

We encountered five recent cases in supply chain risk management that applied multiple criteria analysis models to supply chain risk management decisions. We present value analysis and SMART models, using the contexts of the other studies as a basis. We have simplified the longer models with the intent of presenting the essence of the decision context, while demonstrating value analysis. In this chapter we review these five cases, which usually applied analysis to evaluate alternative suppliers, either relatively as sources of various types of risk, or in a selection decision.

Case 1: Öztürk and Özçelik (2014)¹

This study focused on a method to identify suppliers with emphasis on sustainable awareness. They utilized the triple bottom line paradigm, considering sustainability along with social and financial aspects. These authors used TOPSIS,² which has the relative advantage over SMART of being applicable to large numbers of alternatives. But the treatment of criteria, weights, and scores is common to TOPSIS and SMART. They also used fuzzy modeling, and a group context, but since they converted fuzzy input to crisp numbers and used a group decision set of preferences, the method works the same once numbers are modified. Based on the data provided in their paper, we can infer the following risk order. We provided specific swing weights in Table 4.1:

Scores for suppliers (which we made up) on each criterion are given below, along with resultant value scores in Table 4.2:

Supplier 1 has stronger characteristics with respect to quality, environmental issues and safety, but is expensive. Supplier 2 has good quality, moderate risk and moderate cost. Supplier 3 has lower quality, higher risk, and lowest cost. With this set of scores and one particular set of weights, supplier 2, who emphasizes quality, has the highest score. Value analysis provides a means to utilize these scores to identify areas of potential improvement.

Table 4.1 Case 1 Weights

Risk	Rank	Based on 1st	Weight
ECON1: Costs	1–3	100	0.127
ECON2: Quality	1–3	100	0.127
SOC2: Social responsibility	1–3	100	0.127
ECON3: Lead time/on-time delivery	4–5	90	0.115
ENV2: Resource consumption	4–5	90	0.115
ENV1: Pollution control	6	75	0.096
SOC4: Employment practices	7	60	0.076
ENV3: Green product and eco-design	8	50	0.064
ECON4: Technology capability	9	40	0.051
SOC1: Health and safety practices	10	30	0.038
ENV4: Environmental management system	11–12	25	0.032
SOC3: Education infrastructure	11–12	25	0.032
Total		785	1.000

Table 4.2 Case 2 Scores

Criteria	Weights	Supplier1	Supplier2	Supplier3
ECON1: Costs	0.127	0.200	0.600	0.950
ECON2: Quality	0.127	0.900	0.800	0.600
SOC2: Social responsibility	0.127	0.600	0.850	0.400
ECON3: Lead time/on-time delivery	0.115	0.800	0.600	0.500
ENV2: Resource consumption	0.115	0.300	0.800	0.650
ENV1: Pollution control	0.096	0.850	0.950	0.500
SOC4: Employment practices	0.076	0.700	0.850	0.300
ENV3: Green product and eco-design	0.064	0.950	0.900	0.800
ECON4: Technology capability	0.051	0.850	0.700	0.800
SOC1: Health and safety practices	0.038	0.800	0.950	0.350
ENV4: Environmental management system	0.032	0.800	0.900	0.350
SOC3: Education infrastructure	0.032	0.950	0.850	0.650
Value scores		0.688	0.788	0.588

Value Analysis

Here Supplier 1 clearly is deficient relative to cost and resource consumption. Supplier 2 is relatively strong on everything, but if Supplier 1 vastly improved cost and resource consumption, it could outrank Supplier 2. Supplier 3 is weak on a number of social and environmental factors.

Case 2: Samvedi, Jain and Chan (2013)³

This study applied fuzzy AHP and TOPSIS to a model to assess risk for a supply chain. Thus it did not involve a specific decision, but rather was meant to provide a metric for evaluation of overall supply chain risk. They had four top-level categories of risk {supply risk, demand risk, process risk, and environmental risk by which they included political environment}. The methodology, as in Case 1, could be applied to evaluation of suppliers as well. Table 4.3 gives criteria and shows weight generation, using Samvedi et al. general criteria ranking and our own specific values.

Table 4.4 shows scores for three suppliers the might be evaluated. Supplier 1 might be a high quality, high cost alternative, Supplier 2 a bit inferior to Supplier 1 on cost but higher on quality, and Supplier 3 located in a higher risk area.

The value score can be used to rank suppliers. Here Supplier 2 is better than Supplier 1, and both are radically better than Supplier 3.

