Application of Novel Artificial Intelligent Techniques in Ship Building Using Activity Based Costing and Neural Networks

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Abstract:

This paper is concerned with the development of an Activity Based Costing (ABC) system for application in SMEs in the shipping building industry. It represents a review of Artificial Intelligence (AI) techniques and practices and their application in ABC particularly in determining costs more accurately. The ultimate aim of this work is to design and develop a costing model using either a Knowledge Based System (KBS) and/or a Neural Network (NN).

In the previous work, a neural network was designed and tested for estimating the cost of the activities and the hours of the activities in the shipping industry, by considering the ship parameters such as length of the ships, width, tonnage, etc. Multi-layered feed forward neural network trained by back-propagation algorithm was used in that work. Its results encouraged the research team to develop a new neural network model for representing ABC in designing and costing of ship building activities and processes.

In this paper, a new neural network model was configured for establishing the relationship between the cost of the activities and the indirect costs. The new neural network model is a multi-layered, feed forward neural network. The output layer gives the indirect costs. The proposed neural network has been trained using back-propagation training algorithm. It has been trained by using data of sixteen different ships with a view to design five new ships.

Keywords: Activity based contents, Ship building, system design and manufacturing, knowledge-base-system, neural networks.

Introduction:

Traditional costing systems tend to use a single cost driver to allocate all variable and overhead expenditure e.g.; direct labour hours, machine hours, product volume or material cost**.** Activity Based Costing (ABC) is primarily an information system developed in 1980s as an alternative to traditional accounting mainly to allocate overhead costs to specific products and hence have more meaningful methods of costing and pricing individual products. ABC provides a means of costing the activities associated with a given product or service and hence allows overhead costs to be allocated to each activity taking place in the production of a product or the provision of a service (Ziarati et al, 1989).

ABC can be most effective where there is a medium to large range of products or where there is a product with a wide component range. In summary where there is a highly diverse product or component range in size or complexity, or both. The ABC is particularly effective when there are multiple production operations and/or there is an excessive overhead rate but where current costing practises are applied viz., quoted job prices are regularly accepted by customers.m primarily due to lack of competitive forces in the market for given products or a product range.

There have been a number of papers referring to the innovative application of ABC in manufacturing operations. The paper by Ozbayrak et al (2003) refers to the application of ABC in advanced manufacturing systems applied within either Material Requirements Planning (MRP) or Just in Time (JIT) strategies with a view primarily to estimate the manufacturing and product costs in an automated environment. Kaplan and Cooper (1998) have gone even further promoting the idea that an overall strategic management system could be developed by applying an ABC approach through consideration of operating processes supported by management and support processes. They claim that these processes can be broken down into activities and 'costed'. The authors argue that the ABC provided a method which overcomes many limitations of traditional costing systems and at the same time provide an innovative overall strategic management system for manufacturing a range of products or a product with a range of variations.

Activity-based costing reported (Cokins, 2001) to be a high-powered decision support tool that is well within the means of SMEs. It is noted that with ABC, a company can gain the accurate and relevant cost information it needs to support the myriad of decisions it makes that require cost information. According to Coking the key to effective use of ABC is to understand that it is a concept, not a system. Although large businesses may need a complex and costly systems to benefit from the concept due to the disadvantages of largeness, the SMEs can gain the same benefits by exploiting the advantages of smallness and using ABC to create an economic model of the organisation that will provide the accurate and relevant cost information it needs to support critical management decisions of all types (Hicks, 2001).

It has already been stated that ABC overcomes some of the limitations of traditional cost accounting systems. In recent work by Kim and Han (2003) it has been stated that ABC has achieved improved accuracy over traditional methods in estimating costs as it enables multiple cost drivers to trace the cost activities to the products associated with the resources consumed by those activities.

The research here has shown (Ziarati et al, 1989) that there is a great deal to be achieved in developing Activity Based Costing using non-linear approaches to costing of ship building processes such as Artificial Neural Networks (ANN) and also devoting efforts in establishing criteria for cost drivers as the basis for a model for application in ship building. Removing these weaknesses of the ABC is expected to provide an opportunity for a new approach in application of ABC in general and in ship building in particular.

