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Web based casting supplier evaluation using analytical hierarchy process

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Manufacturing companies are increasingly dependent on outsourcing to improve their competitive position. At the same time, the approach to supplier selection has dramatically changed from being price-driven to one based on overall capability of the supplier, very much in evidence in the automobile castings sector facing the challenge of mass customization. In this study, 18 criteria have been identified for casting supplier assessment and segregated in four groups—product development capability, manufacturing capability, quality capability, and cost and delivery. A systematic approach to evaluating casting quality suppliers has been developed using the analytical hierarchy process, which enables the combination of tangible and intangible criteria and checking the consistency of decision-making. The approach has been implemented in a prototype web-based system.

Keywords: supplier evaluation; outsourcing; AHP; internet; casting

Introduction

Today, manufacturing companies are facing intense global competition and consequently an incredible pressure to reduce the cost and development time of a new product. It is well known that a substantial proportion of the cost of a typical engineering product is accounted for in raw material, components and other supplies; on average, manufacturers' purchases of goods and services amounts to 55% of revenue.[1] Purchasing is thus one of the most crucial and vital activities of business, as it has a significant impact on finance, operations and competitiveness of the organization.[2]

In this context, outsourcing is rapidly gaining importance due to a number of reasons related to cost, core competence and managerial complexities of organization and activity specialization.[3] Therefore, many organizations are now allocating more resources for outsourcing activities to increase their competitive position. This is mainly achieved by a judicious combination of in-house manufacturing and outsourcing while preserving the core competencies of the organization. Selecting an appropriate supplier for outsourcing is now one of the most important decisions of the purchasing department, as it has to fulfil the strategic goals apart from operational requirements of the organization.[2] This decision generally depends on a number of different criteria.[4] Traditionally, *cost* has been the main criterion used in selecting a supplier, but slowly *non-price* criteria such as quality, delivery and overall capability are becoming equally important.[5]

Outsourcing activities have to be organized with the overall goal of customer requirement in terms of cost, quality and delivery. Often the supplier may have to be selected globally to achieve the above objective, in particular, to reduce the lead-time for procurement in a time-based competitive environment.[6] With the emergence of new information technology tools (World Wide Web, Internet and electronic commerce) the time required for information management and data communication have drastically reduced.[7] These technologies can be leveraged to speed up the process of sending enquiries and part drawings to any global supplier, obtaining the quotation from them and even sending invoices and payments in real time.

The shift in the approach to supplier selection (from price-based criteria to capability-based criteria) is very much in evidence in the automobile and other engineering sectors with respect to cast components.[3] Casting is the preferred process to manufacture intricate parts (cylinder block, exhaust manifold, differential casting, steering knuckle, brake drum, etc.). Manufacturing a sound casting right first time is, however, a difficult task and it largely depends on the foundry capabilities developed by the engineers over years of experience. Today, a number of newer technologies such as solid modeling, process simulation and rapid prototyping are available to foundry engineers to reduce the casting development time. Similarly, there are a wide variety of foundry facilities for molding, core making, melting and cleaning. Thus,

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foundries greatly differ from each other in terms of capabilities, facilities, technology and management, making it quite difficult to assess and select the best supplier foundry by simultaneously considering the multiple aspects of the decision.

Supplier selection methods

The decision of selecting the best supplier from a wide supplier base is an unstructured, complicated and time-consuming problem.[8] The process involves evaluation of different alternatives based on various criteria, some of which have to be maximized and others minimized; some conflict with others, whereas some overlap with others.[9] Categorical, linear weighted and cost-ratio methods are generally used to rank the suppliers.[10] According to a review of 74 articles on supplier selection criteria and methods over the last 30 years, the linear weighting model is the most commonly utilized quantitative approach.[11] In this method, a weight is subjectively given to each criterion and the total score of each supplier is obtained by summing up the supplier performances for the given criteria multiplied by the respective weights. A shortcoming of the linear weighting model is the subjective assignment of weights to each criterion. The above review also indicated that only 10 out of 74 articles discussed the use of mathematical models, which included linear programming, mixed integer programming and multi-objective mathematical programming. Interestingly, most of the articles indicated more than one criterion, demonstrating the multi-objective nature of supplier selection decisions.

Another multi-criteria decision-making method, called *Analytic Hierarchy Process* (AHP), is also reported in the literature for evaluating suppliers. In one application, AHP incorporated with capabilities of a spreadsheet was developed to aid the supplier selection process by using the top 8 criteria from a list of 23 important supplier selection criteria.[12] In another investigation, AHP has been demonstrated with a real-life example to explain its usefulness in the supplier selection decision process.[8] In a recent application on vendor rating, an AHP case study was discussed in a government Entrepreneur Development Program in Malaysia.[10]

AHP is a multi-criteria decision-making method developed by Saaty.[13] AHP aims at quantifying relative weights for a given set of criteria on a ratio scale. Two features of AHP differentiate it from other decision-making approaches. One, it provides a comprehensive structure to combine the intuitive rational and irrational values during the decision making process. The other is its ability to judge the consistency in the decision-making process. A number of applications of AHP have been published in the literature indicating its widespread use in industry and government organizations, for product development, planning, facility location, resource allocation, market selection and portfolio selection.[14,15]

GM's case study on 'Quad-4 automobile engine development' is a good example of product-engineering co-ordination to reduce the launch time of a new product.[6] In this case, the supplier management effort concentrated more on evaluating the capabilities of suppliers for their early involvement in the product design phase. Even quotes were not obtained prior to source selection. A cross-functional team approach was used to identify multiple criteria for evaluating the potential casting suppliers. The list includes quality, cost management, manufacturing capabilities and facilities and product development criteria. For evaluation purposes, team members visited nearly 100 foundries from around the world to survey the supplier's facilities and capabilities. The case used a linear weighting model to rank the potential suppliers.

