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Abstract

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Keywords - Purchasing strategy, Portfolio model, SME, AHP

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1. Introduction

Many manufacturers spend approximately 50% to 70% of each sales dollar on purchased materials and components (van Weele, 2005), so their success is heavily influenced by the performance of their suppliers and purchased components. Purchasing has become one of the most critical activities of a manufacturing business (Parikh and Joshi, 2005)(Sarkis and Talluri, 2002). It is a key strategic activity for achieving high quality, high variety, low cost and fast delivery of the end-product.

The purchasing function is largely responsible for specifying the characteristics of purchased materials, components and services, selecting suitable suppliers and managing the transaction so that purchases are delivered in a timely manner (Burt, 1989 cited in Krause et al., 2001). The buyer must determine and manage the purchasing strategy on the basis of its business strategy and a deep understanding of its products (Watts et al., 1995) (van Weele, 2005) to achieve "strategic purchasing". For example, if the corporate strategy is concentrated on providing customers with high quality products, then both the manufacturing strategy and the purchasing strategy must also focus on quality. If the basis of competition is cost then the focus of both must be on reducing costs although qualifying levels of quality must be maintained.

A survey of 111 purchasing executives in the UK concluded that, "Strategic purchasing leads to improved supplier integration and socialisation mechanisms, giving overall improvements in buyer performance." (Lawson et al, 2008). Chen and Paulraj (2004) placed strategic purchasing at the centre of their theoretical framework for supply chain management research, referring to the "imperative role" of strategic purchasing within supply chain management. The widely cited Hayes and Wheelwright (1984) model of the relationship between business strategy and functional strategy is unequivocal in that functional strategies should support the business strategy and be internally consistent. Based on a survey of 180 pairs of manufacturing and purchasing executives from manufacturing firms in the USA, Pagell and Krause (2002) confirmed that higher levels of consensus among internal functions regarding competitive priorities are associated with higher levels of performance and competitive advantage.

Major manufacturers such as Motorola, Honda and Toyota have benefited from strategically managing purchasing and relationships with their suppliers (Metty et al., 2005)(Pressey et al., 2007), attaining higher quality, increased operational flexibility, shorter lead-times and cost reductions as a result (Janda and Seshadri, 2001). Strategic purchasing can also benefit small firms (Carr and Pearson, 2002). However, small and medium size enterprises' (SMEs') use of portfolio models is much lower than that of larger enterprises (Gelderman and van Weele, 2005). Instead, purchasing decisions in small firms are generally made by the owner or a chosen few on the basis of intuition and personal experience (Cagliano and Spina, 2002), or possibly misconception, and this can lead naturally to poor performance. Moreover, small firms may find it difficult to gain interest in development and collaboration from their suppliers because they have little purchasing power (Quayle, 2002) (Gonzalez-Benito et al, 2003) and lack the management resource to find and develop alternative suppliers and solutions (Gadde and Hakansson, 2001). Most previous research into purchasing strategy has been in the context of large companies (Cagliano and Spina, 2002), so little has been reported on purchasing strategy for SMEs in particular. This paper reports the development of a portfolio model for developing purchasing strategy and applies it in two SMEs. The focus is on the development of a practical approach that is simple enough for SMEs to implement with their limited resources and limited access to quantitative supplier data (they have less power), although the approach is still intended to be valid for all sizes of enterprises.

ABC inventory analysis has been used widely to classify the importance of components by cost of consumption, i.e. unit-cost times units-consumed. This indicates priorities for inventory management, but it does not provide any purchasing strategies for the categories, it merely provides information on the concentration of purchase spend (Gelderman and van Weele, 2005). ABC analysis is easy to understand and use, but it has major weaknesses (Flores et al., 1992). It can over-emphasize items that have a high cost of consumption but no critical effects on production operations or the quality of the end-product, whilst it may under-emphasize items that have a low cost of consumption but are critical to quality. The problem stems from ABC classification using a single measure, cost of consumption, when there are other important criteria such as inventory cost, obsolescence, durability and stock-out penalty (Ng, 2007)(Partovi and Anandarajan, 2002). When manufacturers buy components they should focus on the total overall cost rather than simply the lowest price (Burt, 1989).

Kraljic (1983) introduced a portfolio approach to purchasing in which purchased items are classified on the basis of two dimensions, importance of the purchase and complexity of the supply market. Items are classified by evaluating and positioning them into one of four quadrants of the two-dimensional portfolio model. The quadrants represent different purchasing strategies. Gelderman (2003) defined a portfolio model as a tool that uses two or more dimensions to define heterogeneous categories for which different strategic recommendations are provided. Following on from Kraljic, others have developed similar portfolio models based on a two-dimensional framework, for example see (Bensaou, 1999) and (Olsen and Ellram, 1997). Purchasing portfolio models enable a business to identify the more important purchased items from the point of view of purchasing strategy, helping it to achieve a sustainable competitive edge and high profitability (Wagner and Johnson, 2004) through differentiated purchasing strategies (Gelderman and van Weele, 2005).

Recently, purchasing portfolio models have received a great deal of attention in the academic and business fields. They are easy to understand and give practical guidelines on how to manage different purchased items, suppliers and supplier relationships (Dubois and Pedersen, 2002). Surveys found that 74% of Dutch purchasers (Gelderman, 2003) and 55% of French purchasers (Kibbeling, 2005) in the manufacturing and engineering sectors use purchasing portfolio analysis. In a survey of 122 companies in the UK across the manufacturing, service and other industry sectors, purchasing portfolio analysis was found to be the second most used of 65 purchasing and supply tools, with vendor rating coming first (Cox and Watson, 2004).

2. Existing Portfolio Models

Markowitz (1952) originally developed portfolio theory for financial investment decision-making and it has been used widely in strategic planning and marketing. Kraljic (1983) introduced the first portfolio matrix for purchasing and supply management (Gelderman and van Weele, 2005), but until recently application within purchasing had been limited (Nellore and Soderquist, 2000). Portfolio models have been applied in related areas such as supplier involvement in product development (Wynstra and ten Pierick, 2000), e-purchasing (Bartezzaghi and Ronchi, 2004), the specification process (Nellore and Soderquist, 2000) and inter-organisational competence development (Moller et al., 2000).

In Kraljic's portfolio matrix, purchased items are classified by two dimensions; the profit impact of the purchase and the complexity of the supply market (supply risk). Profit impact is defined in terms of the volume purchased, the percentage of the total cost of purchases and the impact on product quality or competitive strategy. Supply risk is assessed in terms of availability, the number of suppliers, competitive demand from others for the supplied item, make-or-buy opportunities, storage risks and substitution possibilities (alternatives). Each dimension spans the values high and low, so the segmented (2 x 2) matrix in Figure 1 is used to classify purchases into four categories, strategic, bottleneck, leverage and non-critical, that lay the foundations of the purchasing strategy. A summary of the nature of the purchasing strategies implied by these categories is synthesised below from (Kraljic, 1983) (de Boer et al., 2001) and (Gelderman and van Weele, 2005).

Strategic purchases are critical to success and require close interactions between the buyer and the supplier, they cannot be left to the vagaries of open-market based supply. The purchasing strategy is to maintain a strategic partnership, so the manufacturer should manage these purchases by regular information exchanges with suppliers, frequent visits from both partners and long-term supply relationships, perhaps moving towards virtual integration. A long-term relationship perspective increases the intensity of buyer–supplier co-ordination (De Toni and Nassimbeni, 1999), which could extend to a manufacturer involving a supplier in its product development.

Leverage purchases are easy to manage but have high strategic importance. They could be obtained from various suppliers, so the general recommendation is to exploit purchasing power, managing these purchases by supplier selection, product substitution and targeted pricing negotiations. The purchasing strategy could be based upon the principle of competitive bidding.

Bottleneck purchases are difficult to manage but have low strategic importance. They cause significant problems and risks in their supply, possibly because suppliers are scarce and/or too powerful. The core of the purchasing strategy is to ensure the volume of components, so these purchases should be managed by supplier control, safety stock and backup plans. Alternative suppliers could be found.

Non-critical purchases are easy to manage and have low strategic importance. They cause only few technical or commercial problems from the point of view of purchasing. However, they are ordered frequently from many suppliers, so their logistical and administrative costs are high. Therefore, the focus of the purchasing strategy is to reduce transaction costs through efficient processing, product standardisation and the optimisation of order volumes and inventory levels. The number of suppliers could be reduced through category management.