The companies involved with shipbuilding have their own method of costing and make use of a variety of software product with varying degree of complexity. However, no company of those contacted/investigated currently uses ABC or has a systematic method of distributing indirect costs to each activity within a given project. Although these companies have similar conventional cost systems, there are two essential differences, type (1) more attention is paid to detailing direct costs and type (2) more effort is paid to detailing indirect costs. The latter may find it easier to adapt ABC than the former (Urkmez et al, 2006).

Analysis of the data collected so far shows that the method often used in costing ship building is relatively simple; the shipyard simply lists direct equipment costs by use of spreadsheet based software e.g. MS Excel. The labour costs are accepted as the average cost for building such a ship based on per unit kg in shipyards in Turkey.

Some Companies also make use of commercial costing project management and scheduling software to define activities and timing and leave the costing to a parallel exercise where each activity is 'costed' using historical or empirical data.

One company used MS Project software rather innovatively where all activities were plotted against time schedule and then costs were estimated for each activity. Generally, there are almost 400 activities in the manufacture of a ship. Although the activities are 'costed', it is not an ABC system, as indirect costs have not been distributed to each activity.

The analysis of costing systems of these ship building companies has shown that the historical data has not been effectively used for future ship building project 'costing'. A review of neural network applications indicated that such networks could provide a means of accumulating historical data and also a decision making tool. To this end a neural network which had been used successfully elsewhere (Ziarati et al, 2001, Urkmez et al, 2006) was adapted to develop an ABC system.

Method:

In this paper, a new neural network model was configured for establishing the relationship between the cost of the activities and the indirect cost parameters of the activities.

The new neural network model is a multi-layered, feed forward neural network. It has two hidden layers. The first hidden layer is between the input layer and the second hidden layer; it works as a pre-processor layer and it is not fully connected. The second hidden layer is structured between the pre-processor layer and the output layer. In the input layer, number of the input neuron is set to the number of the ship parameters. This is because the input nodes are the ship parameters.

The Neural network model estimates the indirect costs of the ships considering the ship parameters. There are 11 defined parameters to identify the ships. These parameters are classified into three groups such as manufacturing parameters, geometric parameters and capacity parameters as shown in Table 1.

MANUFACTURING PARAMETERS		**GEOMETRIC PARAMETERS**		**CAPACITY PARAMETERS**	
Parameter	**Value**		**Value -Unit**		**Value-Unit**
Company Name	0, 0.5, 1	LOA	meters	DWT	Dwt
Type of the Ship	0, 0.25, 0.5, 1	LBP	meters	Engine Power	Kwatt
Order Number	1-7	BM	meters	Speed	Knot
		DM	meters		
		Maximum Draught	meters		

Table 1. Input parameters of the ships.

Manufacturing parameters are consisting of three parameters such as company name, type of the ship and the order number. The parameter, "Company name" can take three different value since we took the data from three shipbuilding company; ADIK, TORGEM and EREGLI Shipyard. These company names were coded as 0, 0.25 and 1.0 respectively.

The parameter, "Type of the ship" represents manufacturing purpose of the ship. It can take four different values such as chemical tanker, multi purpose ship, container and bulk carrier. These ship types were coded as 0, 0.25, 0.5 and 1 respectively. If a shipbuilding company build a few ships with same design, cost of the first ship is more expensive than the later ships. For this reason, the other manufacturing parameter order number is an important parameter to affect the costs.

Geometric parameters represent the geometric properties of the ships. These five parameters are LOA - length of overall, LBP - length between perpendiculars, BP - breadth moulded, DM - depth moulded and maximum draught of the ships. The other parameter group is the capacity parameters and they give the information about the capacity of the ships. These three parameters are DWT – Dead Weight tonne (tonnage of the ships), engine power and maximum speed of the ship.

We have defined 6 indirect cost pools during the ship building overall process. These cost pools are:

1- Purchasing and Logistics
2- Design
3- Supervision and Production Control
4- Bookkeeping and Accounting
5- Maintenance and Administrative
6- Costumer relationships

We have gathered the cost data of 22 ships during building process from three different shipyards. All the indirect costs of these ships were distributed to the indirect cost pools regarding the ABC rules. For instance, as book-keeping and accounting costs of any ship is calculated, first, average cost of a document such as invoices has been calculated considering the labour hours, then, number of the invoices is multiplied by this average cost of an invoice.