With emerging technologies such as the WWW and Internet, many foundries are now demonstrating (advertising) their facilities and capabilities on-line.[16,17] Indeed, the first on-line foundry was reported in 1995.[18] Today the concept of e-bidding is being taken up very fast and there are many web portals offering on-line bidding services such as AutoXchange (auto-xchange.com), TradeXchange (gmtradexchange.com), MarketSite (marketsite.net) and SupplyPower (gmsupplypower.com). The increasing awareness and importance of on-line buying is also discussed in a recent article.[19] Auto giants are moving to web-based procurement to save costs through reduced transactions and inventory. Fuci Metals of USA has recently launched two e-commerce sites (fuci.com and basemetalsexchange.com) to fulfil Ford's foundry purchases for alloy materials and supply management.[20]

The use of Intelligent Software Agents (ISAs) for the procurement of parts on the web using client (buyer) and host (supplier) server architecture has been reported.[7] Using the client server, buyers provide product specifications and assign weights (between 1 to 9) to each specification, indicating its relative importance, and place them on the web. In addition, a list of web sites of potential suppliers known to each buyer is also provided to ISA. The host server authenticates the buyer's request before any transaction and retrieves the database (supplier ability) for the product specifications. The score of a particular supplier is given by $\sum[|(\text{buyer specification} - \text{supplier specification})|/\text{buyer specification}] \times \text{weight}$. The approach is discussed by a sample example of sourcing spur gears. This procedure automates and speeds up the procurement function and allows many potential suppliers to participate, in contrast with conventional purchasing.

The literature review clearly indicates that the supplier selection problem is a multi-criteria decision making process. The supplier selection criteria are of two types: objective (quantitative) and subjective (qualitative). The multi-criteria decision models allow the integration of both types of criteria to produce an aggregate performance measure. But some multi-criteria methods do not permit trade-offs among the decision criteria. For example, the *Lexicographic* method uses secondary criteria only as tiebreakers and the *Dominance* method requires that all criteria support the same ranking.[21] Methods that allow direct trade-offs among all criteria are preferred because they integrate all criteria into a single overall score for ranking alternatives. The AHP is one such scoring methods, which considers multiple criteria, quantitative as well as qualitative, and allows them to integrate into a single overall score. It is also possible to incorporate sensitivity analysis into the AHP model to answer different 'what-if' questions: for example, what happens if the importance of one criterion is doubled or if one more supplier joins the evaluation process.[8]

As far as supplier selection criteria are concerned, traditionally, price (least cost bid) has been the dominant criterion, which may not be a good indicator of long-term real value. Suppliers using a discounted price to enter the market often find it difficult to maintain quality at those prices. Interestingly, the Japanese follow a policy of accepting a *reasonable* initial price with promises of price cuts over time. Nowadays, the ability to meet quality requirements and delivery schedules has become equally important. The supplier selection problem is application-specific[4] and the strategic management decision may affect the criteria used in the decision-making process.[11] This implies that the type of criteria and their relative importance vary from one domain to the other (or even one company to another). For example, geographical location of supplier is an important criterion in companies following the JIT system as it prefers local suppliers.

While there are several studies on supplier selection, there appears to be no report of a systematic multi-criteria decision making (MCDM) approach for global supplier evaluation implemented in a web-based environment, especially for casting application. In this work, a prototype system for Web based casting supplier evaluation using the AHP methodology has been developed. In the following sections, we describe the criteria and methodology for evaluating casting suppliers, followed by a description of the Web-based supplier evaluation system, including a sample session.

Casting supplier evaluation criteria

The overall approach to casting supplier evaluation using the MCDM AHP methodology is shown in Figure 1. The buyer defines product requirements, based on which, compatible suppliers are identified from the database. The buyer views the facilities and capabilities of the supplier (and confirm them if necessary) to short-list further. The short-listed suppliers view the detailed product specifications and send their quotes. These suppliers are evaluated by a set of criteria and their performance score is presented to the buyer for the final selection.

In this study, 18 criteria for selecting casting suppliers have been identified after a detailed study of technical literature, discussion with experts and visits to final assemblers as well as foundries.[22] These are listed in Table 1. These criteria have been hierarchically structured in three levels (Figure 2) in accordance with the AHP framework. The top level contains the overall objective for supplier selection. Level 2 consists of four groups of criteria: Product Development Capability (PDC), Manufacturing Capability (MC), Quality Capability (QC), and Cost and Delivery (C&D). Level 3 contains the detailed criteria under each of the above groups.

For subjective criteria, attribute values have to be defined. In most cases, the preference of one attribute value over another is usually clear, but the extent of preference may require expert input. For example, for the 'sand preparation' criterion, 'mechanized' may be a preferred attribute value than 'manual', but the relative importance needs to be quantified.

The remainder of this section describes the group criteria, and the way they contribute to the overall objective. The detailed list of criteria (level 3), sub-criteria (if any) under the criteria and the criteria values (subjective only) are shown in Table 1. Most of the important criteria have been included, but the list is by no means sacrosanct, and the AHP program developed in this investigated allows introduction of new criteria along with their attribute choices (if any).

