchy process has been presented as an appropriate methodology for assessing factors that enable achievement of efficient and cost-effective materials supply logistics to support construction.

Keywords: Analytic hierarchy process, customer service, enablers, materials supply logistics, performance indicators.

## BACKGROUND

Logistics is the umbrella term covering materials management and physical distribution (Rushton and Oxley, 1989; Gattorna et al, 1991). Traditionally, the construction industry refers to the flow of materials for incorporation into the facility being constructed as materials management (Alkaabi, 1994; Construction Industry Institute, 1987; Stukhart, 1995). This arises out of the fact that most construction facilities are geographically fixed and there are no distribution elements after their production. Viewing the flow of physical inputs to support construction activities from the logistics perspective is useful in order to capture elements, such as customer service, that may otherwise be overlooked when the process is considered from a materials management perspective.

Logistics is a relatively new area that many companies are focusing upon to gain competitive advantage in an increasingly aggressive business environment. The Institution of Production Engineers (1989) considers competitive material logistics as essential not only for gaining competitive advantage but also for sustaining it.

Companies, through integrated logistics, seek to achieve efficient material flows in their business transactions and processes for the focused purpose of satisfying their customers. This helps in keeping and expanding their current markets.

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Advances in information and communication technologies are making the integration of the logistics function within and between organisations a reality. However, their are several hurdles to be crossed before rewards of full integration can be realised. Turner (1993) stated that among the companies that had claimed to have fully implemented integrated logistics, few claimed to have sustained the benefits that successful integration should have created. While there have been many casualties among some of the pioneers, there is agreement that effective integrated logistics can be a major source of competitive advantage (Turner, 1993).

Changes in information and communication technologies are irreversible. These technologies, and ever higher customer awareness, are creating paradigm shifts and pressure on businesses to change their transaction and production methods. This is mainly because their competitors are seeking to invest in technologies which improve the effectiveness of their supply chains and competitiveness in aggressive business environments (Hammant, 1995).

The construction industry is currently directing considerable effort towards improving productivity by harmonising relationships among clients, contractors, sub-contractors and designers (Latham, 1994; Building, 1995). As this is happening, opportunities to accrue even greater benefits should be explored and capitalised upon from every available angle. Management of construction materials on well founded integrated logistics principles has the potential to yield results and augment efforts being made in other areas at making construction efficient. Baxter and McFarlane (1992) recognised that greater opportunities exist in improving construction efficiency through the use of Just-in-Time (JIT) practices in construction. Integrated logistics, whilst embracing JIT principles goes much further by taking advantage of the efficiency offered by electronic and data management technologies in communicating and relaying data within and between organisations.

## LOSSES IN PRODUCTIVITY DUE TO SHORTAGES OF MATERIALS

Construction materials and equipment have been cited to constitute 50 - 60 per cent of total project costs (Construction Industry Institute, 1987). Despite the high proportion of the cost of materials in projects, the supply process of the resource has been identified as being fraught with many problems by a number of authors (Majid and McCaffer, 1996; Stukhart, 1995; Thomas et al, 1989). Problems in the delivery process have also been cited as contributing to causes of project delays (Majid and McCaffer, 1996).

From a synthesis of literature, Majid and McCaffer (1996) identified late delivery of materials as one of the critical factors that caused construction programme delays. Other materials-related delays resulted from unreliable suppliers, damaged materials, poor planning, poor quality control, poor monitoring and control, and inefficient communications. Abdul-Rahman and Aldrisyi (1994) conducted a survey in Malaysia in which 55 per cent of responding contractors acknowledged having experienced materials shortages. Shortages resulted from a number of causes which included late delivery, late purchase and failure to monitor inventory on site. In a survey of workforce motivation and productivity on nuclear power projects in the United States, Borcheding and Garner (1981) showed that non-availability of materials led to a loss of six hours per individual craftsperson per week. Problems in the materials supply process are thus world-wide.