Neural Network Model

The new neural network model has four layers; input layer, pre-processing layer, main hidden layer and output layer. It has two hidden layers as shown in Figure 1. The first hidden layer is called as pre-processing layer and the connection structure between the input layer and this pre-processing layer is not fully-connected. These connection structure decreases the number of the elements of the weight matrix between these layers from 77 to 27.

This neural network has been designed to produce the indirect costs at the output layer for a given ship parameters at the input layer during training by using back propagation algorithm. Data of the 18 ships has been used for training of ANN. Input parameters are shown in Table 2. and the output parameters, in the other word, indirect costs are shown in the Table 3.

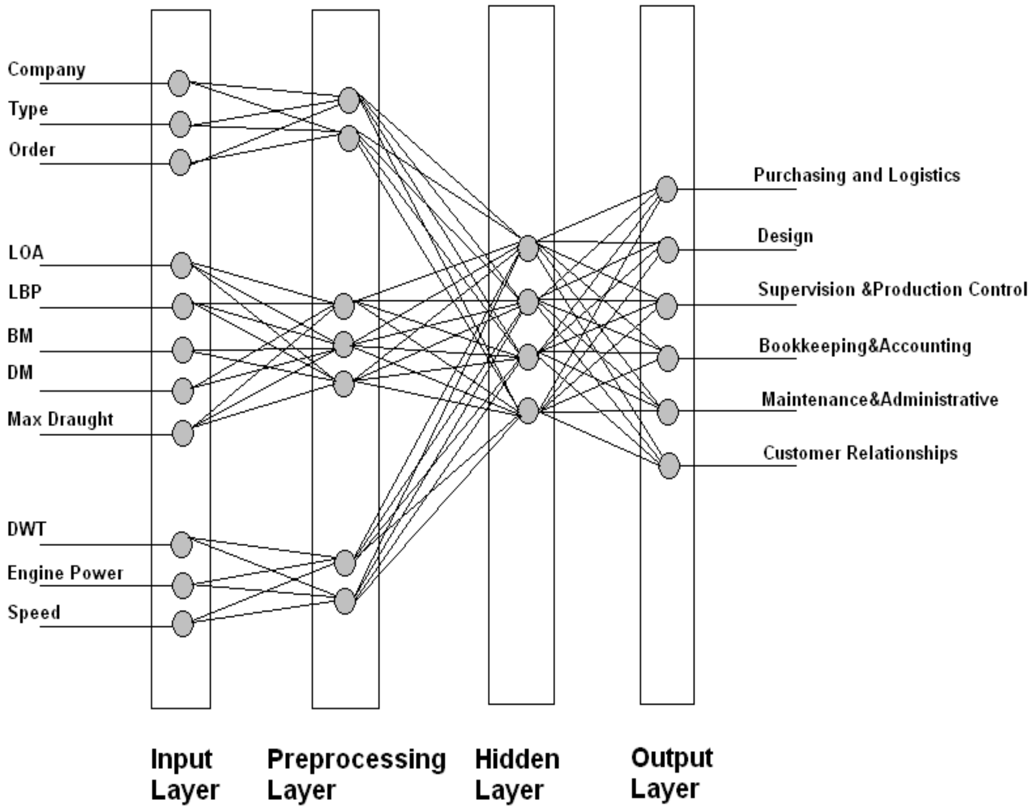


Figure 1. Neural network structure for predicting the indirect costs

Results

After training process, ANN was tested with data of the new four ships. Input data is shown in Table 4. It was expected that the neural network would produce the indirect costs of these ships at its output layer. These desired indirect costs data are given in Table 5.