Product development capability

Assemblers of automobiles and other products today deal with more frequent model changes, upgrades and new introductions than in the past, which requires product development capabilities of the suppliers as well. This can be judged by factors such as the maximum part size, minimum section thickness, complexity, use of software aids in casting design, and pattern making. The type of facilities available in a foundry limits the maximum casting size that can be produced. Capabilities such as minimum section thickness and the maximum complexity (in terms of number of cores handled) are developed over the years with experience. Software for solid modeling, process simulation and NC process planning are important in cutting down the number of trials and the lead time required in product development. Similarly, an in-house pattern making facility is preferred by an assembler as it helps in handling quick design changes.

Manufacturing capability

Sand preparation, molding, core making, melting and pouring, heat treatment and machining are the important

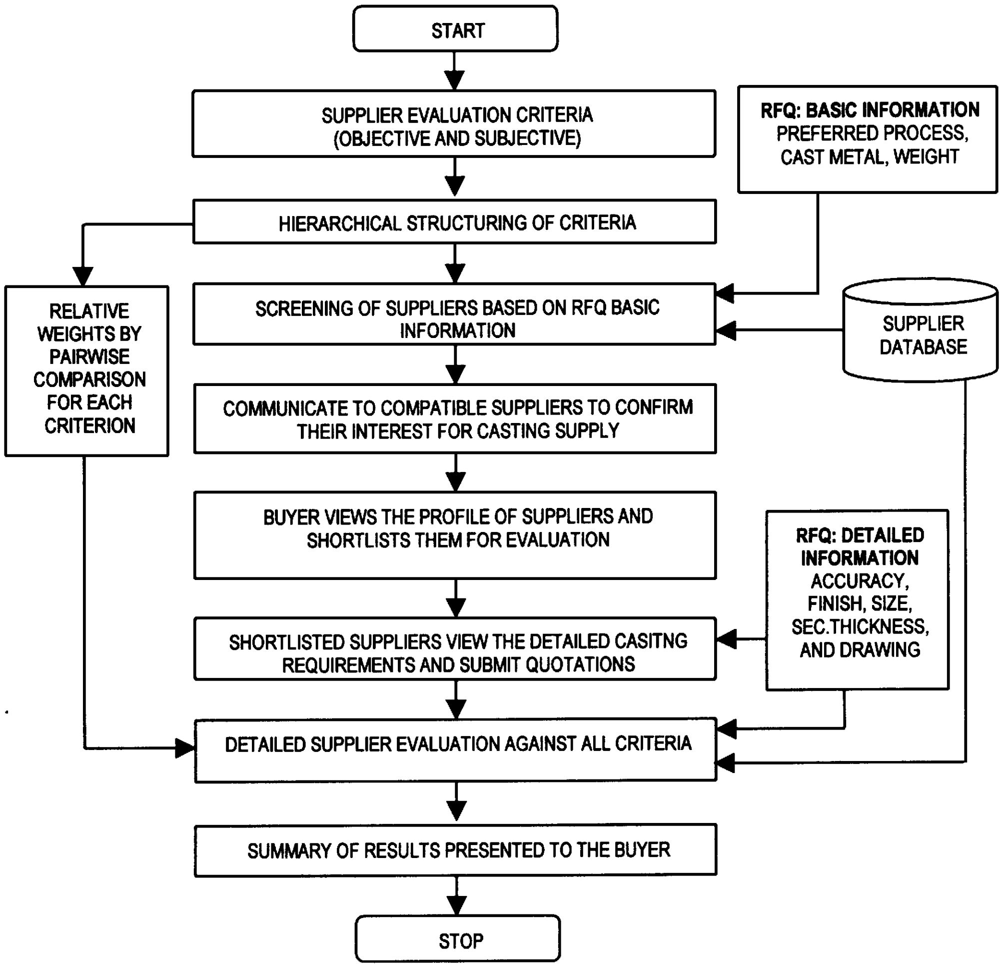

Figure 1 Flow chart for web-based supplier evaluation.

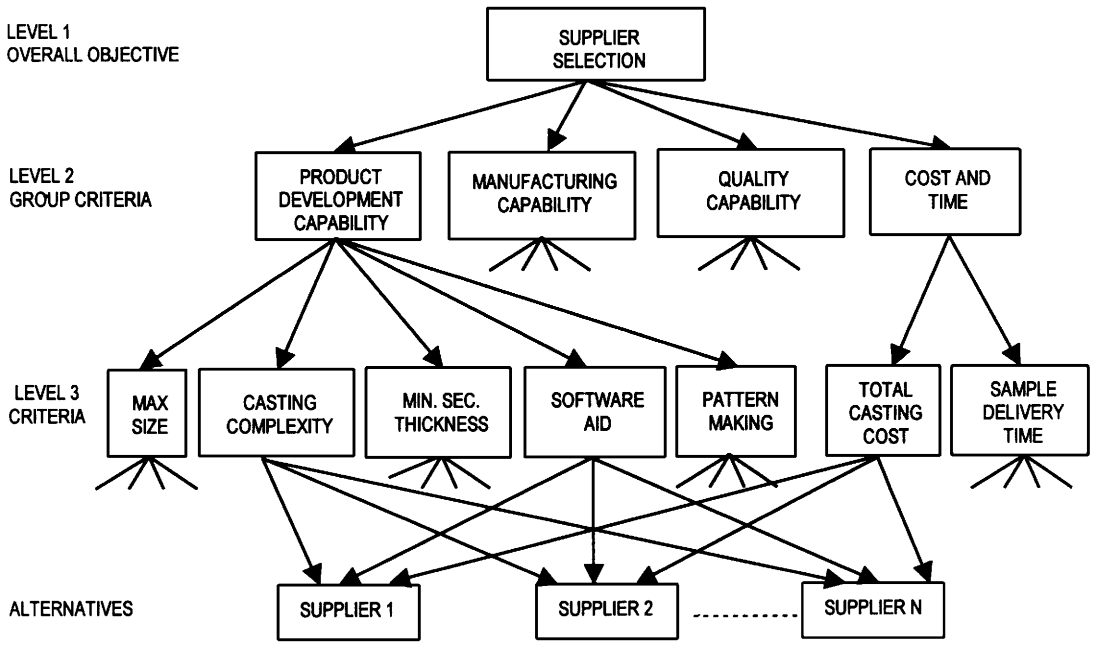

Figure 2 Schematic representation of the AHP model.

