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DETERMINATION OF SUPPLY CONDITIONS, SCENARIOS AND PAY-OFF FOR INDUSTRIAL MACHINERY SUPPLIER SELECTION POST ECONOMIC AND ENGINEERING CONSIDERATIONS

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Abstract
Supply conditions after economics and engineering considerations is important for consideration because machinery and equipment procurement is a tripod of which supply conditions is one. This study identified the attributes of supply conditions, different ways of combining the attributes using simple permutation and combination theories and determined the pay-off as well as the opportunity lost to every scenario used by method of Expected Decision Value (EDV). The attributes were identified as: Due Date of the Supply (A); Technical Capability of Vendor (B); After Sales Services (C); and Vendor's Experience (D). Total number of scenarios were 15 of four (4) options. The pay-off with the opportunity lost to each selected option are: Option1 (25% against 75%); Option2 (50% against 50%); Option3 (75% against 25%); and Option4, 100% where the four (4) strategic decisions were all considered for selecting the supplier turns out to be optimum and in favour of purchaser. Further research in the area of development of a Surrogate Model for Industrial Machinery Supplier Selection Post Economics and Engineering Considerations is recommended.

Keywords: Decision making, Machinery and equipment, Pay-off and opportunity lost, Selection scenarios, Supply conditions.

1.0 INTRODUCTION

Machinery is any mechanical, electrical or electronic device designed and used to perform some function and to produce a certain effect or result. The word includes not only the basic unit of the machinery but also any adjunct or attachment necessary for the basic unit to accomplish its intended function. The word also includes all devices used or required to control, regulate or operate a piece of machinery, provided such devices are directly connected with or are an integral part of the machinery and are used primarily for control, regulation or operation of machinery. Jigs, dies, tools, and other devices necessary to the operation or used in conjunction with the operation of what would be ordinarily thought of as machinery are also considered to be machinery [1].

Equipment is any tangible personal property used in an operation or activity. Industrial machinery and equipment means tangible personal property or other property that has a depreciable life of 3 years or more, that qualifies as an eligible cost under federal procurement regulations, and that is used as an integral part of the process of production of tangible personal property. Industrial machinery and equipment which is an integral part of the production process, as well as in postproduction, such as a forklift, will qualify for the exemption [1].

Supply Chain Engineering considers how modern production and operations management (POM) techniques can respond to the pressures of the competitive global marketplace by integrating all activities in the supply chain, adding flexibility to the system, and drastically reducing production cost. Several POM challenges are answered through a comprehensive analysis of concepts and models that assist the selection of outsourcing strategies and dynamic pricing policies [2]. Original suppliers may have gone out of business entirely, consolidated with other companies or made business decisions (typically owing to reduced market demand) not to produce particular items or not to supply them with the necessary grade certifications. To further complicate the situation, there may be limited information available to support procurement of an exact original component [2]. As industry consolidations occur, technical information and expertise related to certain items can be reduced or lost. This is particularly true for products accounting for a small portion of the supplier's revenue stream and for older equipment that is not currently manufactured. This can pose a possible safety and economic risk to operations and outage planning owing to safety related equipment not being available when required.

A procurement engineering function has originated in some countries as a result of these concerns. The main functions of procurement engineering are to identify item's technical, quality and commercial requirements, and to perform item equivalency evaluations (IEEs) and commercial grade dedication (CGD) in a timely manner [2].

Supply chains have advanced in the last two decades with improved efficiency, agility and accuracy. The recent advancement of Internet technology has brought more powerful support to improving supply chain performance. In this context, e-supply chain management becomes a new term that distinguishes itself by net-centric and real-time features from traditional supply chain management [3].

A payoff matrix is a visual representation of all the possible outcomes that can occur when two people or groups have to make a strategic decision. The decision is referred to as a strategic decision because each decision maker has to take into consideration how their choice will affect their opponent's choice and how their opponent's choice will affect their own choice. The payoff matrix illustrates each possible strategy that one side can choose, as well as every combination of outcomes that are possible based on each opponent's choice [4].

Literature review and a proposed framework for future research in digital supply chain; the role of smart technologies in managing the digital supply chain; Solutions for more sustainable distribution in the short food supply chains were the research done by [5-8]. Akcan, and Gülde worked on integrated multi criteria decision-making (MCDM) methods to solve supplier selection problem using a hospital as case study [9].