ANN results for these ships are given in Table 6. While Tables 5 and 6 are compared with each other, it can be seen that ANN results (Table 6) are much closer to real indirect costs (Table 5). The results are shown graphically in Figure 2 and it can be seen are very encouraging. Indirect cost item, purchasing and logistics costs in YTL of these four test ships are shown in Figure (2.a). The other five indirect costs such as design costs, supervision and production control costs, book-keeping and accounting costs, maintenance and administrative costs and costumer relationships costs are shown in Figures 2b-2f). Both the neural network cost prediction and the actual (real) cost of each ship are presented in each figure.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		NB 188	**NB 201**	**NB 203**	**NB 204**	**NB 205**	**NB 206**	**NB 207**	**NB 208**	**NB 209**	**NB 210**	**NB 211**	**NB 213**	**NB 214**	**NB 215**	**NB 216**	**NB 217**	**NB 219**	**NB 94**
INPUT PARAMETERS	**COMPANY**	ADIK	ADIK	TORGEM	ADIK	ADIK	ADIK	ADIK	EREGLI	ADIK	EREGLI	ADIK	ADIK	ADIK	ADIK	ADIK	ADIK	ADIK	TORGEM
	TYPE	CHM	MP	BC	CHM	CHM	MP	CON	CON	CON	CON	CON	CHM	CHM	CHM	CHM	CHM	CHM	CHM
	Order	1	1	1	2	3	2	1	2	3	4	5	1	2	4	5	6	3	1
	LOA (m)	122,66	126,08	186,45	122,66	122,66	126,08	145,6	145,6	145,6	145,6	145,6	147,5	147,5	122,66	122,66	122,66	147,5	107,34
	LBP (m)	116,08	113,75	177	116,08	116,08	113,75	134,28	134,28	134,28	134,28	134,28	140	140	116,08	116,08	116,08	140	101,6
	BM (m)	17,2	20	30	17,2	17,2	20	22,6	22,6	22,6	22,6	22,6	22,4	22,4	17,2	17,2	17,2	22,4	15,8
	DM (m)	8,8	10,4	16,2	8,8	8,8	10,4	11,3	11,3	11,3	11,3	11,3	12,6	12,6	8,8	8,8	8,8	12,6	8,25
	Max Draught(m)	6,86	8,08	11,48	6,86	6,86	8,08	8,4	8,4	8,4	8,4	8,4	9,8	9,8	6,86	6,86	6,86	9,8	6
	ENGPOWER (Kwh)	3840	4790	7100	3840	3840	4790	9480	9480	9480	9480	9480	5300	5300	3840	3840	3840	5300	2620
	Speed (Knots)	14	14	14,5	14	14	14	18	18	18	18	18	14	14	14	14	14	14	13
	DWT	8100	9300	42000	8100	8100	9300	12750	12750	12750	12750	12750	18000	18000	8100	8100	8100	18000	6000

Table 2. Input parameters of 18 ships used for training of ANN

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
		NB 188	**NB 201**	**NB 203**	**NB 204**	**NB 205**	**NB 206**	**NB 207**	**NB 208**	**NB 209**	**NB 210**	**NB 211**	**NB 213**	**NB 214**	**NB 215**	**NB 216**	**NB 217**	**NB 219**	**NB 94**
DIRECT COSTS	**Purchasing& Logistics**	125,625	133,075	314,825	123,950	122,250	130,875	200,700	196,750	193,850	192,675	191,200	227,200	223,250	120,675	118,550	118,125	220,075	122,100
	Design	125,750	230,610	681,510	117,060	103,300	220,450	150,960	142,900	125,780	125,490	123,360	207,160	196,100	101,320	95,940	97,890	191,210	205,880
	Supervision& Prod. Control	653,250	691,990	1637,090	644,540	635,700	680,550	1043,640	1023,100	1008,020	1001,910	994,240	1181,440	1160,900	627,510	616,460	614,250	1144,390	634,920
	Bookkeeping& Accounting	452,250	479,070	1133,370	446,220	440,100	471,150	722,520	708,300	697,860	693,630	688,320	817,920	803,700	434,430	426,780	425,250	792,270	439,560
	Maintenance& Administrative	854,250	904,910	2140,810	842,860	831,300	889,950	1364,760	1337,900	1318,180	1310,190	1300,160	1544,960	1518,100	820,590	806,140	803,250	1496,510	830,280
	Costumer Relationships	75,375	79,845	96,895	74,37	73,35	78,525	85,42	83,05	81,31	80,605	80,72	86,32	83,95	71,64	71,13	72,405	82,045	73,26

Table 3. Indirect costs of the ships used for training ANN

		T1	T2	T3	T4
		NB 212	**NB218**	**NB 220**	**NB 95**
INPUT PARAMETERS	**COMPANY**	ADIK	ADIK	ADIK	TORGEM
	TYPE	CON	CHM	CHM	CHM
	Order	6	7	4	2
	LOA (m)	145,6	122,66	147,5	107,34
	LBP (m)	134,28	116,08	140	101,6
	BM (m)	22,6	17,2	22,4	15,8
	DM (m)	11,3	8,8	12,6	8,25
	Max Draught(m)	8,4	6,86	9,8	6
	ENGPOWER (Kwh)	9480	3840	5300	2620
	Speed (Knots)	18	14	14	13
	DWT	12750	8100	18000	6000