Value Analysis

The score matrix in Table 4.4 is fairly clear on relative advantages, as always. The best performance is indicated by bold scores. Supplier 2 is safest on natural disaster, demand fluctuation, market change, and cost hikes. Supplier 1 has advantage on economic stability, political stability, and anti-terrorism program. Supplier 3 is

Table 4.3 Case 2 Weights

Risk	Rank	Based on 1st	Weight
Env3: Natural disasters	1	100	0.184
Env4: Economic downturns	2	67	0.123
Dem1: Sudden demand fluctuation	3	54	0.099
Env2: Political instability	4	42	0.077
Dem2: Market changes	5	41	0.075
Sup4: Sudden hike in costs	6	36	0.066
Env1: Terrorism	7	30	0.055
Sup1: Outsourcing risks	8	29	0.053
Dem4: Forecasting errors	9–10	27	0.050
Sup2: Supplier insolvency	9–10	27	0.050
Proc1: Machine failure	11	20	0.037
Sup3: Supply quality	12	16	0.029
Proc3: Quality problems	13	15	0.028
Dem3: Competition change	14	14	0.026
Proc2: Labor strike	15	11	0.020
Proc4: Technological change	16	8	0.015
Env5: Social & cultural grievances	17	7	0.013
Total		544	

Table 4.4 Case 2 Scores

Risk	Weights	Supplier1	Supplier2	Supplier3
Env3: Natural disasters	0.184	0.70	0.80	0.30
Env4: Economic downturns	0.123	0.60	0.50	0.20
Dem1: Sudden demand fluctuation	0.099	0.70	0.90	0.10
Env2: Political instability	0.077	0.95	0.80	0.20
Dem2: Market changes	0.075	0.70	0.80	0.40
Sup4: Sudden hike in costs	0.066	0.50	0.70	0.30
Env1: Terrorism	0.055	0.80	0.50	0.10
Sup1: Outsourcing risks	0.053	1.00	1.00	0.30
Dem4: Forecasting errors	0.050	0.70	0.80	0.40
Sup2: Supplier insolvency	0.050	0.60	0.80	0.30
Proc1: Machine failure	0.037	0.90	0.95	0.50
Sup3: Supply quality	0.029	0.90	1.00	0.40
Proc3: Quality problems	0.028	0.95	1.00	0.50
Dem3: Competition change	0.026	0.80	0.90	0.50
Proc2: Labor strike	0.020	0.80	0.40	0.50
Proc4: Technological change	0.015	0.70	0.50	1.00
Env5: Social & cultural grievances	0.013	0.70	0.60	0.20
Value scores		0.735	0.765	0.296

relatively inferior except for the ability to adapt to technological change. Furthermore, this set of criteria focused on risk, without emphasis on cost advantage. Suppliers usually can't do much about these types of risks—they are inherent in location. It is possible that such risks might be valuable to consider in site location decisions.

Case 3: Onat, Gumus, Kucukvar and Tatari (2006)⁴

This study used TOPSIS and intuitionist fuzzy multi-criteria decision making modeling to evaluate alternative vehicle technologies. They compared seven types of vehicles with 16 criteria (using the triple bottom line paradigm of economic, social, and environmental) as in Table 4.5:

The seven vehicle types were:

- Internal combustion vehicles (ICV)
- Hybrid electric vehicles (HEV)
- Plug-in electric range 10 miles (P10)
- Plug-in electric range 20 miles (P20)
- Plug-in electric range 30 miles (P30)
- Plug-in electric range 40 miles (P40)
- Battery elective vehicles (BEV)

Table 4.6 gives scores and shows value calculations:

Table 4.5 Case 3 Weight development

Criteria	Rank	Based on 1st	Weight
Env7: Total GHG emissions	1–2	100	0.084
Env9: Water withdrawal	1–2	100	0.084
Env8: Total energy consumption	3	99	0.083
Soc1: Employment	4	96	0.081
Soc3: Injuries	5	85	0.072
Econ1: Foreign Purchases	6–9	79	0.066
Econ3: GDP	6–9	79	0.066
Env5: Carbon fossil fuel	6–9	79	0.066
Env6: Carbon electricity	6–9	79	0.066
Env3: Forestry	10	74	0.062
Env4: Cropland	11–12	68	0.057
Env10: Hazard waste	11–12	68	0.057
Soc2: Tax	13	63	0.053
Econ2: Profit	14	58	0.049
Env2: Grazing	15	48	0.04
Env1: Fishery	16	13	0.011
Total		1188	