There have been empirical studies to test and develop Kraljic's model (Caniels and Gelderman, 2007) (Gelderman and van Weele, 2003) (Wagner and Johnson, 2004). Whilst Gelderman (2003) argues that it is not clear why Kraljic selected the particular dimensions used, endorsement is seen in their use by others and in the use of similar dimensions in the literature reviewed below. This paper makes a contribution through the interpretation, justification and subsequent development of these dimensions.

Based on the work of Kraljic (1983) and Fiocca (1982) and following on from Narasimhan (1983), Olsen and Ellram (1997) proposed a portfolio model to assist in managing different kinds of supplier relationships. They renamed the vertical and horizontal dimensions in Figure 1, "strategic importance of the purchase" and "difficulty of the purchasing situation" respectively, although in effect there is little change in meaning. They assess strategic importance by three factors internal to the firm: competence, economics and image. These factors have three, four and two measures respectively, resulting in a total of nine measures. The difficulty of managing the purchasing situation is assessed by three factors external to the company: product, supply market and environmental characteristics. Each of these factors has two measures, resulting in a total of six measures, so that overall Olsen and Ellram use fifteen measures, as listed in Table 1. The dimensions make up a portfolio model with the same four categories or matrix quadrants used by Kraljic. However, they have been criticised for not testing their model empirically (Zolkiewski and Turnbull, 2000). Moller et al. (2000) found the model impractical because it incorporates too many factors and measures.

Bensaou (1999) developed a portfolio model using the two dimensions, buyers' specific investments and suppliers' specific investments. These are broadly defined and can include anything from tangible to intangible resources developed to meet the needs of specific suppliers or customers. They are typically difficult or expensive to transfer to another relationship and may lose their value when redeployed. Bensaou's model classifies supplier relationships into four categories: strategic partnership, captive supplier, captive buyer and market exchange - see Figure 2. Wasti et al. (2006) tested this model on a case study taken from the automotive industry in Turkey, with the result that no captive buyer relationships were identified. Comparing their findings with those of Bensaou, the Turkish situation resembles that seen in Japan where there are few captive buyer relationships and that seen in the USA where there are fewer market exchange relationships than strategic partnerships. Since Bensaou's model has been developed primarily for the automotive industry, there is insufficient guidance provided for practical use in other industries, which can be quite different, so it has not seen widespread application (Gelderman, 2003). Large automobile manufacturers sit at the top of their supplier pyramids and their relationships with their major suppliers are generally closed and involve contracts for long periods of time, so that the suppliers become very dependent upon them. This is why the level of specific investments is important in determining strategy in Bensaou's automotive model. In contrast, the model developed in this paper is based on Kraljic's approach, which is not sector specific. A summary of the dimensions of the models discussed above is given in Table 1.

The existing approaches to purchasing portfolio modelling show that a common problem in defining dimensions is the synthesising of qualitative and quantitative measures (Ahone and Salmi, 2003). If it is difficult discriminating between high and low on the dimensions' scales then the classification of purchases will be arbitrary (Gelderman and van Weele, 2003). The Analytic Hierarchy Process (AHP) is a decision making tool that can help in setting priorities and making the best decisions using both qualitative and quantitative data. It scores or weights alternative courses of action based on the decision makers' judgments of the relative importance of the criteria and the extent to which they are met by each alternative (Nydick and Hill, 1992). For this reason, it is introduced in the portfolio purchasing model presented in this paper. On the use of the Kraljic (1983) matrix in the determination of purchasing strategy, Gelderman and van Weele (2003) state, "In-depth discussions on the positions in the matrix are considered as the most important phase of the analysis. Strategic discussions provide deeper in-sights and may lead more easily to consensus-based decisions." The AHP can facilitate and encourage such consensus reaching discussion as it makes the decision-making process very transparent, highlighting misconceptions (Drake, 1998). As it synthesises the perspectives of different people, counteracting the vested interests or restricted vision of individuals, it provides the triangulation that is desired when dealing with qualitative data in particular.

3. Development of the purchasing portfolio model

3.1 The dimensions

The dimensions used for the portfolio model and the way in which they are measured need to be defined. The authors propose the use of the 'component value' and 'risk in the supply market' dimensions. This section gives a justification for these and a practical but justified way in which they can be measured. This discourse is an important contribution as the dimensions and measures used are at

the core of the proposed approach to purchasing strategy formulation and weaknesses identified in existing approaches are addressed.

Note, the application presented here concerns production-related items (raw materials and components) used in manufacturing an end-product, i.e. strategic purchases. These have different purchasing structures and strategies compared to non-production-related items such as maintenance, repair and overhaul (MRO) items, i.e. non-strategic purchases (Xideas and Moschuris, 1998).

It has been seen that the common form of a purchasing portfolio model has one dimension related to the importance of a purchase and one related to the nature of the supply. The importance of a purchase depends on the product in which it will reside; is the purchase critical to the product's quality, competitive stance and profitability? The supply dimension is fundamentally concerned with risk assessment and here it is labelled 'risk in the supply market'. It relates to the performance of the suppliers and factors outside the control of the buyer. For example, a component that has only one supplier who in turn is financially unstable is higher risk than a component that has numerous, stable suppliers.

3.2 Measuring the 'component value' dimension

If purchasing strategy is to support business strategy, it follows that the importance of a particular purchase is determined by the competitive priorities of the business. Hayes and Wheelwright (1984) introduced the term "competitive priorities" and argued that companies compete in the marketplace by virtue of one or more of the four, core competitive priorities; cost, quality, delivery time and flexibility. Following their research, there has been a consensus in the operations management literature that these are the four main competitive priorities, for example see (Dangayach and Deshmukh, 2001) and (Krajewski and Ritzman, 2005). Any company, regardless of the industry in which it operates, should improve its product quality and service (flexibility or availability) and reduce lead times and cost simultaneously as illustrated in Figure 3 (Johansson et al., 1993), which portrays the calculation of the total value of the product to the customer and gives insight into what is covered by each of the four priorities.

According to Krause et al.'s (2001) empirical research, purchasing's competitive priorities are conceptualised as being similar to the competitive priorities in operations management. Manufacturers use materials and components sourced from external suppliers, so their products and customer service are affected significantly by the performance of their suppliers in terms of cost, quality, time and availability (Krause and Scannell, 2002). These four competitive priorities are measured on the basis of the importance of the factors in Table 2 to the process of purchasing components. These factors are adopted here in measuring the importance dimension, which is labelled 'component value' in line with Johansson et al. (1993), as the fundamental importance of a component is determined by its contribution to the value of the product to the customer. Note, in the literature the words service, flexibility and availability are effectively used interchangeably and availability is used from hereon in this paper.

It has been argued that quality is the most important concern for strategic supplier management (Chao and Scheuing, 1994). The assurance of an adequate supply of materials and components is certainly one of the key elements of total quality management (Gonzalez-Benito et al, 2003). The quality of purchased components is a major determinant of the quality of the end-product (Gadde and Snehota, 2000). In this paper, the importance of quality is measured on the basis of the importance of the durability, reliability and innovation of the component. Quality is associated with conformance to specifications and meeting the customers' expectations (Dangayach and Deshmukh, 2001)(Miltenburg, 2005)(Slack and Lewis, 2002) and durability and reliability in particular must conform (Chan and Chan, 2004). In general, these two measures are often used as measures of quality (Krause et al., 2001)(MacKenzie and Hardy, 1996)(Park and Hartley, 2002)(Shin et al., 2000). Innovation is included as a measure of quality as it can be central to achieving competitive advantage, and high innovation in purchased components is often the quickest and easiest way to improve the quality of the end-product (Burt, 1989). Pagell and Krause (2002) included innovation as a separate, 5th competitive priority. The method of analysis presented here could be modified to do this, however, in the present analysis innovation is explicitly accounted for within quality.

The importance of availability is measured on the basis of the importance of volume flexibility, modification flexibility and technological capability. Volume flexibility directly impacts customers' perceptions by preventing out of stock conditions of products when demand is suddenly high and modification flexibility is a value-adding attribute that is immediately visible to the customer (Vickery et al., 1999). Modification flexibility relates to the ability to meet the demands of high variety and personalised products. If the purchasing function of a firm can manage effectively its supplier capabilities, the result could be an increase in manufacturing flexibility (Clark, 1989) (Narasimhan and Das, 1999). Technological change is one of the principal factors of competition (Porter, 1985) and new technologies present opportunities to enter into the market with a new product (Christensen and Bower, 1996). For these reasons, the technological capability of suppliers has received focal attention as a supplier selection criterion (Katsikeas et al., 2004).