Table 4. Input parameters of the ships for test stage of ANN

		T1	**T2**	**T3**	**T4**
		NB212	**NB218**	**NB 220**	**NB95**
INDIRECT COSTS	**Purchasing&Logistics**	190,700	118,125	217,425	120,975
	Design	121,960	96,750	188,790	195,730
	Supervision&Production Control	991,640	614,250	1130,610	629,070
	Bookkeeping&Accounting	686,520	425,250	782,730	435,510
	Maintenance&Administrative	1296,760	803,250	1478,490	822,630
	Costumer Relationships	82,420	70,875	85,455	72,585

Table 5. Real indirect costs of the ships for test stage

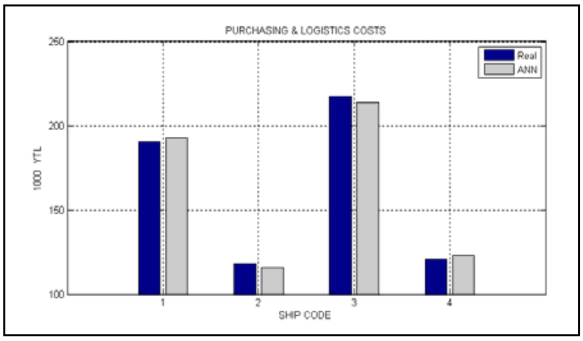
		T1	**T2**	**T3**	**T4**
		NB212	**NB218**	**NB 220**	**NB95**
INDIRECT COSTS	**Purchasing&Logistics**	192,851	116,005	213,612	122,852
	Design	120,024	98,603	184,129	198,215
	Supervision&Production Control	995,352	610,114	1132,211	632,060
	Bookkeeping&Accounting	691,520	428,250	779,615	434,247
	Maintenance&Administrative	1302,760	806,514	1485,414	818,746
	Costumer Relationships	81,386	71,240	83,289	72,001

Table 6. Indirect costs of the ships predicted by ANN

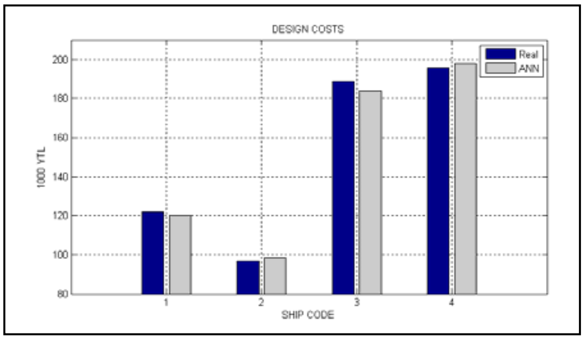
ANN results for these ships were given in Table 6. While Tables 5 and 6 are compared with each other, it can be seen that ANN results (Table 6) are much closer to real indirect costs (Table 5).

The results are shown graphically in Figure 2. Indirect cost item, purchasing and logistics costs in YTL of these four test ships are shown in Figure (2a). The other five indirect costs such as design costs, supervision and production control costs, bookkeeping and accounting costs, maintenance and administrative costs and costumer relationships costs were shown in

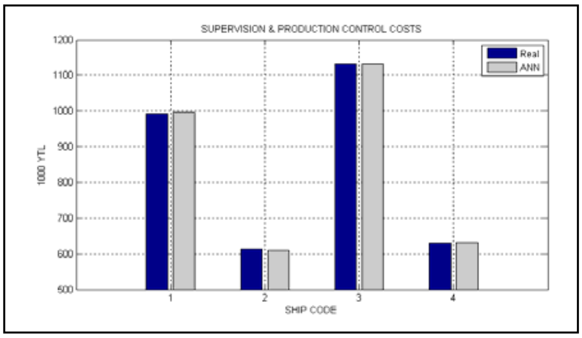
Figures 2 b-2f). Both the neural network cost prediction and the actual (real) cost of each ship are presented in each figure.