Table 1 Casting supplier evaluation criteria

Group criteria	*Criteria*	*Sub-criteria*	*Criteria value*
Product development capability	Maximum casting size		
	Minimum section thickness		
	Casting complexity		Low, medium, high, very high
	Software aid		Solid modeling, process simulation, NC process planning
	Pattern making		Inhouse, outsourcing
Manufacturing capability	Sand preparation		Manual, mechanized, sand plant
	Molding	Equipment	Manual, jolt squeeze, high pressure
		Processes	Green sand, dry sand, shell mold
	Core making		No bake, cold box, hot box, shell, CO_2 (sodium silicate)
	Melting and pouring	Melting equipment	Oil and gas fired, electric arc, induction, cupola
		Pouring methods	Manual, controlled, automatic
	Heat treatment		In-house, outsourcing
	Machining		In-house, outsourcing
Quality capability	Dimensional tolerance		
	Surface roughness		
	Testing facilities		Sand lab, physical lab, spectrometer, radiography, other NDT
	Quality certification		Self certification, ISO 9000, QS 9000
	Quality awards		Nil, national, international
Cost and time	Total casting cost		
	Sample delivery time		

criteria classified under this group, to evaluate the manufacturing capability of a supplier. Mechanized sand preparation systems (sand plants) are preferred over manual methods on account of capacity and consistency. The molding criterion is evaluated in terms of process (green sand, dry sand and shell mold) and equipment (manual, jolt squeeze and high pressure molding), while the core-making criterion is evaluated in terms of process (CO_2, shell, cold box and hot box). The melting and pouring criterion is evaluated in terms of melting equipment and pouring methods. The type of furnace should be compatible with the material and quality requirements of the casting: a cupola may be acceptable for melting cast iron, whereas induction furnaces are preferred for steel and ductile iron. Pouring requires special attention in terms of maintaining or controlling the molten metal temperature, its atmos-phere, amount of molten metal required, speed and time of pouring; controlled or automatic pouring facility is preferred. Foundries having in-house heat treatment and machining facilities are considered important, as subcontracting these operations will require an additional member in the casting supply chain, in turn influencing cost and lead time.

Quality capability

The criteria for quality capability consist of part accuracy (dimensional tolerance), surface finish (roughness), testing facilities, certification and awards. Casting accuracy and surface finish are mainly governed by the day-to-day shop floor practices adopted, developed over many years. Testing facilities (sand lab, physical lab, chemical lab, spectrometer and non-destructive testing or NDT facilities like radiography, ultrasonic and dye penetration) available in a foundry enable characterization of materials and products during various stages of manufacturing. Certification is an assurance by, or under the supervision of a competent and independent organization, that products produced are consistently in conformity with a standard or specification. This includes ISO 9000, QS 9000 and self-certification. Foundries with quality awards will be preferred over others as these are an indication of past performance.

Cost and time

This group comprises two criteria: total casting cost and sample delivery time. Total cost of casting is given by the summation of net price after discount (if any), transportation cost and unloading cost. Also important is the product development time, especially for time based competitive products. It is the sum of the time required in casting design and development, including the tooling fabrication and sample testing of a product.

Supplier evaluation using AHP

As described in the previous section, level 1 of AHP model contains the overall objective of supplier selection, level 2 contains the four groups of criteria and level 3 contains different criteria under each group. The bottom level of the

AHP model consists of various alternatives (suppliers) to be evaluated. Calculation of the relative importance (weight) to each criterion and the performance measurement of each feasible supplier are described next.

Criteria weight calculations

Relative weights are assigned to the criteria using the 1–9 scale of AHP (Table 2). Weights are first assigned to the group criteria and then to individual criteria in a particular group. The sum of weights of individual criteria in a particular group is normalized to one. The sum of weights of the four criteria groups is also normalized to one. Thus the effective weight of any particular criterion is equal to the product of its own weight and the weight of the criteria group.

For example, consider the estimation of relative weights (Table 3) for group criteria. All the diagonal elements of the matrix are 1 (as the elements are compared with themselves). Comparisons in only the upper triangular matrix are sufficient; the reciprocal of these values from the lower triangular matrix. In the first row of the matrix, the importance of the product development capability group criterion is considered moderate-to-strong over manufacturing capability, equal-to-moderate compared to quality capability and moderate compared to time and cost criterion. Similarly the second row shows the comparative importance of manufacturing capability over quality capability and time and cost criterion. The third row shows the importance of quality capability compared with time and cost criterion. The reciprocals of these values are shown in the lower triangular matrix. The size n of comparison matrix is 4. The weight of a criterion is calculated by taking the nth root for the product of n elements in each row and then normalizing the resulting values. To judge the consistency of comparisons, consistency ratio (CR) is calculated for each matrix as per the AHP methodology. In this work, the two sub-criteria (equipment and process) belonging to the molding criterion and another two sub-criteria (melting equipment and pouring methods) belonging to the melting and pouring criterion are assumed to be equally important.