The importance of cost is measured on the basis of the importance of purchasing cost, inventory cost and quality cost. Purchasing cost is clearly one of the fundamental measures in assessing the importance of overall cost (Kraljic, 1983) (Olsen and Ellram, 1997). Inventory cost is important in the wider context of supply chain management (Childerhouse and Towill, 2000). The quality of components has substantial implications for cost (Bowersox et al., 2002). Purchasing high quality components reduces the inventory cost (Nicholas, 1998) and production costs by eliminating rework, scrap and inspection in manufacturing processes (Pitts and Lei, 2000). A firm can improve its cost position by ensuring that the quality of purchased components meets its requirements (Porter, 1985) and if the cost of inspection of purchased items is reduced, then the quality cost is reduced (van Weele, 2005).

The importance of time is measured on the basis of the importance of delivery speed, delivery reliability and development speed. These times can be crucial in determining the success of a product (Christopher and Towill, 2000) and many businesses are gaining a competitive advantage by purchasing from suppliers who offer a reduction in standard delivery times (Lee and Billington, 1992).

As discussed earlier, to combine these measures to give an overall measure for 'component value' the AHP is used as described in Section 5. To achieve the aims and objectives set by the business strategy one must focus on the strategic or competitive priorities, i.e. that which contributes most, and 'priority' is a relative measure. This means that 'component value' is a relative rather than absolute measure. For example, the impact of a component on cost depends on its proportion of the overall cost of the end-product, i.e. its costs relative to the cost of the other components. This makes the AHP appropriate.

3.2 Measuring the 'risk in the supply market' dimension

However, 'risk in the supply market' is quite different. If a component fails to be delivered then the final product cannot be completed. High risk purchases must be managed accordingly, irrespective of whether other components are more or less risky. Consider for example the number of suppliers; having only one or two suppliers is high risk. However, having many suppliers is low risk. If two components had (say) 20 and 100 potential suppliers respectively, then both are low risk on an absolute basis. If a relative view was taken, 20 is much smaller than 100 so would be classed, incorrectly, as high risk. Therefore, the AHP is not appropriate, as the risk associated with an individual component should be measured independently or directly. This difference between how 'component value' and 'risk in the supply market' are measured (relative versus absolute) is important to appreciate as it results in different treatments in the model presented here.

The dimension of 'risk in the supply market' is based on the similar dimensions used by Kraljic (1983) and Olsen and Ellram (1997). Kraljic used the following factors in measuring the "complexity of the supply market": availability; number of potential suppliers; competitive demand; make-or-buy opportunities; storage risks; substitution possibilities. Olsen and Ellram used three factors with seven sub-factors for measuring "difficulty of the purchasing situation": product characteristics (sub-factors: novelty and complexity); supply market characteristics (sub-factors: suppliers' power, suppliers' technical and commercial competence); environmental characteristics (sub-factors: risk and uncertainty). These measures require the acquisition of data external to the business. It is not easy to get all the required data for either of these sets of factors using a business's internal resources as much time and expense may be required. Rajagopal and Sanchez (2005) argued that data is only available from the closest suppliers and even when it is available, it can be incorrect due to reasons such as the commitment of the supplier and the fundamental size and complexity of the task of data acquisition. It may be particularly difficult for an SME to acquire accurate data from suppliers as SMEs do not have the 'power' of large customers to command the attention of suppliers. In the case study SMEs introduced in the following section, the staff reported that they certainly did not have the data required. Furthermore, even though Olsen and Ellram used several factors and sub-factors they still noted that the list was not comprehensive and it may need to vary for individual businesses. It is reiterated that Moller et al. (2000) found Olsen and Ellram's model to be impractical because it is too elaborated. The argument subscribed to in this paper is that the over elaboration of the measurement of this dimension is neither immediately helpful nor practical.

It is proposed here that two simple factors can be used to assess 'risk in the supply market'. First, 'size of supplier' is a way of measuring the "supplier's power" as used by Olsen and Ellram, on the assumption that power is typically related to size. **Larson et al. (2005) argue that small firms are dependent and in less powerful negotiating positions in supply chain management. A buyer should assess 'size of supplier' relative to its own size rather than in absolute terms, as it is the relative size that fundamentally determines power.** Second, the measure 'monopoly conditions' is used to combine and simplify Olsen and Ellram's use of "product characteristics" and "environmental characteristics". Looking at the sub-factors, if a purchase exhibits "novelty" or "complexity" then it will typically be available from only one or very few suppliers, which means that there are monopoly or at best oligopoly conditions creating risk. The supply risk matrix in Figure 4 combines the two factors, 'size of supplier' and 'monopoly conditions' to score the 'risk in the supply market' in the range 1 to 9. As with the AHP, the supply risk matrix converts the qualitative measurement of the factors into a quantitative measurement or score to use with the purchasing portfolio model.

4. The Case Studies and Data Acquisition

Two South Korean, electric elevator manufacturers, Company-A and Company-B, provide case studies. Their profiles are summarised in Table 3. As these are similar, the companies provide a test to see how different or similar portfolio models may be produced to meet the needs of ostensibly similar businesses.

An elevator is designed for a specific building, considering such factors as the height of the building, the number of users on each floor and the expected usage periods.

The numbers of components varies with the number of stories and the complexity of the design of the elevator. Customers provide functional requirements such as speed and capacity, desired style options and the dimensions of the building. An appropriate set of elevator components is specified and ordered from the component suppliers. This is a high-variety, low-volume market in which competition is very high. As the cost of in-house manufacturing of components is much higher than the cost of outsourcing, elevator manufacturers focus on design, assembly, marketing and sales and most in-house component manufacturing has ceased (van Weele, 2005). Discussions with several elevator manufacturers revealed that they spend typically more than 70% of each sales dollar on purchased components, so they should strive to improve not only availability but also to reduce costs. The key to success in this industry is the ability to embrace both efficiency and customisation. Elevator manufacturers are representative of many other manufacturers as they are noticing the criticality of purchased components, supplier performance and, therefore, purchasing strategy to competitiveness.

The data for the portfolio mapping exercise was gathered by questioning five of Company-A's staff who are involved directly or indirectly with component purchasing; two from the purchasing department, one from engineering, one from manufacturing operations and one from accounting. In Company-B only three staff were available for questioning. They came from purchasing, manufacturing operations and accounting; but the member of staff from manufacturing operations was responsible for the engineering function also. These samples give coverage of different functions and therefore perspectives. Nicholas (1998) referred to purchasing, manufacturing operations, engineering and accounting as the four key functions to have represented in a supplier selection team. Interviews with the staff required visits to the companies to gather data 'face to face'. During each interview, the specific terminology of the decision criteria was explained as necessary. Special care was taken to avoid the pitfall of using leading questions when asking the staff for their evaluations.

5. Applying the AHP to measure the 'component value' dimension

The staff of Company-A and Company-B were the 'evaluators' for the purposes of the AHP, which was implemented using the Expert Choice (2004) software. The AHP is explained in detail by Saaty and Vargas (2001) and succinctly by Drake (1998). An introduction in the context of purchasing strategy and the elevator application is given here. In summary, it proceeds as follows:

i. Select the criteria and their sub-criteria (measures) according to which the components are to be prioritized; these encapsulate the competitive priorities of the business.
ii. Weight the relative importance of the criteria using pair-wise comparisons based on a '1 to 9' relative importance scale as described below.
iii. Weight the relative importance of the sub-criteria within each criterion using pair-wise comparisons and the '1 to 9' scale and multiply these weights by their parent criterion weights to get overall sub-criterion weights.
iv. Score the impact of each component on each sub-criterion using the direct rating scale described below and weight these scores using the sub-criterion weights before summing to give an overall score for the component.

To structure the problem, the goal is placed at Level 1 of the AHP hierarchy, as shown in Figure 5. The goal in this application is the ranking or scoring of each component's impact on the competitive priorities of the business. Level 2 of the hierarchy contains the competitive priorities (ranking criteria) introduced above. Level 3 contains the sub-criteria that are used to assess or 'measure' the criteria. The relative importance of the competitive criteria and sub-criteria to the business and the parent criteria respectively are rated using the basic AHP approach of pair-wise comparison. Level 4 of the hierarchy contains the rating scale for assessing the impact of individual components of the elevator on the sub-criteria. This is different from the usual AHP approach in that an absolute measurement is assigned to each sub-criterion for each component to be purchased, instead of pair-wise comparisons of the components on the basis of each sub-criterion. This direct approach avoids the large number of pair-wise comparisons and has been used in supplier selection (Chan and Chan, 2004)(Tam and Tummala, 2001). The last level of the hierarchy consists of the components of the elevator's bill of materials (BOM) to be evaluated.