The researched works of [10-14] focused on: Ordinal priority approach (OPA) in multiple attribute decision-making; Fuzzy analytic hierarchy process (AHP) and Fuzzy Vikor approach modelling for flood control project selection; An integrated d-MARCOS method for supplier selection in an iron and steel industry; A two-phase Fuzzy AHP-Fuzzy Topsis model for supplier evaluation in manufacturing environment; and A novel integrated fuzzy Piprecia–interval rough saw model for Green supplier selection.

Multi-criteria supplier selection using fuzzy AHP; Selection of furniture raw material suppliers using fuzzy AHP; Fucom method in group decision-making: Selection of forklift in a warehouse; The application of fuzzy Vikor for the design scheme selection in lean management; Divergence measures on hesitant fuzzy sets; Applications of the fuzzy electre method for decision support systems of cement vendor selection; A simplified description of fuzzy Topsis method for multi criteria decision making ; and Multi-criteria copras method based on parametric measures for intuitionistic fuzzy sets were the researches of [15-22]. While An integrated model for solving problems in green supplier selection and order allocation and a rough multi-criteria decision-making approach for sustainable supplier selection under vague environment were the works of [23-24].

Comparison of three fuzzy MCDM methods for solving the supplier selection problem; Green supplier selection for process industries using weighted grey incidence decision model; Hesitant fuzzy swara-complex proportional assessment approach for sustainable supplier selection; Integrated AHP and mixed integer programming for supplier selection in mold and dies industry; and Assessment of conditions for implementing information technology in a warehouse system using a novel fuzzy Piprecia method were carried out by [25-29].

While [30-33] focused on: Sustainable supplier selection in healthcare industries using a new MCDM method; Measurement of alternatives and ranking according to compromise solution (MARCOS); New integrated quality function deployment approach based on interval neutrosophic set for green supplier evaluation and selection; and New integrated quality function deployment approach based on interval neutrosophic set for green supplier evaluation and selection [34]. A risk-based integrated decision-making model for green supplier selection: Using case study of a construction company in Spain; A multi-criteria decision-making framework for agriculture supply chain risk management under a circular economy context; An integrated decision-making model for supplier evaluation in public healthcare system: The case study of a Spanish hospital; and A multi-tier sustainable food supplier selection model under uncertainty were researched by [35-38].

Modeling equipment procurement strategic decision competing for limited available budget under redundant accessory course; Modeling machinery procurement with emphasis on engineering features; and Data mining and statistical analysis for available budget allocation pre-procurement of manufacturing equipment were the works of [36-38].

As at the time of this research, the literature at the reach of the authors shows that "Determination of Supply Conditions, Scenarios and Pay-Off for Industrial Machinery Supplier Selection Post Economic and Engineering Considerations" is a gap in literature that worth researched, hence the need for this research.

The objectives of this research therefore is to identify the attributes of supply conditions, different ways of combining the attributes using simple permutation and combination theories and determine the pay-off as well as the opportunity lost to every scenario used by method of Expected Decision Value (EDV) and to make conclusion(s) on the optimum method of selecting a qualified industrial machinery and equipment supplier base on the research result(s).

2.0 METHODS

The methodology of the research involved investigating and identifying the strategic decisions required for selecting machinery and equipment supplier, identify attributes of each strategies decisions and modeling the identified strategic decisions.

2.1 SUPPLY CONDITIONS

Investigation on required strategic decisions for machinery and equipment supplier selection of some selected industries such as Nigeria Brewing Lagos, Mobile Petroleum, Cement Industry, Shagamu, Cocoa Processing Industry, Ile-Oluji, Wire and Cable Industry, Akure were carried out. The identified strategic decisions for selecting machinery or equipment suppliers were identified as: Due Date of the Supply (A); Technical Capability of Vendor (B); After Sales Services (C); and Vendor Experience (D).

2.1.1 Due Date

This is the date that something is expected to happen. As per this research, this is the predetermined date the supplier should deliver the machine or equipment procured. Attributes to this strategic decision are: Recognition of needs ; Transmit the need; Investigate suppliers; Prepare and Issue Order; Vendor Acknowledgement; Follow up the order; Vendor ships Equipment; Machinery Received; Machinery Inspected; Machinery Audited; and Order Closed.