Table 2 Scale of relative importance

Intensity	*Definition*
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Table 3 Estimating relative weights of group criteria

	PDC	*MC*	*QC*	*TC*	*Weight*
Product dev. capability (PDC)	1	4	2	3	0.4766
Manufacturing capability (MC)	0.25	1	1	2	0.1810
Quality capability (QC)	0.5	1	1	3	0.2383
Time and cost (TC)	0.33	0.5	0.33	1	0.1040
					Consistency ratio = 0.0467

Performance measurement calculations

The measurement of performance evaluation of a supplier against a particular criterion depends on the type of criteria. The criteria are either objective type (example: total cost and accuracy) or subjective type (example: complexity and quality awards). Supplier performance against objective criteria is obtained by a *normalization* method while for subjective criteria a *rating* approach is used.[23,24] The normalization approach uses actual data to evaluate the performance of supplier against an objective criterion. The rating approach enables qualitative judgements to be converted to quantitative values by a pairwise comparison of the qualitative terms for a particular criterion. The methodology is described in detail here.

Objective criteria evaluation. The objective criteria are evaluated, depending on whether the maximum or minimum value of the criterion is most desirable.

(a) If the *maximum value* is the most desirable (such as the maximum part size produced by a supplier must have the highest preference), then performance measure for the particular criterion is calculated by normalizing the values. For example, if the maximum size offered by three suppliers S1, S2 and S3 are 800 mm, 600 mm and 900 mm then the three suppliers' performance for the criterion maximum size possible is 0.3478, 0.2608 and 0.3913, respectively.
(b) If the *minimum value* is the most desirable (such as the supplier with minimum cost must have the highest preference), then the relative performance measure of the supplier is calculated by taking the reciprocal of values first and then normalizing the values. For example, if the total casting cost offered by 3 suppliers S1, S2 and S3 is 5000, 5500 and 4300 rupees, respectively, then the total cost performance of these three suppliers S1, S2 and S3 is 0.3255, 0.2959 and 0.3785, respectively.

Subjective criteria evaluation. The relative performance measure of each supplier for subjective criteria is obtained by quantifying the ratings, which are expressed in qualitative terms. For example, the casting complexity of a supplier is identified by the rating low, medium, high and very high. Similarly, the rating for quality certification criterion is expressed by the words ISO 9000, QS 9000 and self certification. To quantify a particular qualitative rating, a pairwise comparison of all ratings belonging to that criterion is carried out. These quantitative rating values are then used to calculate the overall performance of each supplier.

For some criteria, such as software aids, testing facilities, quality certification and quality awards, a supplier may possess multiple ratings. For example, a supplier can have both a physical lab *and* chemical lab as in-house testing facilities. Similarly, the foundry may win national as well as international awards indicating excellent past performance. In such cases, supplier performance for the criterion is calculated by summing the performance values of all the ratings. For example, if supplier S1 only has a solid modeling facility, and supplier S2 has all three types of software aid (solid modeling, process simulation and NC process planning), then the performance of the two suppliers for the software aid criterion will be 0.48 and 1.0, respectively.

After calculating the performance values of all suppliers against a particular subjective criterion, the values are normalized, so that they add up to 1.0. This approach ensures consistency (among objective and subjective criteria) in calculating the overall performance score of a supplier.

Overall score of supplier. The overall score of a supplier is given by the sum of the product of the performance of the supplier in each criterion and the relative weight of the respective criterion:

$$S_k = \sum_{i=1}^{4} \sum_{j=1}^{N_i} W_i \, w_{ij} \, P_{ijk}$$

where

S_k = overall score of kth supplier,
W_i = importance (weight) of ith group criteria,
w_{ij} = importance of jth criterion belonging to ith group,
P_{ijk} = performance measure of kth supplier for jth criterion of ith group,
N_i = total number of criteria belonging to ith group criteria.

The supplier with the highest overall score is considered the most suitable one.

Web-based supplier selection

The supplier evaluation methodology described above is being implemented in a prototype web-based system. The system comprises a set of programs and databases. To test the system, a web page called InterCAST (Figure 3) has been created on the casting domain portal 'metalcasting-world.com'. It is intended to provide an easy-to-use facility for interaction between casting buyers and suppliers. A typical session is described below.

Initially, interested casting buyers and suppliers can register themselves as members of the InterCAST service by providing a profile of their companies, as well as unique login names and passwords for authentication purposes

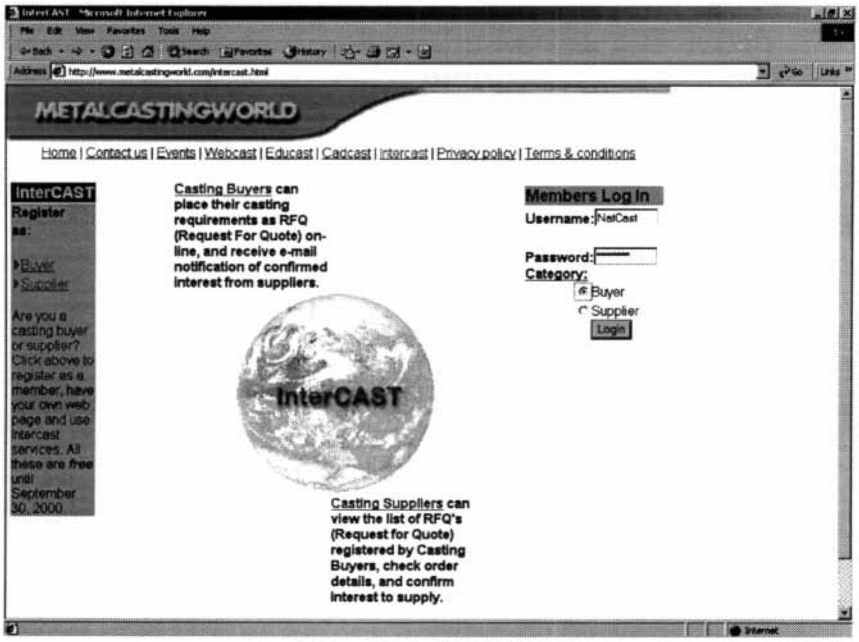

Figure 3 InterCAST section of metalcastingworld.com.