Losses in labour productivity resulting from non-availability of materials has been estimated to be 6 - 8 per cent (Construction Industry Institute, 1987). In the USA, from a single case study of a five-storey commercial office building, Thomas and Sanvido (1989) calculated losses in productivity resulting from poor materials management to be in the order of 18 per cent. Kerridge (1987, pp. 63) stated that materials "*control 80 per cent of the project schedule from the initial materials acquisition step to delivery of the last material item*".

## IDENTIFIED BENEFITS OF IT FROM PREVIOUS WORK

A number of studies have been performed on materials management in the construction industry. The Construction Industry Institute (CII, 1987) detailed construction management practices in the United States. The book, Construction Materials Management, by Stukhart (1995) is based mainly on articles and case studies which were outputs of research activities. Research has also advanced to the simulation of the integrated procurement process of construction materials in the USA (Back and Bell, 1994) and in the UK (Carter et al, 1996). The two simulation exercises estimated that full exploitation of electronic technologies in the construction materials procurement process could achieve 76-85 per cent reduction in the total cycle time and save costs (labour) by 50-75 per cent.

Previous studies, however, indicate that the use of information and communication technologies in construction materials supply logistics had not taken-off in the first half of the 1990s (Alkaabi, 1994; Finch et al, 1996; Stukhart, 1995).

Alkaabi (1994) proposed a conceptual framework for improving management of construction materials using bar coding and other automatic identification techniques (auto-IDs). The methodology proposed the integration of materials supply logistics using bar codes and EDI. Out of 58 responses to a total of 144 questionnaires sent to leading materials suppliers and building and civil contractors, only 7 per cent of the respondents indicated that they were using bar coding techniques for their internal use and all were materials suppliers.

Alkaabi (1994) also performed a bar coding feasibility study at a company specialising in the manufacture of precast concrete flooring systems. The study established the following savings (Alkaabi, 1994, pp. 348):

- "an 85 per cent time saving in clerical time for entering data onto the company's computer;
- a 70 per cent time saving in checking of beams onto a trailer prior to delivery; and
- a 30 per cent time saving in locating a beam within the stockyard".

Alkaabi (1994) concluded that bar codes and other auto-IDs facilitate efficient data capture of resources used in the construction industry such as labour, plant and materials. He observed, however, that benefits of this technology is limited by the level of sophistication in the management information systems used by a company.

The above and other research that has been conducted on the use of information and communication technologies indicates that substantial benefits can be gained in the materials supply logistics process of the construction industry.

Despite the existence of information and communication technologies that can contribute to efficient materials supply logistics, these technologies remain underexploited. Problems in materials supply logistics persist world-wide, causing losses in productivity and delays in construction schedules.

## PARADIGM SHIFTS IN LOGISTICS

Christopher (1992) noted a number of paradigm shifts in the logistics focus of enterprises: from functions to processes; from profit to profitability; from transactions to relationships; and from inventory management to information management. These changes should result in: new business practices; integral management of materials and goods flow; more focus on resource management and utilisation; more focus on markets and customers; co-manufacture and co-shipping partnership; and resource based replenishment and quick response systems (Christopher, 1992).

The paradigm shifts and changes in business practices have been induced by aggressive competition across markets and industries and ultimately are a search for long-term survival of companies. While the changes may be well suited for the long-term survival of companies in relatively steady-state manufacturing and retailing environments, there might well be factors which inhibit their full deployment in the project-based construction industry. It is necessary, therefore, to gain greater insight into current practices and trends in the implementation of integrated materials supply logistics in the construction industry.

Efficient materials supply logistics is critical to improving productivity and reducing costs in the construction industry. Contractor factors, such as planning and management capability of site staff, can influence the efficiency of the materials supply process. However, the recognition in new working relationships between organisations is that the capability and co-operation of trading partners are essential elements for achieving competitiveness (Christopher, 1992). Evaluation and selection of construction materials suppliers plays a significant role in contributing to improvements in the delivery of construction projects. Paradigm shifts have introduced other considerations in supplier evaluation and selection, thus increasing the complexity of the process. New approaches which can handle complexity in decision making when selecting suppliers can, therefore, be of great value.