2.1.2 Technical Capability of Vendor

The attributes needed under this strategic decision are: Quality of Mechanic Used; Quality of Staff Used; Level of Research Work Done; Level of Quality Control; and Quality of Companies Patronizing the Vendor.

2.1.3 After Sales Services

Attributes considered for decision making under this strategic decision are: Installation of Machine; Machine Condition Monitory; Preventive Maintenance; Breakdown Maintenance; Spare parts Procurements; and Training of Staff.

2.1.4 Vendor Experience

The attributes to vendor experience determination of vendor includes: Age of Plant of Vendor; Records of Contract Carried over; Record of some affiliated companies; and Level of Exposure to New Technology.

2.1.5 Scenarios Development for Supplier Selection

Buyers have different methods of making request for supply of machinery or equipment, these methods are hereby refers to as scenarios for supplier or vendor's selection. These scenarios were developed from the available strategies which were defined as: Due Date of the Supply (A); Technical Capability of Vendor (B); After Sales Services (C); and Vendor Experience (D). Customer's interest dominates always due to his/her interest and grace to determine the condition(s) required. He / She may need only one of these, at times combine two or three of these or require all the four strategic decisions to be fulfilled. This turns to problem of permutation and combination.

2.1.6 Permutation and Combination Models for Total Number of Scenarios Determination Using [39]'s models.

Permutation: Any ordered sequence of k objects taken from a set of n distinct objects is called a permutation of size k of the objects. The number of permutations of size k that can be constructed from the n objects is denoted by $P_{k,n}$.

The number of permutation of size k is obtained immediately from the general product rule. The first element can be chosen in n ways , for each of the n ways the second element can be chosen in $n-1$ ways, and so on; finally, for each ways of choosing the $k-1$ elements , the k^{th} element can be chosen in $n-(k-1) = n-k+1$ ways. Equation 1 below shows the permutation equation.

$$P_{k,n} = n(n-1)(n-2)\ldots\ldots\ldots\ldots(n-k+2)(n-k+1) \quad (1)$$

Where; $P_{k,n}$ is permutation, n is total number of objects and k is the number of objects selected.

The use of factorial notation allows $P_{k,n*}$ to be expressed more compactly as shown in equation 2 below.

For any positive integer $m, m!$ is defined by $m! = m(m-1)\ldots\ldots(2)(1)$. Also $0! = 1$.

Therefore: $$P_{k,n} = \frac{n!}{(n-k)!} \quad (2)$$

Combination: Given a set of n distinct objects, any unordered subset of size k of the objects is called combination. That is occasions when the selections will be made where the order does not matter meaning that the arrangement c, d will be the same as d, c. The number of combination of size k that can be formed from n distinct objects will be denoted by ^nC_k. The number of combinations of size k from a particular set is smaller than the number of permutations because when order is disregarded, a number of permutations correspond to the same combination. Equation 3 below shows the combination equation.

Therefore: $$^nC_k = \frac{n!}{k!(n-k)!} \quad (3)$$

Where; ^nC_k is number of combinations, n is number of objects in the set and k is the number of objects choosing from the set.

2.1.7 Application of the Permutation and Combination Models for Total Scenarios Determination

Total Number of supply conditions $(A, B, C, and\ D) = 4 = n$.

Possibility of selection $k = 0, 1, 2, 3, or\ 4$.
Option 1 where $n = 4$ and $k = 0$. Therefore: $^nC_k = {}^4C_0 = 1\ scenario$.
Option 2 where $n = 4$ and $k = 1$. Therefore: $^nC_k = {}^4C_1 = 4\ scenarios$.
Option 3 where $n = 4$ and $k = 2$. Therefore: $^nC_k = {}^4C_2 = 6\ scenarios$.
Option 4 where $n = 4$ and $k = 3$. Therefore: $^nC_k = {}^4C_3 = 4\ scenarios$.
Option 5 where $n = 4$ and $k = 4$. Therefore: $^nC_k = {}^4C_4 = 1\ scenario$.

Equation 4 gives the total number of scenarios to be 16 scenarios.

$$\textbf{Total scenarios} = \sum_{i=0}^{4} op = op1 + op2 + 0p3 + op4 + op5$$
$$= 1 + 4 + 6 + 4 + 1$$
$$= 16\ Scenarios \quad (4)$$

Table 1 shows the combination and computation correlation of the scenarios.