The nine-point scale in Table 4, suggested by Saaty and Vargas (2001), is used in making the pair-wise comparisons of the criteria and sub-criteria. For example, if an evaluator decides that quality is moderately more important than time, then the former is rated '3' and the latter '1/3' in this pair-wise comparison. Within each criterion, the sub-criteria are compared pair-wise to establish their relative importance to their parent criterion. For example, if component durability is considered absolutely (maximally) more important in determining quality compared to component reliability, then it is rated '9' and component reliability '1/9' in this pair-wise comparison. Matrices of pair-wise comparisons are obtained by the completion of all the pair-wise comparisons. Table 5 gives the five comparison matrices for Evaluator-1 for Company-A, one for the criteria and one for each of the four groups of sub-criteria within the criteria.

There is the possibility of inconsistency in the pair-wise comparisons. For example, an evaluator may rate quality as '7' against cost, cost as '7' against time and time as '7' against quality. This is inconsistent as the first two '7's imply that quality should be rated more highly than time. To understand Saaty's (1980) treatment of inconsistency, let a_{ij} denote the comparison of criterion i against criterion j, the element of the comparison matrix at row i, column j. A matrix is then called "consistent" if $a_{ik} = a_{ij}a_{jk}$, for all i, j, k. Based on this, Saaty then shows that for a pair-wise comparison matrix of size (n x n) to be "absolutely consistent", it must have one positive eigenvalue $\lambda_{max}= n$, while all other eigenvalues equal zero. In the real world, human evaluators do not usually achieve absolute consistency; so to be pragmatic Saaty introduces the consistency index (C.I.) to measure the "closeness to absolute consistency":

$$\text{C.I.} = (\lambda_{max} - n) / (n - 1) \qquad (1)$$

Having measured the closeness to absolute consistency, there is then a need to interpret the level to determine if it is acceptable, i.e. sufficiently close enough to zero. Saaty's basis for making this decision starts with the premise that, if one has little or no information about the factors being compared, then judgments will appear to be random (Forman and Selly, 2001). Saaty then introduced the consistency ratio (C.R.) to assess whether a matrix is sufficiently consistent or not. This is the ratio of the C.I. to the random index R.I., which is the C.I. of a matrix of comparisons generated randomly:

$$C.R. = C.I. / R.I. \qquad (2)$$

C.R.= 0 indicates perfect consistency because C.I. = 0, but this is not expected in practise. C.R.=1 indicates C.I. = R.I., which would be achieved if judgments were made at random rather than intelligently. The closeness of C.R. to 0, relative to the range 0 to 1, is used as a measure of the degree of consistency. The rule of thumb that is applied by Saaty and generally by others is that C.I. should be less than 10% of R.I. to be acceptable, i.e. C.R. < 0.01, see for example (Forman and Selly, 2001) (Bhattacharya et al, 2005).

The value of R.I. will increase with *n*. Random pair-wise comparisons have been simulated to produce average random indices for different sized (n x n) matrices. In Saaty and Vargas (2001), for n = 3 to 10 the R.I. values given are 0.52, 0.89, 1.11, 1.25, 1.35, 1.40, 1.45 and 1.49 respectively. So for n=3, C.R. should be <0.05 and for n=4 it should be <0.09, applying the 10% criterion. Each pair-wise comparison matrix in Table 5 is presented with its C.R. and these satisfy this consistency test. However, for another of Company-A's staff C.R.>0.09 for the (4x4) criterion comparison matrix, so his data was removed from the analysis; this was the representative of the accounting department. C.R. values very close to 0.05 for his (3x3) cost and time comparison matrices provide further support for this decision.

As suggested by Saaty and Vargas (2001), the geometric mean (the n^{th} root of the product of n items), rather than the arithmetic mean, is used to consolidate the pair-wise comparison matrices of the individual evaluators. This yields the five 'consensus matrices' in Table 6 for Company-A and Table 7 for Company-B. The next step is to compute the 'priority vectors' to define the relative priorities of the criteria and sub-criteria (the final columns of Tables 6 and 7). There are potentially many ways in which this might be done. However, Saaty's consistency principle that $a_{ik} = a_{ij}.a_{jk}$ and subsequent argument for using the special case of the consistent matrix formed by elements $a_{ij} = w_i/w_j$, where w_i and w_j are the elements of the priority weight vector corresponding to criteria i and j (i.e. their priorities), leads to the following method that is used here. In terms of matrix algebra, a priority vector is computed as the normalized, principal (largest) eigenvector of the consensus matrix of pair-wise comparisons. The calculation is complex and is normally executed using proprietary software. However, there are simpler methods for calculating an approximate solution. **For example, normalize the ratings in a consensus matrix by dividing each entry in a column by the sum of all the entries in that column, so that the entries in the column add up to one, and then average these normalized weights across the rows to give an average priority weight for each criterion. The normalization down the columns makes it statistically sound to compare and average scores across the columns to give row averages. Drake (1998) has provided a detailed demonstration of this algorithm and it can be implemented readily in a spreadsheet.**

The priority vectors in Tables 6 and 7 are used to produce the overall or global weights for the sub-criteria in Table 8. The corresponding criterion and sub-criterion weights are multiplied to give a global weight for each sub-criterion, so that the importance or weight of a sub-criterion is measured by its importance to its parent criterion weighted by the importance of the parent criterion to the business strategy. **For example, looking at Table 8, Company-A has generated a weight of 0.21 for quality when rating it against the other criteria (availability, cost and time). Within quality, a weight of 0.51 has been assigned to component durability when rating it against component reliability and component innovation. So the overall or global weight for component durability is 0.21 x 0.51 = 0.11. This is the weight given to this sub-criterion relative to all the sub-criteria across all the criteria and the sum of all such global sub-criterion weights is then 1.**

In the second stage, the evaluators used absolute measurement to rate the strength of the impact of the individual elevator components on the sub-criteria using the five-point scale (VH=very high; H=high; M=medium; L=low; VL=very low) suggested by Tam and Tummala (2001). Table 9 gives the ratings of two example evaluators. Table 10 shows the normalized weights calculated for the five-point scale using the AHP procedure described above. Absolute or direct measurement is used because there would be an intractable number of pair-wise comparisons to perform. There are 23 components to be rated against the 12 measures in Table 2, resulting in ${}_{23}C_2 = 23!/2!(23-2)! = 253$ pair-wise comparisons for each of the 12 measures, giving a total of 253 x 12 = 3036 comparisons. Absolute measurement reduces this to 23 x 12 = 276 direct measurements. This difference would grow very rapidly with increases in numbers of components. Tam and Tummala (2001) and Chan and Chan (2004) also used direct measurement for this reason.

For each component, the results obtained with the five-point rating scale are multiplied by the global weights of the sub-criteria. **This process is illustrated in Table 11 for the control panel component for Evaluator-1 in Company-A. For example, the global weight for component durability is 0.11 (from Table 8) and the impact of the control panel on durability has been assessed as high, which equates to weight of 0.26 from Table 10. So the score for control panel in respect of durability is 0.11 x 0.26 = 0.028.** The total score for each component is normalized by dividing by the sum of the total scores across all the components, so that they sum to 1. **Looking at Table 11, the total score for the control panel is 0.028 + 0.019 + ….. + 0.002 = 0.242. The sum of the total scores across all the components was calculated as 2.547. So the normalized score for the control panel is 0.242/2.547 = 0.095.** The normalized, total scores for each component from each evaluator are then combined using the geometric mean to give the results in the final two columns of Table 12.

As the AHP is based on the 1 to 9 weighting scale the 'component value' scores are transformed onto this scale for consistency using Equation (3). The scaled scores are used in positioning the components in the purchasing portfolio matrix.

$$Z_i = 8\,(y_i - \mathrm{Min}(y)) / (\mathrm{Max}(y) - \mathrm{Min}(y)) + 1 \qquad (3)$$

where:

Z_i = transformed score of component i;

y_i = normalised score of component i;

Min(y) = minimum normalised score across all components;

Max(y) = maximum normalised score across all components.

For example, for Company-A in Table 12 the mean score for the brake $y_1 = 0.051$, Min(y) = 0.021 and Max (y) = 0.097. So, the transformed score for the brake on the 1 to 9 scale is $Z_1 = 8\ (0.051-0.021) / (0.097-0.021) + 1 = 4.16$. This score is used as the 'component value' ordinate in Figure 6.

After scoring 'component value', the 'risk in the supply market' is scored by the evaluators using the supply risk scoring matrix in Figure 4, giving the results in Table 13.

Finally, the components are positioned in the purchasing portfolio matrix using their scores for 'component value' and 'risk in the supply market', as shown in Figure 6.