## OBJECTIVE DECISION MAKING IN SUPPLIER SELECTION

From the logistics standpoint, one aspect which is useful when examining construction materials management is the customer service element. All logistics activities involved in materials management should ensure the highest level of customer service at any given total materials supply logistics cost.

An approach which can be used to quantify the relative importance of logistics elements, hereafter referred to as performance indicators and enablers, which can be used for evaluating suppliers is the analytic hierarchy process (AHP). A logistics performance indicator may be defined as a metric by which a supplier can be evaluated in satisfying customer requirements, and an enabler is the characteristic of a supplier which make it possible for that supplier to meet customer requirements. Logistics performance criteria include: delivery reliability; flexibility; and lead times (NEVEM-workgroup, 1989). Whereas enablers may include such characteristics as: information and communication technologies; long-term customer-supplier relationships; quality management systems of suppliers; a supplier’s capability viewed in terms of financial strength, product technology and operational efficiency; location of supplier in relation to the project; and a supplier’s quoted prices.

Any level of customer service has a proportional logistical cost associated with it. One important approach for obtaining value for money at a preferred level of customer service when making logistical decisions is trade-off analysis. Obtaining efficient materials supplies, at an optimised total logistics cost, involves trade-off decision-making among various logistics elements. The AHP can be used to demonstrate the relative importance of factors that contribute to efficient supply of materials to support construction. The AHP, which was developed by Thomas L. Saaty in the 1970s, offers a systematic framework that is well suited for dealing with quantifiable and intangible criteria at the same time in a complex trade-off decision making process. Formulation of the analytic hierarchy process model follows the steps outlined in Figure 1.

The AHP is based on three main problems solving approaches: decomposition; comparative judgements; and synthesis of priorities (Saaty, 1983).

## DECOMPOSITION

Decomposing a complex problem into a hierarchy reduces it to manageable elements at lower levels. Decomposition can be performed up to the most specific elements of the problem. Such structuring of a decision situation provides an efficient way of dealing with complexity and identifying and segregating the major elements of the decision-making process.

Using the AHP, a decision model for evaluating logistics performance criteria and enablers to facilitate efficient materials supply logistics can be decomposed as shown in Figure 2. The defined overall objective in this case is ensuring efficient, cost-effective materials supplies. The next step after decomposing the problem is to make comparative judgements.

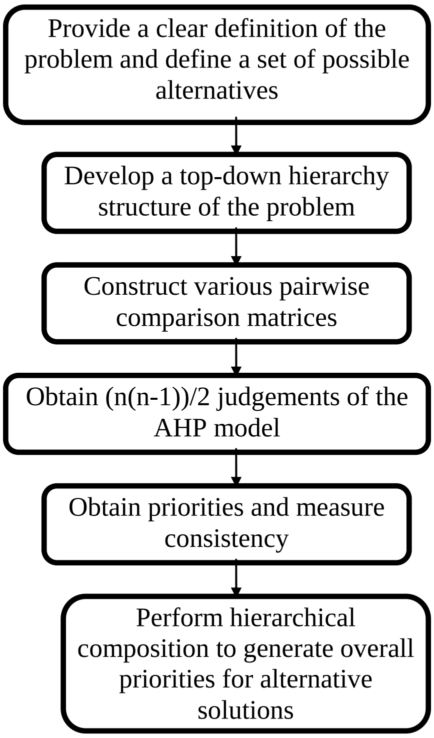


**Figure 1: Steps of the Analytic Hierarchy Process**

## COMPARATIVE JUDGEMENTS

A measurement methodology is used to set priorities among elements of every stratum. This is accomplished by asking the decision maker(s) to evaluate stratum elements pairwise with respect to elements in the next higher stratum. This measurement methodology is the central feature of AHP and constitutes the framework for data collection and analysis.

The 9-point scale given in Table 1 is widely used for making numerical judgements in pairwise comparisons (Anderson, 1986; Dyer and Forman, 1992; Korpela and Tuominen, 1996; Saaty, 1983; and Thompson,1994).