Table 4.6 Case 3 scoring

	Weight	ICV	HEV	P10	P20	P30	P40	BEV
Env7	0.084	1.00	.40	.30	.25	.30	.35	.70
Env9	0.084	.40	.30	.60	.70	.80	.90	1.00
Env8	0.083	.90	.40	.50	.60	.70	.80	.85
Soc1	0.081	.60	.58	.40	.45	.50	.70	.90
Soc3	0.072	.70	.75	.50	.55	.65	.75	.80
Econ1	0.066	.50	.40	.34	.30	.32	.36	.38
Econ3	0.066	.40	.38	.30	.36	.37	.39	.60
Env5	0.066	.60	.40	.38	.34	.34	.34	.50
Env6	0.066	.60	.50	.35	.37	.40	.48	.70
Env3	0.062	.40	.45	.30	.35	.60	.70	.90
Env4	0.057	.60	.50	.40	.45	.55	.65	.80
Env10	0.057	1.00	.60	.40	.30	.25	.20	.10
Soc2	0.053	.80	.70	.60	.50	.40	.30	.35
Econ2	0.049	.60	.55	.50	.53	.70	.75	.90
Env2	0.040	.70	.70	.50	.60	.60	.65	.70
Env1	0.011	.60	.55	.40	.55	.60	.70	.90
Value		0.652	0.493	0.421	0.443	0.501	0.564	0.677

Value Analysis

In this case, there were clear distinguishing performance scores, and each of the alternatives has some compensating advantage. There were quite a few criteria. While it is often best to focus on fewer criteria, if there are a number of measurable items falling into clear categories, as is the case here, it can work. In this case criterion Env1 (related to fisheries) there is very little impact, and in fact the small weight of 0.011 is further minimized by the range of scores of the seven alternatives (0.4–0.9).

Alternative BEV scores highest, and is best on many metrics, weak on hazardous waste, tax, and foreign purchases. Alternative ICV is very close to BEV in weighted score, with strengths in GHG emission, hazardous waste, and energy consumption while having slight weakness on water withdrawal and GDP impact. The HEV vehicle has few strengths, although it is best on grazing impact, which has a low weight. The plug-ins are best on nothing, although none are dominated (as often is the case with many criteria). As to value analysis, looking at weaknesses provides guidance for design improvement for any of the alternatives.

Case 4: Infante, de Mendonça, Purcidiño and Valle (2013)⁵

This study used ELECTRE multi-criteria decision making modeling to evaluate oil and gas companies, again using the triple bottom line. They compared the biggest five global oil and gas companies with two economic, ten environmental, and three social criteria as in Table 4.7:

Table 4.7 Infante et al. criteria

Criteria			
Econ1	Total production	Economic value/day	Max
Econ2	Investment impact	qualitative	Max
Env1	Direct energy consumption	Barrels/year	Min
Env2	Water withdrawal	Barrels/year	Min
Env3	Greenhouse gas emission	Tons/barrel/year	Min
Env4	Indirect greenhouse gas emission	Tons/barrel/year	Min
Env5	Sulphur oxide emission	Tons/barrel/year	Min
Env6	Nitrous oxide emission	Tons/barrel/year	Min
Env7	Water discharge	Volume & quality	Min
Env8	Waste	Tons/barrel/year	Min
Env9	Spill volume	Volume	Min
Env10	Expenditure—environmental protection	Dollar/barrel/year	Max
Soc1	Workforce employed	Employees	Max
Soc2	Work-related deaths	Deaths/employee	Min
Soc3	Work-related illness	Rate/hour	Min

Infante et al. evaluated firms over time, with scores provided for each year from 2005 through 2010. We will base our scores to reflect 2010 numbers in their data. The matrix of scores for each criterion by option are given below, along with calculation of overall value score. Table 4.8 shows input measures from the original article:

Infante et al. utilized equal weights, and then demonstrated sensitivity to weights in some variants. Based on ELECTRE approaches, scores were generated in one of the metrics that method offers, with a score of 0 below some minimum (a q parameter) and 1 at or above some maximum (a p parameter). The scores in Table 4.9 reflect a linear formulation for input measures between q and p.