6. Analysis of results

The weights calculated for the competitive priorities are given in Tables 6 and 7 (final column, rows 1-4) for Company-A and Company-B respectively. In the case of Company-A, availability (0.39) is nearly twice as heavily weighted as quality (0.21) and over four times more heavily weighted than time (0.09). Since this elevator manufacturer has adopted the make-to-order (MTO) strategy, availability is naturally the supreme competitive priority. Cost (0.31) is the second priority, which is justified as Company-A spends more than 70% of each sales dollar on purchased materials and components. Quality still maintains a significant weight for safety reasons; elevators are built to strict quality standards such as ASME A17 for the U.S.A. and the EN 81 series for Europe. Time has the lowest weight due to the overriding importance of availability and cost, agreeing with Quayle's (2003) survey, which found that the highest priority requirements placed on suppliers by SMEs are pricing, quality and capability, while time to market and procurement have lower importance.

Company-B's results are strikingly similar to Company-A's for availability and time, underlining again the importance of availability to the MTO strategy. A difference seen is that quality and cost are rated equally by Company-B, whereas Company-A rates cost more highly. This difference is justified as Company-A targets the housing estate market, which has a typical batch size of more than 10, whereas Company-B targets the market for office buildings and flats, which has a typical batch size less than 5. Company-A's customers expect a quantity discount as they are ordering in large batches, so cost is a higher priority.

The weightings of the sub-criteria within each competitive priority seen in Tables 6 and 7 (final column, rows 5-16) show remarkably strong agreement between the companies for quality and fairly strong agreement for cost. For availability and time there is a larger difference in the weightings between the companies. However, the ranking of the sub-criterion weights within each competitive priority is consistent across the companies. The conclusion drawn here is that there is a fairly high level of consistency between the companies' weighting and ranking of the sub-criteria.

The global weights for the sub-criteria, in Table 8, show consistency in the ranking of the sub-criteria between the companies with only minor differences, but there are some differences in their values. Most notably, Company-A yields higher global values for the two biggest weights, modification flexibility and purchasing cost. As their parent criteria, availability and cost respectively, are also more heavily weighted by Company-A, there is the effect of multiplying 'peak' values, which amplifies differences.

The rating of the strength of the impact of the components on the competitive priority measures (the sub-criteria) is given in Table 9 for two example components and two evaluators from Company-A and Company-B respectively. Where there are differences between their evaluations they are small. Analysing the data across all the evaluators, this high level of consistency was observed in general.

Table 11 gives the total score for the impact of the control panel for Evaluator-1 in Company-A. As discussed above, Company-A has high weights for modification flexibility and purchasing cost. As Evaluator-1 considers the control panel to have a high impact on these measures, it follows that the overall score for the control panel in respect of these measures is high.

Figure 6 shows the final result, the positioning of the components within the purchasing portfolio. Company-B has a large number of components in the low value, low risk, non-critical items category, whereas Company-A has moved several of these further along the 'risk in the supply market' dimension into the bottleneck category. Company-B has placed more components into the high levels of 'component value'.

Company-A has a clear natural-break in its 'risk in the supply market' values in the region of the middle value of 5. This is important because the use of this middle value as the boundary between low and high has no real justification, whereas a natural-break in the data is an intuitively more reasoned boundary between strategic groupings. Company-A has two components just under 5 on the 'component value' scale, so there is not a natural-break at 5. However, a natural-break does appear moving up the value scale beyond 5 towards the position of the motor generator. Company-B has a natural-break in its scores for 'risk in the supply market' and 'component value' in the region of 5. It is also noted that the high scores for 'component value' break into two groups for both companies – high and very high.

Due to the differences noted above, differences exist in the implied purchasing strategies. Both companies have a large cluster of non-critical items to be managed accordingly. Company-A also has several low-value components to be managed on the basis of high 'risk in the supply market', i.e. bottleneck items, whereas Company-B has only one such item. Company-B has more components classified as clearly high value.

7. Recommendations to companies.

Company-A has many components with high 'risk in the supply market', so it should focus on reducing this risk. For its many bottleneck items, it should develop supplier control, use safety stocks and backup plans, and seek alternative suppliers. For the strategic items it should ensure close relationships and frequent information exchange with its suppliers, involving them in product and supply chain development. For its many non-critical items it can continue with its underlying strategy of competing on price. This can be done through efficient, low-cost transactions, product standardisation and optimised inventory management. As Company-A has few components with high 'component value', it should consider more carefully which components have high impact on achieving its competitive strategies in case some important impacts have been underestimated.

As Company-B has many non-critical components, it has the opportunity to pursue lower costs. It has been identified that Company-B attaches equally high weight to cost and quality in its competitive priorities. However, the purchasing portfolio matrix is showing that Company-B has a number of very high value components that need to be managed for quality and a large number of non-critical components that need to be managed for cost. This is what the equal importance of cost and quality mean, rather than every component should be managed on the basis of high quality and cost. So whilst Company-B should focus on close relationships with its suppliers of high value components to achieve high quality, it should not ignore the opportunity to reduce the cost of its many non-critical items by exploiting market-based supply. Generally, for its non-critical items Company-B should aim to reduce transaction costs through efficient processing, product standardisation and the optimisation of order volumes and inventory levels, whilst the number of suppliers could be reduced through category management. Having seen Company-A rate far more components as high 'risk in the supply market', Company-B should consider whether it is being complacent in assessing its own risk as being lower or reassure itself that its own risk is indeed lower.

8. Conclusion

The case for aligning purchasing strategy with business strategy has been argued. Purchasing portfolio models have received great attention in both the academic and business fields recently and the evidence suggests that they are effective tools for developing differentiated purchasing strategies that are aligned with business strategy. However, their application still has some limitations, so this paper has presented a purchasing portfolio modelling approach to address some of these limitations.

Factors and their measures for defining competitive priorities in a tractable way have been identified and justified. Further interpretation and justification of the dimensions of Kraljic's purchasing portfolio model have been provided, as well as their further development into the pragmatic 'component value' and 'risk in the supply market' dimensions. The positioning of purchases on the 'component value' scale has been made systematic by the application of the AHP to consolidate the qualitative measures of the competitive priorities into a single quantitative measure of a component's impact on the value of the end-product. The positioning of purchases on the 'risk in the supply market' scale has been made simple by the use of the supply risk matrix which quantifies the risk based on a qualitative assessment of 'monopoly conditions' and the 'size of the supplier'. As justified in the paper, measurement is direct for each purchased component in respect of 'risk in the supply market' but relative to other components in respect of 'component value'. The use of methods based on the users' qualitative judgments rather than hard, quantitative data is of particular value to SMEs that lack the power and resource to acquire the large quantity of quantitative data required, which may in any case lack integrity.

The purchasing portfolio approach developed here has been applied to two South Korean elevator manufacturers using face-to-face interviews with their staff. This has yielded some notable differences in the positioning of their purchased components in the purchasing portfolio matrix, even though these companies have ostensibly similar situations. These differences have been analysed and related to the business strategies of the companies so that recommendations have been made on the future purchasing strategies of the companies. **It is acknowledged that the approach presented should now be tested, exercised and, if necessary, refined on more industrial case studies.**

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Table 9: Absolute ratings given by Evaluator-1 of Company-A and Evaluator-1 of Company B to some of the components

Table 10: Pair-wise comparison judgment matrix for five-point rating scale

Table 11: Calculation of overall score for the *control panel* component for Evaluator-1 in Company-A

Table 12: Summary of normalized 'component value' scores

Table 13: Scores for 'risk in the supply market'

Appendix

The Questionnaire

Part 1: Criteria and Sub-criteria; competitive priorities and their measures.

(1) Compare the criteria on a pair-wise basis, decide which is most important and circle the weight that indicates how much more important it is.

Criteria	Importance ←								Equality								→ Importance	Criteria
Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Availability
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time
Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time
Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Time

(2) Compare the sub-criteria for measuring **quality** on a pair-wise basis, decide which is most important and circle the weight that indicates how much more important it is.

Sub-criteria	Importance ←								Equality								→ Importance	Sub-criteria
Component durability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Component reliability
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Component innovation
Component reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Component innovation

(3) Compare the sub-criteria for measuring **availability** on a pair-wise basis, decide which is most important and circle the weight that indicates how much more important it is.

Sub-criteria	Importance ←								Equality								→ Importance	Sub-criteria
Volume flexibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Modification flexibility
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technological capability
Modification flexibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technological capability

(4) Compare the sub-criteria for measuring **cost** on a pair-wise basis, decide which is most important and circle the weight that indicates how much more important it is.

Sub-criteria	Importance ←								Equality								→ Importance	Sub-criteria
Purchasing cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Inventory cost
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality cost
Inventory cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality cost

(5) Compare the sub-criteria for measuring **time** on a pair-wise basis, decide which is most important and circle the weight that indicates how much more important it is.