Table 1: Combination table for the computation correlation

Options	Possibilities of selection						Scenario(s)
Select (0)							1 Scenario
Select 1s	A (or)	B (or)	C (or)	D			4 Scenarios
Select in 2s	AB (or)	AC (or)	AD (or)	BC (or)	BD (or)	CD	6 Scenarios.
Select in 3s	ABC (or)	ACD (or)	BCD (or)	ABD (or)			4 Scenarios
Select the 4s	ABCD						1 Scenario.

Total Scenarios = 4 + 6 + 4+ 1 = 16 Scenarios.

3.0 RESULTS AND DISCUSSIONS

Payoff and Opportunity Loss Determination for each Decision Making, The Expected Decision Value (EDV) And Expected Opportunity Loss to each option is determined and discussed.

3.1 RESULTS

The statistical analysis of each scenario (combination) is computed and presented.

3.1.1 Determination of Scenarios Equally Likely Value of Each Option.

The equally likely value of each option is probability of each selected scenario divided by number of scenario to the selected scenario as presented in equation 4 below.

$$(SELV)_i = \frac{Pr(S)_i}{N(S)_i} \quad (5)$$

Where; $(SELV)_{\boldsymbol{i}}$ is the equally likely value of a scenario, $Pr(S)_{\boldsymbol{i}}$ is the probability of a selected scenario and $N(S)_i$ is the number of scenario to the selected scenario.

In this study, $i = (1, 2, 3, 4)$. To check for the correctness of results multiply equally likely result with the number of scenarios to the selected option as presented in equation 5 and 6 below.

$$Pr(S)_{\boldsymbol{i}} = (SELV)_{\boldsymbol{i}}\, x\, (N(S)_i) \qquad (6)$$

Therefore; $(SELV)_{\boldsymbol{i}} = Pr(S)_{\boldsymbol{i}}$ (7)

For Option 1: $Pr(1) = 0.25$ while $N(S) = 4$. Therefore: $(SELV)_1 = \left(\frac{Pr_1}{4}\right) = \frac{0.25}{4} = 0.0625$
Check:$\mathrm{Pr}(S)_1 = (SELV)_1\big(N(S)\big) = (0.0624\; x\; 4) = 0.25$

For Option 2: $Pr(2) = 0.5$ while $N(S) = 6$. Therefore: $(SELV)_2 = \left(\frac{Pr_2}{6}\right) = \frac{0.5}{6} = 0.0833$
Check:$\mathrm{Pr}(S)_2 = (SELV)_2\big(N(S)\big) = (0.0833\; x\; 6) = 0.5$

For Option 3: $Pr(3) = 0.75$ while $N(S) = 4$. Therefore: $(SELV)_3 = \left(\frac{Pr_3}{4}\right) = \frac{0.75}{4} = 0.1875$
Check:$\mathrm{Pr}(S)_3 = (SELV)_3\big(N(S)\big) = (0.1875\; x\; 4) = 0.75$

For Option 4 : $Pr(4) = 1.00$ while $N(S) = 1$. $(SELV)_4 = \left(\frac{Pr_4}{4}\right) = \frac{4}{4} = 1.00$. Therefore: $(SELV)_4 = \left(\frac{Pr_4}{4}\right) = \frac{0.25}{4} = 0.0625$.
Check: $\mathrm{Pr}(S)_4 = (SELV)_4\big(N(S)\big) = (0.0625\; x\; 4) = 1.0$

Table 2 shows that $(SELV)_i = Pr(S)_i$ as claimed in equation 6.

Table 2: $(SELV)_i = Pr(S)_i$ proof computation

Scenarios	$\boldsymbol{Pr(S)_i} = [\mathbf{1,2,3,4}$	$\boldsymbol{(SELV)_i} = [\mathbf{1,2,3,4}$	$\boldsymbol{N(S)_i} = [\mathbf{1,2,3,4}$	$(SELV)_i = [1,2,3,4]$
	(i)	(ii)	(iii)	(ii) x (iii)
Scenario 1	0.25	0.0625	4	0.25
Scenario 2	0.50	0.0833	6	0.50
Scenario 3	0.75	0.1875	4	0.75
Scenario 4	1.00	1.0000	1	1.00

Figure 1 below revealed that all the four strategic decisions considered were equally likely considered under each option selected. This is why under each option, the strategic decision were all of equal height and figure 2 shows the relationship of the scenarios' probability and the scenarios' effective values.