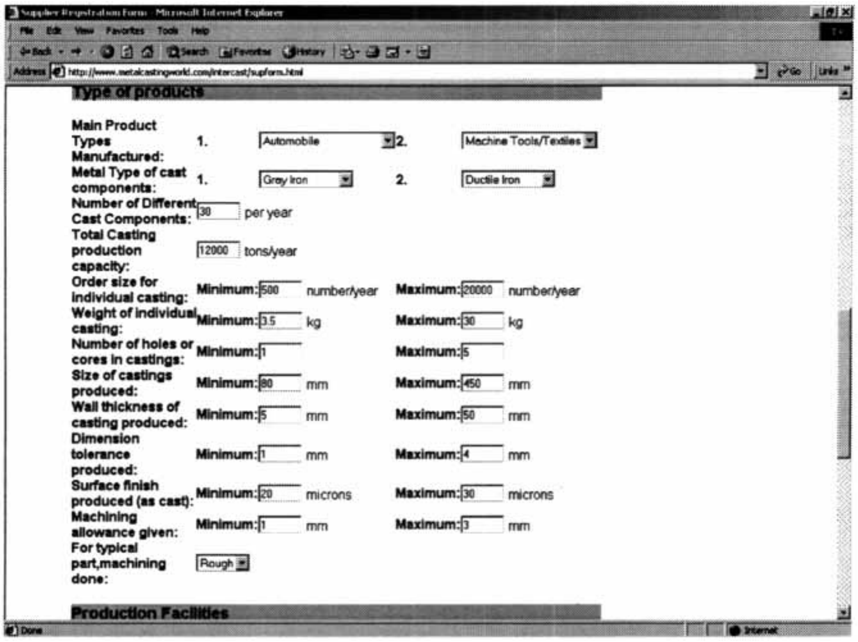

Figure 4 Supplier registration form.

(Figure 4). This information is stored in separate databases for casting buyers and suppliers. A registered buyer can log into the site and fill the Request For Quotation (RFQ) form for specifying the casting requirement (Figure 5). These include basic information (material type of cast components, preferred casting process, weight, order size, preferred date for confirming interest to supply) and additional information (casting size, minimum wall thickness, dimensional tolerance, surface roughness, number of cores and the preferred date for sample delivery).

Based on the RFQ, compatible suppliers are identified by comparing the metal type and preferred process fields (of RFQ) with corresponding fields in the supplier profile database. Automatically generated e-mails are sent to these suppliers inviting them to visit the site and check the RFQ. The suppliers log into the site, view the RFQ and

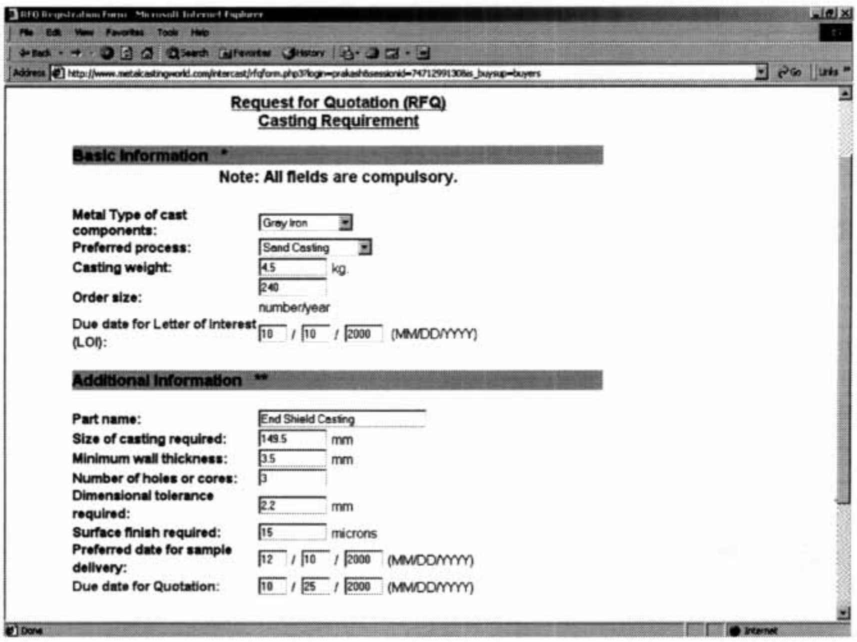

Figure 5 Request For Quotation (RFQ) form.