Sub-criteria	Importance ←								Equality								→ Importance	Sub-criteria
Delivery speed	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery reliability
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Development speed
Delivery reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Development speed

Part 2: Component assessment to be completed for each component

(1) What is the name of component? ________________________________

Rate the impact of the component on the following measures of the competitive priorities:

(2) Quality

(2.1) Durability
_____Very High _____High _____Moderate _____Low _____Very Low

(2.2) Reliability
_____Very High _____High _____Moderate _____Low _____Very Low

(2.3) Innovation
_____Very High _____High _____Moderate _____Low _____Very Low

(3) Availability

(3.1) Volume flexibility
_____Very High _____High _____Moderate _____Low _____Very Low

(3.2) Modification flexibility
_____Very High _____High _____Moderate _____Low _____Very Low

(3.3) Technological capability
_____Very High _____High _____Moderate _____Low _____Very Low

(4) Cost

(4.1) Purchasing cost
_____Very High _____High _____Moderate _____Low _____Very Low

(4.2) Inventory cost
_____Very High _____High _____Moderate _____Low _____Very Low

(4.3) Quality cost
_____Very High _____High _____Moderate _____Low _____Very Low

(5) Time

(5.1) Delivery speed
_____Very High _____High _____Moderate _____Low _____Very Low

(5.2) Delivery reliability
_____Very High _____High _____Moderate _____Low _____Very Low

(5.3) Development speed
_____Very High _____High _____Moderate _____Low _____Very Low

(6) Supply Risk

(6.1) Circle the component's position in the matrix below to score its 'supply risk'.

Monopoly conditions (Number of suppliers) / **Size of supplier**

	small	middle	large
few	5	7	9
several	3	5	7
many	1	3	5

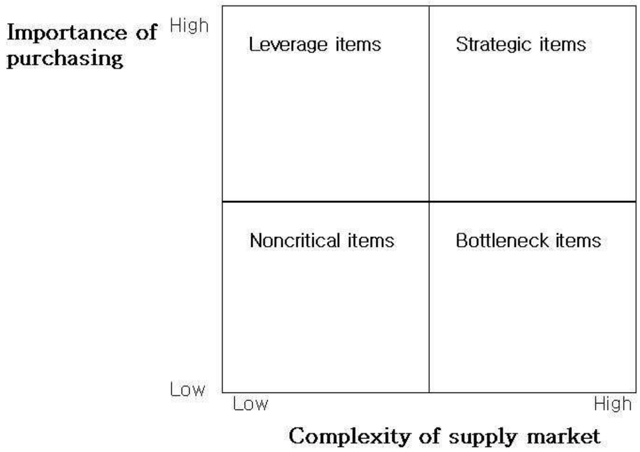

Figure 1: Purchasing Portfolio Model Kraljic (1983)

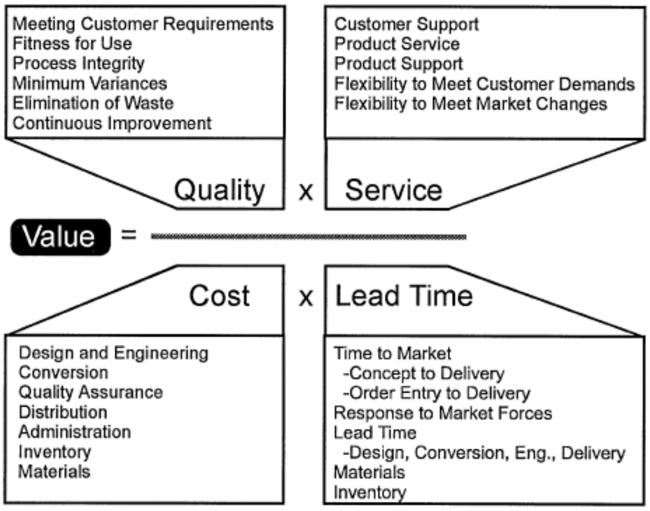

Figure 3: Calculating Value (Johansson et al., 1993)

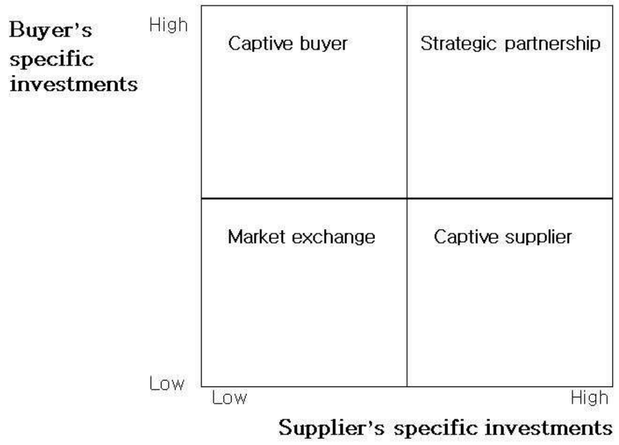

Figure 2: Purchasing Portfolio Model Bensaou (1999)

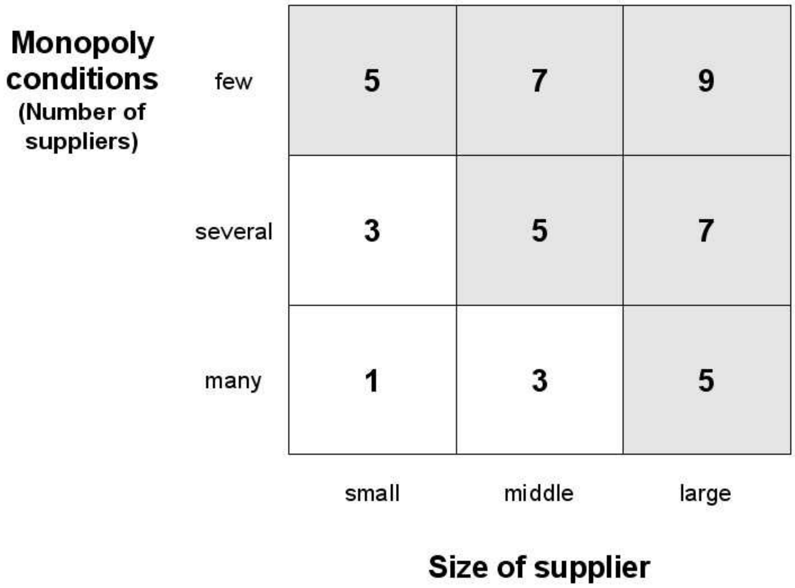

Figure 4: Supply risk scoring matrix

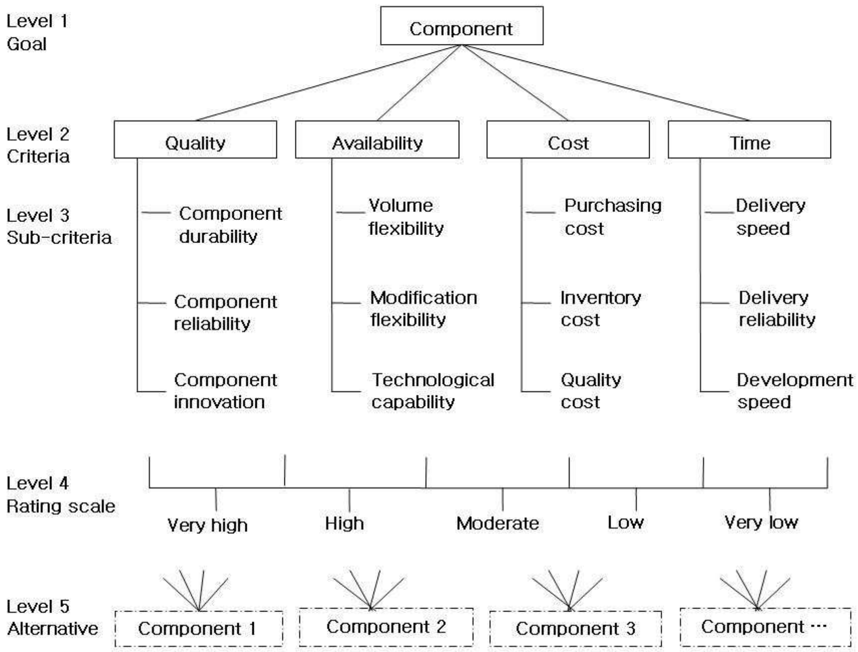

Figure 5: AHP model for analysis of *'component value'* for the elevator manufacturer