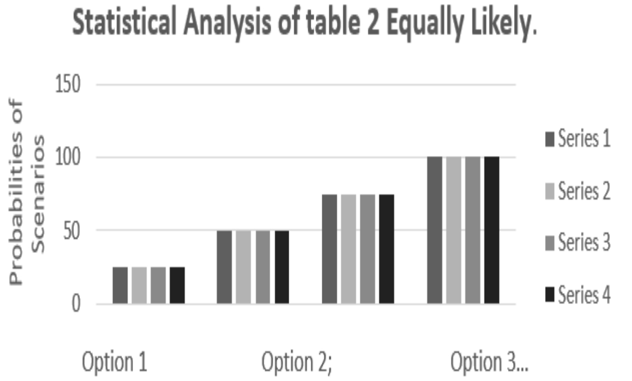

Figure 1: Statistic Analysis of table 2 equally likely

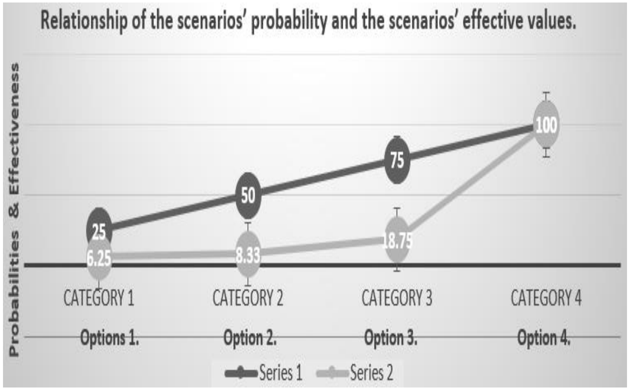

Figure 2: Shows relationship of the scenarios' probability and the scenarios' effective values

3.1.2 Payoff and Opportunity Loss determination for each decision making

A Payoff table is a listing of all possible combinations of decision alternatives and states of nature.

The Expected Decision Value (EDV) for a given course of action is the weighted sum of possible payoffs for each alternative. It is obtained by summing the payoffs for each course of action multiplied by the probabilities associated with each state of nature.

$$EDV\ (Course\ of\ action)(Sj) = \sum_{i=1}^{m} Pij\ x\ Pj \qquad (8)$$

Where: m is the number of possible state of nature; Pi is probability of occurrence of state of nature, Ni. and Pij is payoff associated with the state of nature Ni, and course of action Si.

Expected Opportunity Loss (EOL) also called "Regret" is the different between the highest pay off value for a state of nature and the actual profit obtained for the particular course of action taken.

Mathematically it stated as presented in equation 9 below.

$$EOL\ (State\ of\ nature, Ni) = \sum_{i=1}^{m} l_{ij}\ x\ Pi \qquad (9)$$

Where: l_{ij} is opportunity loss due to state of nature, Ni and the course of action Sj, and Pi is the probability of occurrence of state of nature.

3.1.3 Determination of Expected Decision Value (EDV) and Expected Opportunity Loss to Each Option.

To each strategic decision is assigned 5 as scored value. The four have equal importance. Therefore: $A = 5;\ B = 5;\ C = 5;\ and\ D = 5$. Considering all at a time will give optimum value of $(4\ x\ 5) = 20$.

The Expected Decision Value and Expected Opportunity Loss for each option selected is presented in table 2.

Table 2: Expected Decision Value and Expected Opportunity Loss to each option selected

Options	Prob. (Success)	Prob. (Regret)	Optimal Score	EDV	EOL
Option 1: (1/4)	0.25	0.75	20	0.25(20) = 5	0.75(20) =15
Option 2: (2/4)	0.50	0.50	20	0.5(20) = 10	0.50(20) = 10
Option 3: (3/4)	0,75	0.25	20	0.75(20) = 15	0.25(20) = 5
Option 4 : (4/4)	1.00	0.00	20	1(20) = 20	0.00(20) = 0.