Using the given scale, the decision maker or the group of people involved in making a decision exercise judgement about the dominance of each element at a given stratum over the other elements at the same level with respect to each element at the next higher level. This leads to formation of matrices of pairwise comparisons of stratum elements whose eigenvectors give relative weights of the elements with respect to each element of the stratum above.

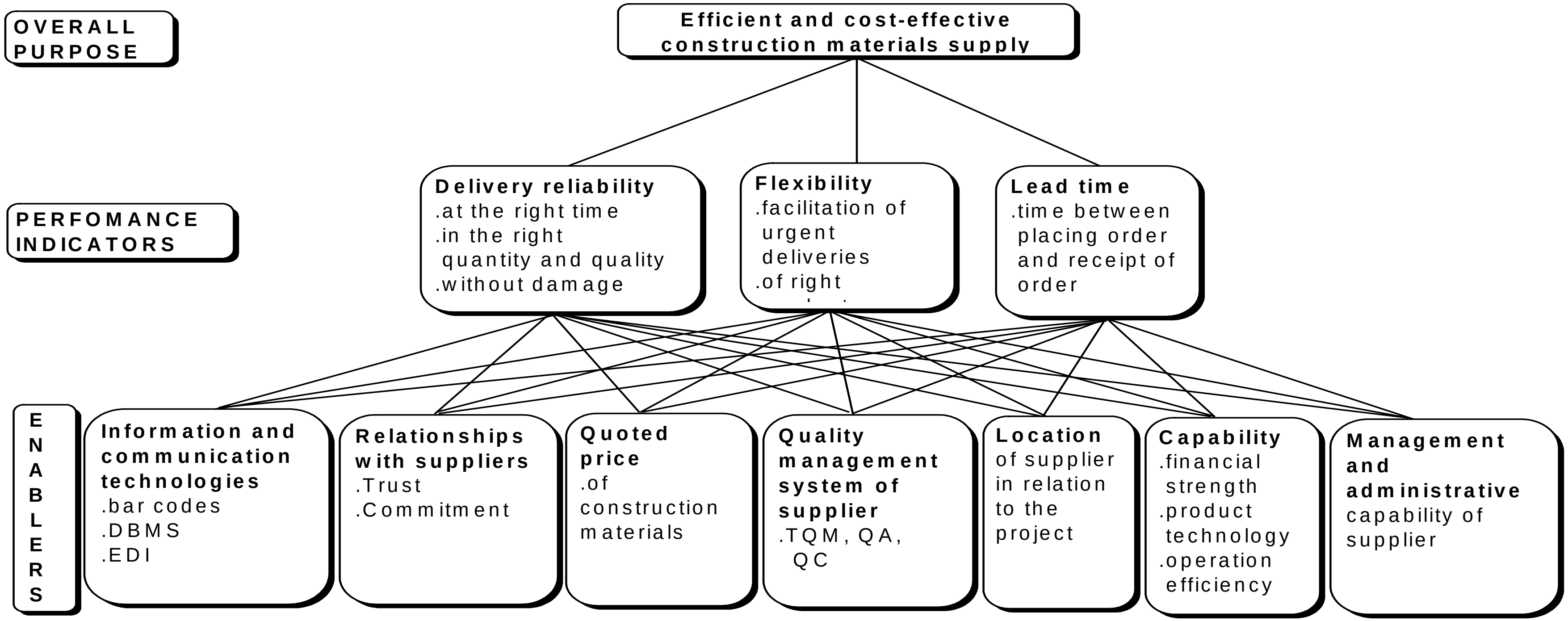


**Figure 2: Analytic Hierarchy Model for construction materials supply logistics**

**Table 1**
**The AHP response scale**

| Rank | Importance of compared to Aj |
|---|---|
| 1 | Equal |
| 3 | Weakly more |
| 5 | Strongly more |
| 7 | Very strongly more |
| 9 | Absolute |

If compromise over importance rating is required, ranks 2, 4, 6 or 8 can be used. When comparing Aj over Ai, the reciprocal of the Ai, Aj comparison is used.