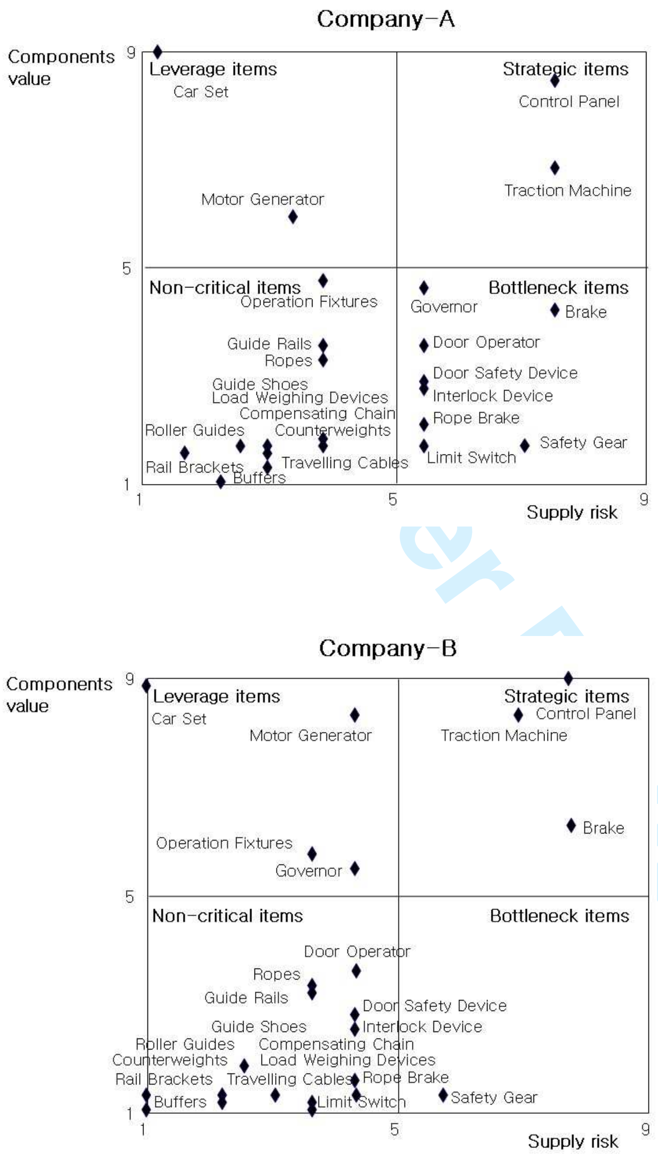

Figure 6: Purchasing portfolio models for Company-A and Company-B

Portfolio models	Classification dimensions: Internal factors	Classification dimensions: External factors
Kraljic (1983)	***Importance of purchase*** - volume purchased, percentage of total purchase cost, impact on product quality and business growth	***Complexity of supply market*** - availability, number of suppliers, competitive demand, make-or-buy opportunities, storage risks and substitution possibilities
Olsen and Ellram (1997)	***Strategic importance of the purchase*** Competence factors 1. extent to which the purchase of the firm's core competencies 2. purchase improves knowledge of buying organization 3. purchase improves technological strength of buying organization Economic factors 4. volume or monetary value of purchases 5. extent to which purchase is part of final product and value adding 6. extent to which purchase is part of a final product and profitable 7. criticality of purchase to get leverage with supplier for other purchases Image factors 8. supplier critical image/brand name 9. potential environmental/safety concerns	***Difficulty of the purchasing situation*** Product characteristics 10. novelty 11. complexity Supply market characteristics 12. suppliers' power 13. suppliers' technical and commercial competence Environmental characteristics 14. risk 15. uncertainty
Bensaou (1999)	***Buyer's specific investments*** Tangible investments - buildings, tooling, equipment Intangible investments - people, time, effort, best practice, knowledge	***Supplier's specific investments*** Tangible investments - plant or warehouse location or layout, specialized facilities, dies Intangible investments - sending guest engineers, developing information systems

Table 1: Classification dimensions of purchasing portfolio models

Quality factors	
1. Component durability	
2. Component reliability	
3. Component innovation	
Availability factors	
1. Volume flexibility	
2. Modification flexibility	
3. Technological capability	
Cost factors	
1. Purchasing cost	
2. Inventory cost	
3. Quality cost	
Time	
1. Delivery speed	
2. Delivery reliability	
3. Development speed	

Table 2: Factors influencing the *'component value'*

	Company A	Company B
Number of employees	53	47
Turnover (2005)	£5M	£4.5M
Product demand	Unpredictable	
Product life cycle	1 year to 2 years	
Profit margin on individual orders	20% to 50%	
Product variety	>100 variants	
Business strategy	Differentiation	
Manufacturing strategy	Make to order (MTO)	

Table 3: Summary of companies' profiles

Intensity of importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one over another
5	Strong importance	Experience and judgement strongly favour one over another
7	Very strong importance	A criterion is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero numbers	If criterion i has one of the above non-zero numbers assigned to it when compared with criterion j, then j has the reciprocal value when compared with i	

Table 4: 1 to 9 scale for AHP preferences

Competitive Priority	Quality	Availability	Cost	Time
Quality	1	1/2	1/2	2
Availability	2	1	2	3
Cost	2	1/2	1	2
Time	1/2	1/3	1/2	1
				Consistency Ratio C.R. = 0.03

Quality	Component durability	Component reliability	Component innovation
Component durability	1	2	5
Component reliability	1/2	1	3
Component innovation	1/5	1/3	1
			C.R.=0.00

Availability	Volume flexibility	Modification flexibility	Technological capability
Volume flexibility	1	1/5	1/3
Modification flexibility	5	1	2
Technological capability	3	1/2	1
			C.R.=0.00

Cost	Purchasing cost	Inventory cost	Quality cost
Purchasing cost	1	7	4
Inventory cost	1/7	1	1/2
Quality cost	1/4	2	1
			C.R.=0.00

Time	Delivery speed	Delivery reliability	Development speed
Delivery speed	1	1/2	3
Delivery reliability	2	1	8
Development speed	1/3	1/8	1
			C.R.=0.01

Table 5: Pair-wise comparison matrices for Evaluator-1 for Company-A

Competitive Priority	Quality	Availability	Cost	Time	Priority weight
Quality	1	0.5	0.5	2.9	0.21
Availability	2.1	1	1.4	3.5	0.39
Cost	1.9	0.7	1	3.1	0.31
Time	0.3	0.3	0.3	1	0.09
				C.R.=0.02	

Quality	Component durability	Component reliability	Component innovation	Priority weight
Component durability	1	1.4	3.9	0.51
Component reliability	0.7	1	2.7	0.36
Component innovation	0.3	0.4	1	0.13
			C.R. = 0.00	

Availability	Volume flexibility	Modification flexibility	Technological capability	Priority weight
Volume flexibility	1	0.3	0.5	0.14
Modification flexibility	3.9	1	2.4	0.59
Technological capability	2.2	0.4	1	0.27
			C.R. = 0.01	

Cost	Purchasing cost	Inventory cost	Quality cost	Priority weight
Purchasing cost	1	5.9	3.7	0.69
Inventory cost	0.2	1	0.5	0.11
Quality cost	0.3	2.0	1	0.20
			C.R. = 0.01	

Time	Delivery speed	Delivery reliability	Development speed	Priority weight
Delivery speed	1	0.5	3.0	0.31
Delivery reliability	1.9	1	6.3	0.59
Development speed	0.3	0.2	1	0.10
			C.R. = 0.00	

Table 6: Geometric mean of pair-wise comparison matrices of all evaluators for Company-A

Competitive Priority	Quality	Cost	Availability	Time	Priority weight
Quality	1	0.6	1.0	2.6	0.26
Availability	1.6	1	1.6	2.9	0.37
Cost	1.0	0.6	1	2.6	0.26
Time	0.4	0.3	0.4	1	0.11
				C.R.=0.01	

Quality	Component durability	Component reliability	Component innovation	Priority weight
Component durability	1	1.6	3.3	0.51
Component reliability	0.6	1	2.6	0.35
Component innovation	0.3	0.4	1	0.14
			C.R.=0.01	

Availability	Volume flexibility	Modification flexibility	Technological capability	Priority weight
Volume flexibility	1	0.4	0.5	0.19
Modification flexibility	2.3	1	1.3	0.45
Technological capability	2.0	0.8	1	0.36
			C.R.=0.00	

Cost	Purchasing cost	Inventory cost	Quality cost	Priority weight
Purchasing cost	1	6.2	2.6	0.64
Inventory cost	0.2	1	0.3	0.09
Quality cost	0.4	3.1	1	0.27
			C.R.=0.01	