3.2 DISCUSSION

Simple mathematical models (Permutation and Combination) were applied to ascertain number of scenarios which were determined to be 15 based on six ways of using the determined strategic decisions (options), which are : Option 1 (None of the strategic decisions considered), procurement is purely on engineering and economic considerations; Option 2 (Only one of the strategic decisions was considered); Option 3 (Two were considered of the four strategic decisions); Option 4 (Three of the strategic decisions were considered); while in Option 5 (All the four scenarios were considered).

Expected Payoffs and Expected Decision Value attached to each scenario selected for decision making were determined using “Decision Theory” (Expected Decision Value and Expected Opportunity Loss), from the results, option 4 is optimal as it gave the highest value of EDV = 20 with EOL = 0. Here the four (4) strategic decisions (A, B, C, and D) were all considered for selecting the supplier. Option 3 followed with EDV =15 and EOL =5; Option 2 came in third EDV = 10 and EOL = 10. (This is point of equal strength of negotiation on supply). While Option 1 is the last or fourth with EDV = 5 and EOL = 15. The regret to this option is high but in favor of supplier. Figure 3 shows a graph of the purchaser vs supplier bargaining effectiveness.

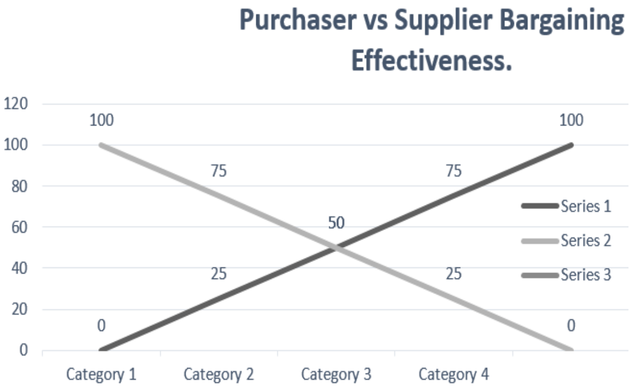

Figure 3: Purchaser vs Supplier Bargaining Effectiveness**.**

From figure 3, it shows that from option1 to option2, the scenarios adopted favoured supplier but declined from 100 to 50 where bargaining strength favour both supplier and purchaser, were equal (EDV = EOL). From this point onward to 100 the scenarios for decision favoured purchaser. Where it is zero on the supplier’s line (descending line from left to right) it shows that all the supply strategic decisions are in favor of purchaser but the zero on the purchaser’s line (ascending line from left to right) shows that all the strategic decisions are in favour of supplier. In this case supply of the proposed machine or equipment is based purely on engineering and economic considerations only, supply condition is out of consideration.

Statistical analysis of the results in Figure 3 made it known that the EDV favoured the purchaser in the ascending order (0, 25, 50, 75 and 100) while it favored the supplier in the descending order (100, 75, 50, 25, and 0). EDV = EOL at 50. Both the supplier and the purchaser share both the Expected Decision Value (EDV) and Expected Opportunity Loss (EOL) equally. Point zero on the declining graph is the sign of worst scenario for the supplier but the best for the purchaser while the zero the ascending graph is the point of worst scenario for the purchaser but the best for the supplier.

4.0 CONCLUSION

Aim as well as the objectives of this study have been achieved. From the research carried out, the required strategic decisions for selecting machinery or equipment suppliers were identified as: Due Date of the Supply (A); Technical Capability of Vendor (B); After Sales Services(C); and Vendor Experience (D). Supply conditions and the required scenarios for their selection for use were successfully determined. The payoffs and the regrets attached to each decision made were ascertained in this study for Industrial Machinery Supplier Selection Post Economic and Engineering Considerations.

The optimum method of selecting a qualified supplier turns out to be the option where the four (4) strategic decisions (A, B, C, and D) were all considered for selecting the supplier as this gives the highest value of EDV = 20 with EOL = 0. This research presents a rational by which a qualified supplier can be selected based on supply considerations post economic and engineering consideration.

Further research in the area of development of a Surrogate Model for Industrial Machinery Supplier Selection Post Economics and Engineering Considerations is recommended (The research area is in progress by the authors to this article).

REFERENCES

[1] "Industrial Machinery Definition Law Insider" https://www.lawinsider.com › dictionary › industrial, Accessed on March 15, 2022.

[2] Dolgui, A. and Proth, J. M. "Supply Chain Engineering: Useful Methods and Techniques", Springer, Paperback, London, 2010.