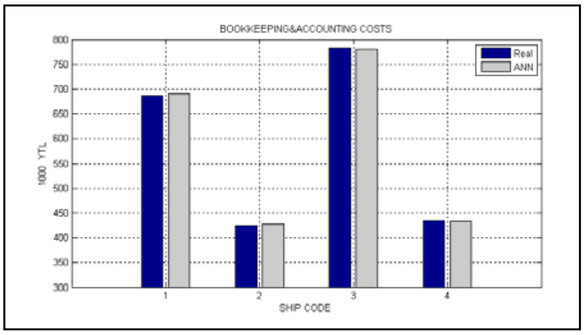
a- Purchasing and logistics costs



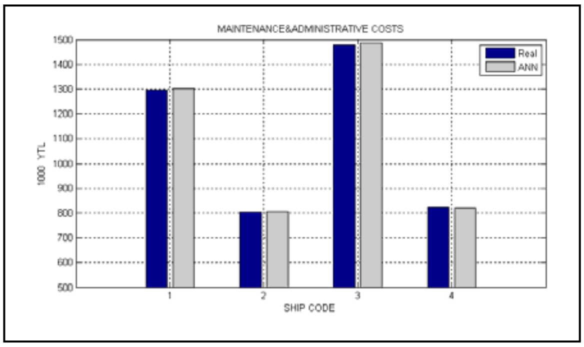
b- Design costs



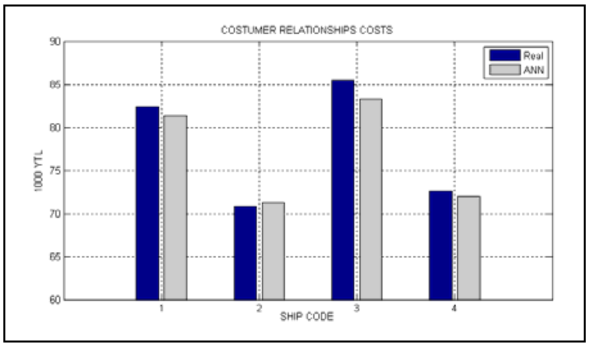
c- Supervision and production control costs



d- Bookkeeping and accounting costs



e- Maintenance and administrative costs



f- Costumer relationships costs

Figure 2. Comparing the results of ANN and actual indirect costs.

Absolute percentage errors between the predicted costs of ANN and actual indirect costs for the test ships are shown in Table 7. It can be seen that maximum relative error occurred is 2.53 % for the costumer relationship costs of the ship NB 220.

		T1	T2	T3	T4
ABSOLUTE PERCENTAGE ERROR		NB212	NB218	NB 220	NB95
INDIRECT COSTS	Purchasing&Logistics	1,128	1,795	1,754	1,552
	Design	1,587	1,915	2,469	1,270
	Supervision&Production Control	0,374	0,673	0,142	0,475
	Bookkeeping&Accounting	0,728	0,705	0,398	0,290
	Maintenance&Administrative	0,463	0,406	0,468	0,472
	Costumer Relationships	1,255	0,515	2,535	0,805

Table 7. Absolute percentage error between the ANN outputs and the real costs

Conclusion

These results encouraged the research team to conclude that ANN can be used in ABC applications successfully. A new tool in costing ship building using ABC and ANN has been developed and successfully tested in Turkey. It is now feasible to conclude all activity costs, both direct and indirect before a ship is constructed. The reliable estimation of indirect costs would help ship builders to have a better understanding of activity costs and hence enable them to make appropriate decisions in design and manufacturing as well as management processes.

References

Ziarati, R. et al (1989), keynote speech, Costing Practices in SMEs, 2nd ManTech Conference, Eurotecnet 89, Southampton Institute, UK

Ozbayrak et al (2003)

(Cokins, 2001)

(Cokins, 2001)

(Hicks, 2001).

Kim and Han (2003)

Urkmez, S. et al (2006), Activity Based Costing for Small and Medium Sized Maritime Enterprises in Turkey, Proceedings of 5th International conference on Manufacturing Research, ICMR 08, UK.p. 301-306, ISBN 978-0-9556714.

Ziarati, M. et al (2001), Optimisation of Economic Order Quantity Using Neural Networks Approach

Cooper, R. (1988), The Rise of Activity Based Costing (Part 1), The Journal of Cost Management, pp 45-54