Relative contribution of enablers to performance indicators can be evaluated (see Figure 2). Such an evaluation can indicate the relative importance of enablers in contributing to efficient and cost effective materials supply logistics. As an example, all the enablers can be evaluated to assess their importance in contributing to, say, delivery reliability as shown in Figure 3.

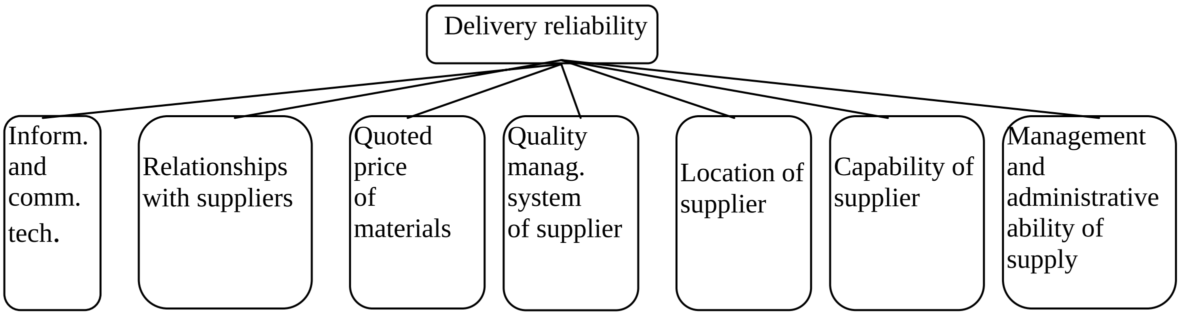


**Figure 3: Assessment of relative importance of enablers with respect to delivery reliability**

## SYNTHESIS OF PRIORITIES

Priorities are then calculated. Assessments arising from the comparisons are entered in a matrix. The matrix is then used for computing weighted priorities for elements of a given stratum over the other elements of the same stratum with respect to each element of the next higher level. In this way, the priorities of the enablers can be determined.

The mathematical procedure for arriving at the priorities involves calculating eigenvalues and eigenvectors of the matrices constructed using pairwise comparisons. Repeating the comparisons for all elements at each level with respect to criteria at the next higher level, relative weights for all elements in relation to higher objectives are calculated. Then the total weight of a given objective can be calculated by summing up the weights of the elements which contribute to the objective. The computation to arrive at the prioritisation of elements has been made simpler by the use of a software package called expertchoice.

## CONSISTENCY TEST

After synthesis of the priorities, a consistency test is performed to assess the quality of the judgements made during the pairwise comparisons. Consistency in the AHP methodology is obtained by calculating the consistency ratio (Saaty, 1983). Values of the consistency ratio above 0.10 are indicative of inconsistent judgements and those below 0.10 indicate that judgements in the pairwise comparisons were consistent. In the event the consistency ratio is greater than 0.10 the decisions made in the pairwise comparisons should be revised.

## CONCLUSION

Problems in supply of construction materials are well acknowledged in literature. However, the materials supply part of the construction process is not receiving as much attention as the effort currently being directed at improving efficiency in the construction process by bringing the main contracting parties together, despite the fact that materials and plant cost more than 50 per cent of projects. Besides the costs incurred through inefficiencies, poor materials flow further lead to losses in productivity. Advances in information and communication technologies and the contemporary shift towards improving business relationships between trading organisations present new opportunities to address problems that have so far been recognised.

A logistics perspective of materials management is helpful in identifying elements that can be used to leverage improvements in construction materials supply. The central focus of logistics management is superior customer service. Ensuring efficient construction materials flow to support construction involves complex trade-off decision-making among numerous factors that in aggregate contribute to the efficiency of the process. This paper has presented the Analytic Hierarchy Process as an appropriate tool which is well suited for dealing with complexity in trade-off decision making. The AHP can be used to evaluate numerous characteristics of suppliers that enhance efficiency and cost-effectiveness in materials supply logistics.

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