[3] International Atomic Energy Agency (IAEA), "Application of Configuration Management in Nuclear Power Plants", Safety Reports Series No. 65, IAEA, Vienna, 2010.

[4] "Payoff Matrix in Economics: Theory & Examples" https://study.com/academy/lesson/payoff-matrix-in-economics-theory examples.html, Accessed on March 29, 2016.

[5] Büyüközkan G. and Göçer F. "Digital "Supply chain: literature review and a proposed framework for future research", *Computers in Industry*, 97 (1), 2018, pp. 157-177.

[6] Nasiri M., Ukko J., Saunila M. and Rantala T. "Managing the digital supply chain: The role of smart technologies", *Technovation*, 1, 2020 pp. 102-121.

[7] Todorovic T., Maslaric M., Bojic S., Jokic M., Mircetic D. and Nikolicic S. "Solutions for More Sustainable Distribution in the Short Food Supply Chains", *Sustainability*, 10 (10), 2018, pp. 3481.

[8] Büyüközkan G. and Göçer F. "Digital "Supply chain: literature review and a proposed framework for future research", *Computers in Industry*, 97 (1), 2018, pp. 157-177.

[9] Akcan S., and Güldes M. "Integrated multicriteria decision-making methods to solve supplier selection problem: A case study in a hospital", *Journal of Healthcare Engineering*, 13(1), 2019, pp. 1-21.

[10] Ataei Y., Mahmoudi A., Feylizadeh M. R., and Li D. F., "Ordinal priority approach (opa) in multiple attribute decision-making". *Applied Soft Computing*, 86, 2020, pp. 58-93.

[11] Brahma A. K. and Mitra D. K. "Fuzzy ahp and fuzzy vikor approach modelling for flood control project selection", *International Journal of Applied Engineering Research*, 14(17), 2019 pp 35–58.

[12] Chakraborty S., Chattopadhyay R., and Chakraborty S. "An integrated d-marcos method_for supplier selection in an iron and steel industry". *Decision Making: Applications in Management and Engineering*, 3(2), 2020, pp. 49-69.

[13] Chatterjee P., and Stevi´C. "A two-phase Fuzzy AHP-Fuzzy Topsis model for supplier evaluation in manufacturing environment", *Operational Research in Engineering Sciences: Theory and Applications*, 2(1), 2019, pp. 72–90.

[14] Đali´c I., Stevi´c Ž., Karamasa C., and Puška A. "A novel integrated Fuzzy piprecia–interval rough saw model: Green supplier selection", *Decision Making: Applications in Management and Engineering*, 3(1), 2020), pp. 126-145.

[15] De Santis R. B. and De Aguiar E. P. "Multi-criteria supplier selection using fuzzy analytic hierarchy process: Case study from a Brazilian railway operator", *Brazilian Journal of Operations & Production Management*, 14(3), 2017, pp. 428-437.

[16] Djunaidi M., Utami C. D., Alghofari A. K., and Munawir H. "Selection of furniture raw material suppliers using fuzzy analytical hierarchy process", *Jurnal Teknik Industri*, 20(1), 2019, pp. 12-21.

[17] Fazlollahtabar H., Smailbaši A., and Stevi´c Ž. "Fucom method in group decision-making: Selection of forklift in a warehouse", *Decision Making: Applications in Management and Engineering*, 2(1), 2019, pp. 49–65.

[18] Jing S., Tang Y., and Yan J. "The application of fuzzy vikor for the design scheme selection in

lean management", *Mathematical Problems in Engineering*, 3(1), 2018, pp. 1–15.

[19] Kobza V., Janiš V., and Montes S. "Divergence measures on hesitant fuzzy sets", *Journal of Intelligent & Fuzzy Systems*, 33(3), 2017, pp. 1589–1601.

[20] Komsiyah S., Wongso R., and Pratiwi S. W., "Applications of the fuzzy electre method for decision support systems of cement vendor selection", *Procedia Computer Science*, 157, 2019, pp. 479–488.

[21] Ravi K., and Patil A. "A simplified description of fuzzy topsis method for multi criteria decision making", *International Research Journal of Engineering and Technology*, 4(5), 2017, pp. 2047–2050.

[22] Kumari R., and Mishra A. R. "Multi-criteria copras method based on parametric measures for intuitionistic fuzzy sets: Application of green supplier selection", *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, 44(4), 2020, pp. 1645–1662.