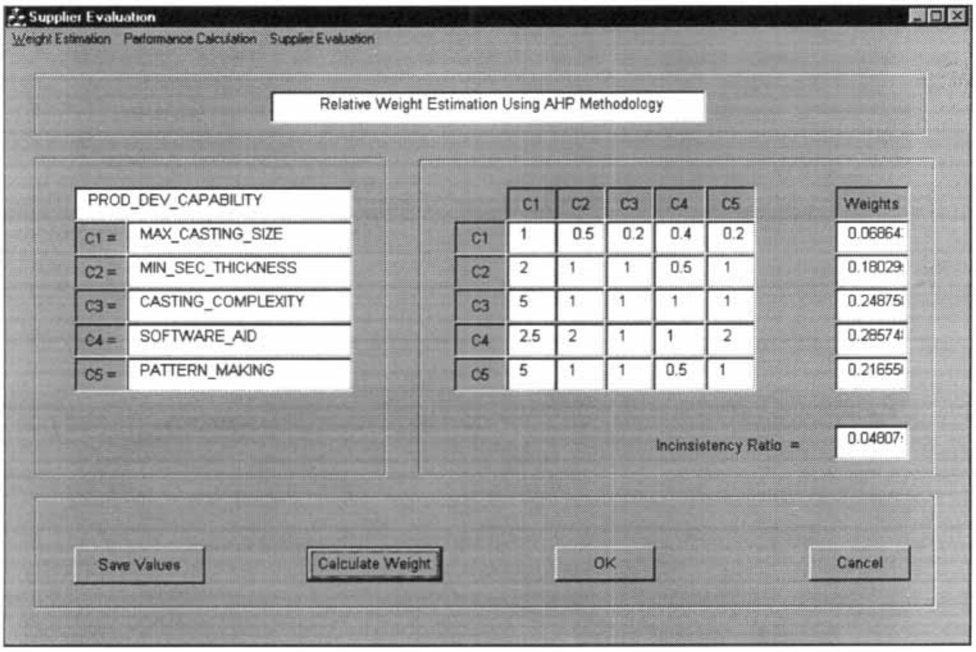

Figure 6 Estimating weights of criteria in product development capability group.

confirm their interest to supply. When the buyer next logs into the site, a list of suppliers who have confirmed their interest for a particular RFQ is displayed. The buyer views the profile of these suppliers, verifies their details if necessary, and short-lists them. The short-listed suppliers then send their respective quotations, including the sample delivery date, to the buyer. The 'supplier evaluation program' evaluates these suppliers and the results are presented to the buyer for a final decision.

As an example case, assume three suppliers: A, B and C have submitted their quotations for a particular RFQ. To enable performance measurement of these three suppliers,

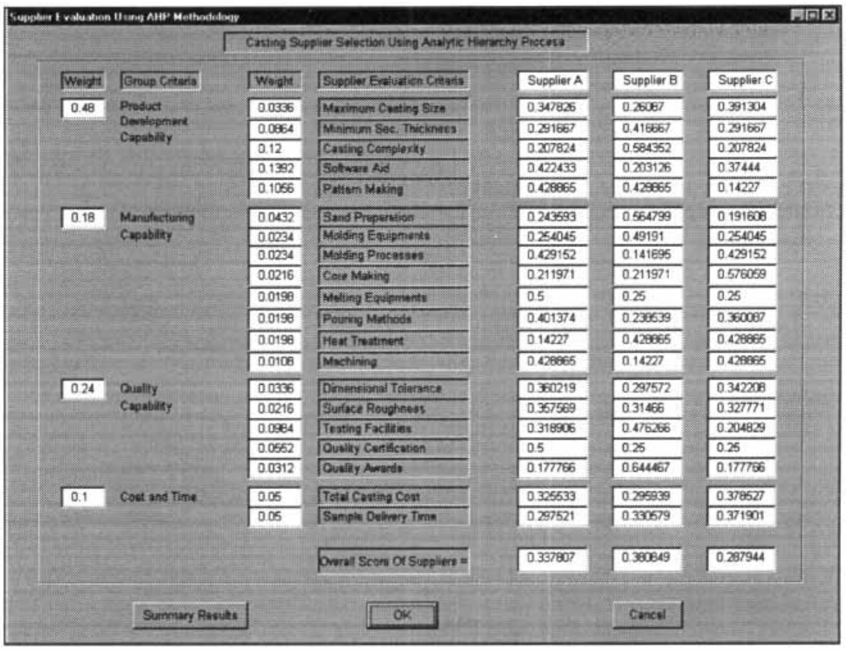

Figure 7 Detailed evaluation of suppliers against all criteria.

the buyer first has to: (1) decide relative weights for supplier selection criteria based on the casting specification (RFQ), and (2) establish performance rating values for each subjective criterion using a pairwise comparison method. Both these tasks have to be done only once, if the relative importance of the criteria and performance ratings remain the same, which is usually the case of the same class of components (for example, brake drums).

The supplier evaluation program developed in this investigation provides facilities for both the above tasks. Users have to enter their judgments only in the upper triangular half of the pairwise comparison matrix. The program calculates the respective reciprocal values (for the lower half) and the weights (Figure 6). The program also calculates the consistency of the buyer's judgement in terms of the consistency ratio, which should normally be less then 10%. In this example, the criterion software aid in product development has the highest weight (13.9%), followed by casting complexity (12%), pattern making (10.6%), testing facilities (9.8%) and the minimum section thickness (8.6%). For the particular RFQ, these five criteria together account for 54.9% of the total weight (100%) indicating their importance over the remaining criteria (Figure 7). The rating values for all subjective criteria obtained through pairwise comparison are shown in Table 4.

The RFQ data, suppliers' profiles and quotations are extracted from the database and sent to the supplier evaluation program. Based on these inputs, the overall performance for each of the supplier is obtained (Figure 7). The analysis of results for supplier capabilities in group criteria (Figure 8) shows that supplier B has performed well in all four group criteria in comparison with supplier A and also with supplier C except in the cost & time criterion. Thus supplier B has the highest overall performance score (38.1%) followed by supplier A (33.8%) and supplier C (28.8%).