Time	Delivery speed	Delivery reliability	Development speed	Priority weight
Delivery speed	1	0.8	2.6	0.39
Delivery reliability	1.3	1	2.9	0.46
Development speed	0.4	0.3	1	0.15
			C.R.=0.00	

Table 7: Geometric mean of pair-wise comparison matrices of all evaluators for Company-B

Company	Competitive priority	Local weight	Competitive priority measures	Local weight	Global weight	Rank
Company-A	Quality	0.21	Component durability	0.51	0.11	3=
			Component reliability	0.36	0.07	5
			Component innovation	0.13	0.03	9=
	Availability	0.39	Volume flexibility	0.14	0.05	8
			Modification flexibility	0.59	0.23	1
			Technological capability	0.27	0.11	3=
	Cost	0.31	Purchasing cost	0.69	0.21	2
			Inventory cost	0.11	0.03	9=
			Quality cost	0.20	0.06	6=
	Time	0.09	Delivery speed	0.31	0.03	9=
			Delivery reliability	0.59	0.06	6=
			Development speed	0.10	0.01	12
	Total	**1.00**	**Total**		**1.00**	
Company-B	Quality	0.26	Component durability	0.51	0.13	3=
			Component reliability	0.35	0.09	5
			Component innovation	0.14	0.04	9=
	Availability	0.37	Volume flexibility	0.19	0.07	6=
			Modification flexibility	0.45	0.17	1=
			Technological capability	0.36	0.13	3=
	Cost	0.26	Purchasing cost	0.64	0.17	1=
			Inventory cost	0.09	0.02	11=
			Quality cost	0.27	0.07	6=
	Time	0.11	Delivery speed	0.39	0.04	9=
			Delivery reliability	0.46	0.05	8
			Development speed	0.15	0.02	11=
	Total	**1.00**	**Total**		**1.00**	

Table 8: Combined criteria and sub-criteria weights in two elevator firms

Competitive priority	Competitive priority measures \ Component	Company-A Evaluator-1		Company-B Evaluator-1	
		Control panel	Governor	Control panel	Governor
Quality	Component durability	H	H	H	H
	Component reliability	H	H	H	H
	Component innovation	VH	H	VH	H
Availability	Volume flexibility	L	M	L	M
	Modification flexibility	H	M	H	M
	Technological capability	H	H	H	H
Cost	Purchasing cost	H	L	VH	M
	Inventory cost	VL	VL	VL	VL
	Quality cost	M	L	M	L
Time	Delivery speed	H	M	H	H
	Delivery reliability	H	M	H	H
	Development speed	H	L	H	M

VH=very high; H=high; M=medium; L=low; VL=very low

Table 9: Absolute ratings given by Evaluator-1 of Company-A and Evaluator-1 of Company B to some of the components

Rating scale	VH	H	M	L	VL	Priority weight
Very high (VH)	1	3	5	7	9	0.51
High (H)	1/3	1	3	5	7	0.26
Moderate (M)	1/5	1/3	1	3	5	0.13
Low (L)	1/7	1/5	1/3	1	3	0.06
Very low (VL)	1/9	1/7	1/5	1/3	1	0.04

Table 10: Pair-wise comparison judgment matrix for five-point rating scale

Competitive priority measures	Global weight (from Table 8)	*Control Panel* Scoring		
		Rate	Rating weight (from Table 10)	Global weight x Rating weight
Quality				
Component durability	0.11	H	0.26	0.028
Component reliability	0.07	H	0.26	0.019
Component innovation	0.03	VH	0.51	0.014
Availability				
Volume flexibility	0.05	L	0.06	0.003
Modification flexibility	0.23	H	0.26	0.060
Technological capability	0.11	H	0.26	0.027
Cost				
Purchasing cost	0.21	H	0.26	0.056
Inventory cost	0.03	VL	0.04	0.001
Quality cost	0.06	M	0.13	0.008
Time				
Delivery speed	0.03	H	0.26	0.008
Delivery reliability	0.06	H	0.26	0.015
Development speed	0.01	H	0.26	0.002
Total score				0.242
Normalized score = Total score / Sum of total score across all components				**0.095**

Table 11: Calculation of overall score for the *control panel* component for Evaluator-1 in Company-A

Component	Company-A					Company-B
	Evaluator-1 Score	Evaluator-2 Score	Evaluator-3 Score	Evaluator-4 Score	Mean Score	Mean Score
Brake	0.049	0.047	0.051	0.058	0.051	0.064
Buffers	0.024	0.019	0.018	0.025	0.021	0.024
Car Set	0.110	0.098	0.083	0.101	0.097	0.085
Compensating Chain	0.028	0.025	0.028	0.036	0.029	0.026
Control Panel	0.095	0.089	0.093	0.087	0.092	0.086
Counterweights	0.025	0.022	0.022	0.024	0.023	0.025
Door Operator	0.044	0.053	0.043	0.045	0.047	0.045
Door Safety Device	0.041	0.041	0.040	0.037	0.040	0.039
Governor	0.054	0.052	0.059	0.057	0.055	0.059
Guide Rails	0.043	0.050	0.035	0.045	0.043	0.041
Guide Shoes	0.026	0.029	0.026	0.028	0.027	0.027
Interlock Device	0.040	0.036	0.038	0.035	0.038	0.038
Limit Switch	0.025	0.029	0.026	0.027	0.027	0.027
Load Weighing Devices	0.023	0.031	0.025	0.026	0.026	0.025
Motor Generator	0.066	0.058	0.087	0.064	0.069	0.081
Operation Fixtures	0.059	0.053	0.059	0.061	0.057	0.061
Rail Brackets	0.024	0.029	0.026	0.027	0.026	0.027
Roller Guides	0.024	0.029	0.026	0.026	0.026	0.027
Rope Brake	0.029	0.033	0.026	0.028	0.029	0.029
Ropes	0.038	0.054	0.044	0.037	0.043	0.042
Safety Gear	0.025	0.029	0.026	0.027	0.027	0.027
Traction Machine	0.079	0.071	0.093	0.068	0.078	0.081
Travelling Cables	0.028	0.025	0.028	0.030	0.028	0.031
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.000**	**1.000**

Table 12: Summary of normalized 'component value' scores

Component	Company-A					Company-B
	Evaluator-1 Score	Evaluator-2 Score	Evaluator-3 Score	Evaluator-4 Score	Mean Score	Mean Score
Car set	1	1	3	1	1.3	1.0
Control panel	7	9	7	7	7.5	7.6
Traction machine	7	7	7	9	7.5	6.8
Motor generator	3	3	3	5	3.4	4.2
Operation fixtures	5	3	5	3	3.9	3.6
Governor	5	5	5	7	5.4	4.2
Brake	7	7	7	9	7.5	7.6
Door operator	5	5	5	7	5.4	4.2
Guide Rails	5	5	3	3	3.9	3.6
Ropes	5	5	3	3	3.9	3.6
Door Safety Device	5	5	5	7	5.4	4.2
Interlock Device	5	5	5	7	5.4	4.2
Rope Brake	5	5	5	7	5.4	4.2
Compensating Chain	5	3	3	5	3.9	3.6
Guide Shoes	3	3	3	3	3.0	3.0
Travelling Cables	5	3	3	5	3.9	2.5
Limit Switch	5	5	5	7	5.4	4.2
Load Weighing Devices	3	3	3	3	3.0	3.6
Rail Brackets	3	1	3	1	1.7	1.0
Roller Guides	3	1	3	5	2.6	2.1
Safety Gear	7	7	7	7	7.0	5.6
Counterweights	3	3	3	3	3.0	2.1
Buffers	3	1	3	3	2.3	1.0

9=very high; 7=high; 5=medium; 3=low; 1=very low

Table 13: Scores for 'risk in the supply market'

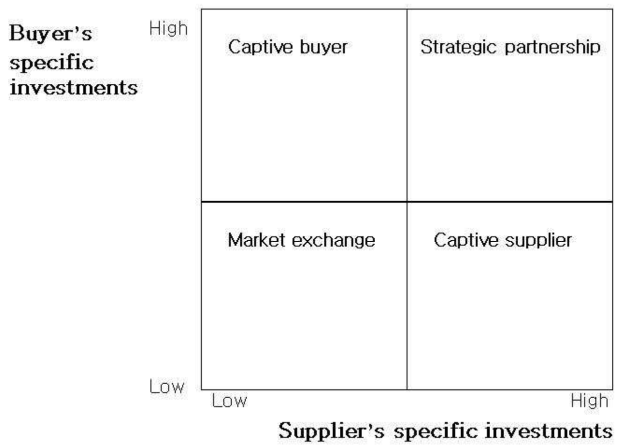

Figure 2: Purchasing Portfolio Model Bensaou (1999)