[23] Liou J. J., Wang H. S. and Tsai Y. S. "An integrated model for solving problems in green supplier selection and order allocation" *Journal of Cleaner Production*, 190, 2018, pp. 339–352.

[24] Jiang S., Song W., and Ming X. "A rough multi-criteria decision-making approach for sustainable supplier selection under vague environment", *Sustainability*, 10(8), 2018, pp. 26-42.

[25] Petrovi´c G., Mihajlovi´c J., C´ojbaši´c Ž., Madi´c M., and Marinkovi´c D., "Comparison of three fuzzy MCDM methods for solving the supplier selection problem", *Facta Universitatis, Series: Mechanical Engineering*, 17(3), 2019, pp. 455-469.

[26] Quan J., Zeng D., and Liu B. "Green supplier selection for process industries using weighted grey incidence decision model", *Complexity*, 10(8), 2018, pp. 26-42.

[27] Rani P., Mishra M., Krishankumar R., Mardani A., Cavallaro F., Soundarapandian K. and Bala-Subramanian K., "Hesitant fuzzy swara-complex proportional assessment approach for sustainable supplier selection (hf-swara-copras)", *Symmetry*, 12(7), 2020, pp. 46-63.

[28] Silalahi A., Sukwadi R., Pramesjwari D., Wahyu C., and Oktavia C. "Integrated analytic hierarchy process and mixed integer programming for supplier selection in mold and dies industry", *Jurnal Sistem Dan Manajemen Industri*, 3(2), 2019, pp. 124–133.

[29] Stevi´c X., Stjepanovi´c Ž., Boži˘ckovi´c Z., Das D., and Stanujki´c D. "Assessment of conditions for implementing information technology in a warehouse system: A novel fuzzy piprecia method", *Symmetry*, 10(11), 2019, pp. 586-608.

[30] Stevi´c Ž., Pamucar D., Puška A., and Chatterjee P. "Sustainable supplier selection in healthcare industries using a new mcdm method: Measurement of alternatives and ranking according to compromise solution (marcos)", *Computers & Industrial Engineering*, 14(15), 2020, pp. 106-128.

[31] Van L. H., Yu V. F., Dat L. Q., Dung C. C., Chou S. Y., and Loc N. V. "New integrated quality function deployment approach based on interval neutrosophic set for green supplier evaluation and selection", *Sustainability*, 10(3), 2018, pp. 838-859.

[32] Yazdani M., Chatterjee P., Pamucar D., and Abad M. "A risk-based integrated decision-making model for green supplier selection: A case study of a construction company in Spain", *Kybernetes*, 49(4), 2019, pp. 1229–1252.

[33] Yazdani M., Gonzalez E., and Chatterjee P. "A multi-criteria decision-making framework for agriculture supply chain risk management under a circular economy context", *Management Decision*, 59(8), 2019, pp. 1–27.

[34] Yazdani M., Torkayesh A., and Chatterjee P. "An integrated decision-making model for supplier evaluation in public healthcare system: The case study of a Spanish hospital", *Journal of Enterprise Information Management*, 33(5), 2020, pp. 965–989.

[35] Yazdani M., Pamucar D., Chatterjee V., and Torkayesh A. "A multi-tier sustainable food supplier selection model under uncertainty", *Operations Management Research*, 10(7), 2021, pp. 1-30

[36] Burity J. "The importance of logistics efficiency on customer satisfaction", *Journal of Marketing Development and Competitiveness*, 15(3), 2021, pp. 26-35.

[37] Osueke C. O., Akinnuli B. O. and Ojo O. O. "Modeling Equipment Procurement Strategic Decision Competing for Limited Available Budget under Redundant Accessory Course", *Engineering Management Research. Canada*

Center of Science and education, 4(2), 2015, pp. 80-86.

[38] Akinnuli B. O. **"**Modeling Machinery Procurement with Emphasis on Engineering Features". *African Journal of Science, Technology, Innovation and Development.* 15(14), 2017, 204-218

[39] Ojo O. O., Akinnuli B. O**.** and Farayibi P. K. "Data Mining and Statistical Analysis for Available Budget Allocation Pre-Procurement of Manufacturing Equipment", *Journal of Engineering Research and Reports.* 15(3), 2019, pp. 26-35