The program allows the buyer to perform 'what-if' iterations to assess the sensitivity of the result obtained, especially when the criteria weights are modified. This involves executing the weight assignment routine again and then evaluating the suppliers with the new weights. In the above example, even if all the four group criteria are made equally important (25% each), supplier B still emerges as the preferred one, with a score of 36.6%, followed by supplier A and C at 33% and 30.8% respectively.

Table 4 Performance rating value for the subjective criteria

Criteria name	*Performance rating*	*Rating values*
Casting complexity	low	0.0882
	medium	0.1462
	high	0.2024
	very high	0.5691
Software aid	Solid modeling	0.4808
	Process simulation	0.4055
	NC process planning	0.1136
Pattern making	In-house	0.8761
	Outsourcing	0.1239
Sand preparation	Manual	0.0643
	Mechanized	0.2372
	Sand plant	0.6987
Molding equipments	Manual	0.1283
	Jolt squeeze	0.2764
	High pressure	0.5954
Molding processes	Green sand	0.1324
	Dry sand	0.2686
	Shell mold	0.5991
Core making	no bake	0.0523
	Cold box	0.2616
	Hot box	0.1066
	Shell	0.2897
	CO_2	0.2897
Melting equipments	Oil and gas fired	0.2500
	Electric ARC	0.2500
	Induction	0.2500
	Cupola	0.2500
Pouring methods	Manual	0.0643
	Controlled	0.3715
	Automatic	0.5608
Heat treatment	In-house	0.8333
	Outsourcing	0.1666
Machining	In-house	0.7509
	Outsourcing	0.2491
Testing facilities	Sand lab	0.2137
	Physical lab	0.1875
	Spectrometer	0.2234
	Radiography	0.3083
	Other NDT	0.0669
Quality certification	Self certification	0.0909
	ISO 9000	0.4545
	QS 9000	0.4545
Quality awards	Nil	0.0686
	National	0.2487
	International	0.6827

Conclusions

A decision-support system for casting supplier evaluation has been designed and linked to a web-based system for casting buyer–supplier interaction in this investigation. The evaluation program is based on 18 criteria, of which 6 are of objective type and 12 are of subjective type, and these are assigned weights using the AHP methodology. A combination of normalization and rating methods (for objective and subjective criteria, respectively) has been employed to evaluate supplier alternatives against the criteria. To the best of our knowledge, this is the first time that a multi-criteria decision-making tool based on the analytical hierarchy process has been combined with a web-based approach and applied to the domain of casting for supplier evaluation.

While the proposed methodology provides a systematic approach for quantitative evaluation of casting suppliers, it is not entirely automated. The procedure of pairwise

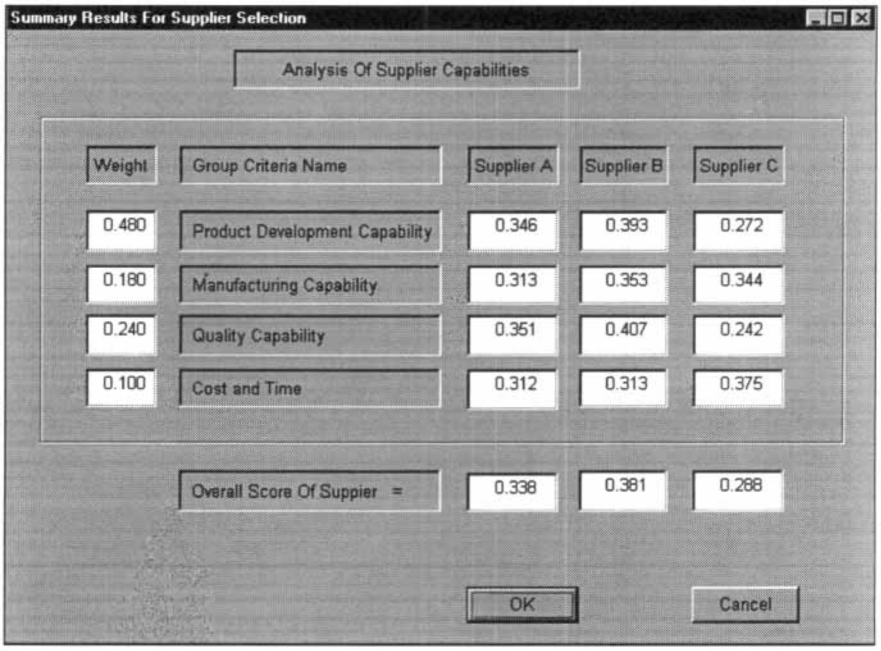

Figure 8 Summary of supplier capabilities.

comparisons to assign criteria weights or to quantify the qualitative ratings being cumbersome, a set of default values is provided by the system. The user may change these for a particular class of components (in terms of geometry, material, process and quality requirements), and set these values as default when suppliers for a similar casting have to be evaluated. Another issue is regarding the validity of the company profile data entered by a casting supplier during registration for the service; this may have to be verified by the buyer or by a third party. Finally, organizational aspects of suppliers such as the level of training, employee–employer relationships and financial position (profit/loss) have not been considered, because of the difficulty in obtaining such information at present, and may need to be considered by the buyer during final negotiations. These issues may be taken up for further investigations, and for making the system more 'intelligent' and automated.

The entire system facilitates casting buyers to identify a larger pool of potential suppliers worldwide, communicate order requirements, short-list capable suppliers, and finally evaluate them in a systematic manner—all with virtually zero 'paperwork' and in days instead of weeks by the conventional route. The proposed methodology and the prototype version have been demonstrated to potential users through a series of one-day workshops in the past few weeks. This has received very good response and encouragement for further work. Based on the response, a scaled-up version for full-fledged use is being planned for implementation with support from the industry.

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