Table 4.8 Case 4 Measures

	q	p	PetroB	BP	RDS	ExMob	Chev
Econ1	0.207	0.413	1.956	3.499	1.793	3.980	2.616
Econ2	0.253	0.507	5	3	2	5	2
Env1	42.372	72.831	756.832	706.766	895.208	929.227	1002.963
Env2	39.322	71.767	255.085	221.129	498.953	195.662	286.909
Env3	12.610	24.439	82.390	89.247	124.973	91.065	49.147
Env4	3.080	6.097	1.334	6.025	22.345	11.727	8.949
Env5	23.365	44.129	196.139	56.743	302.825	126.586	136.751
Env6	18.390	35.578	319.702	130.055	250.98	96.311	131.620
Env7	41.967	77.967	264.318	57.400	438.226	156.468	309.987
Env8	78.333	152.598	663.428	325.166	2311.411	417.909	193.904
Env9	44.993	82.034	404.551	204.825	449.155	172.132	268.284
Env10	191626	383251	1459916	1870477	5161248	3192585	2023640
Soc1	3113.581	6311.123	72088.4	86460	90045	81300	58712
Soc2	0.022	0.045	0.143	0.006	0.087	0.047	0.062
Soc3	0.066	0.138	0.597	0.354	0.720	0.324	0.318

Table 4.9 Case 4 Scores

	PetroB	BP	RDS	ExMob	Chev
Econ1	0.489	0.875	0.448	0.995	0.654
Econ2	1	0.5	0.25	1	0.250
Env1	0.811	0.977	0.349	0.236	0
Env2	0.816	0.930	0.003	1	0.710
Env3	0.537	0.439	0	0.413	1
Env4	0.933	0.699	0	0.414	0.553
Env5	0.415	0.973	0	0.694	0.653
Env6	0	0.850	0.245	1	0.842
Env7	0.388	0.979	0	0.696	0.257
Env8	0.743	0.930	0	0.879	1
Env9	0.318	0.984	0.169	1	0.772
Env10	0	0.106	1	0.484	0.150
Soc1	0.442	0.729	0.801	0.626	0.174
Soc2	0	0.940	0.130	0.530	0.380
Soc3	0.258	0.865	0	0.940	0.955

Table 4.10 Results for weight combinations

Econ	Env	Soc	PB	BP	RDS	ExMob	Chev
0.167	0.033	0.011	0.490	0.770	0.280	0.795	0.515
0.067	0.067	0.067	0.477	0.785	0.230	0.735	0.558
0.444	0.011	0.033	0.668	0.712	0.328	0.937	0.471
0.050	0.080	0.033	0.494	0.782	0.211	0.724	0.571
0.050	0.011	0.267	0.311	0.824	0.302	0.729	0.508

Infante et al. utilized equal weights, with weight changes representing sensitivity analysis. Table 4.10 shows results for various combinations of weights. The first set of weights divides 1/3rd by the number of criteria within each category, yielding weights of 0.167 for economic factors, 0.033 for environmental factors, and 0.111 for social factors. The second row assigns each of the 15 criteria a weight of 0.067, which is equal for all, but biases analysis toward environmental factors because there are ten measures as opposed to two or three. The last three rows show relative emphasis on economic, environmental, and social factors in turn. Highest value function for each oil company is identified in bold:

When economic factors are emphasized, Exxon Mobil performed well in 2011. When environmental factors received heaviest weight, BP did best (possibly in response to Gulf of Mexico oil spill history). BP also did well when social factors were emphasized, again possibly explicable in light of recent history. Infante et al. did a commendable job in looking at annual performances. Here our point is to demonstrate use of multiple criteria models, in this case as a performance measure.

Value Analysis

This example provided more concrete alternatives, making the comparison potentially clearer. The clear winner was to outsource production of finished goods to China. Of course, there are many Chinese manufacturers, so a more focused analysis might be required to select specific vendors.

All of the options considered had equivalent scores on ANSI compliance. That does not diminish the importance of this criterion, but for this set of alternatives, this factor does not bear on the decision. All other criteria distinguished among the available choices to some degree.

The recommended source had some relative weaknesses. Transportation risk is something that might not be able to be improved a great deal, due to geographic location. This also plays a role in relative scores for most of the other criteria where this alternative had relative disadvantage. But China's relative advantages in cost, quality, and fulfillment performance gave it a strong advantage in this analysis.

The second highest value score came from obtaining parts in China, and assembling in existing facilities in Mexico. The scores indicate relative advantages in reducing supplier fulfillment risk and wrong partner risk. This alternative had the greatest room for improvement in transportation risk management, order fulfillment risk, and on-time delivery. It also scored relatively low on a number of other criteria

that had low weights, and thus are less important to improve in this specific decision.

Outsourcing to Mexico was next in value score. This alternative was quite weak in cost, the most important criterion, and average on the second most important criterion of product quality. These clearly would be areas calling for improvement. Constructing the new facility clearly has a high cost impact, giving use of existing Mexican facilities more attractive in this case.

Case 5: Gaudenzi and Borghesi (2006)⁶

This application used AHP in the style of a business scorecard. While the authors gave a good discussion of criteria and its components, the data they provide for relative weights referred only to the top level factors of On-time delivery, completeness, correctness, and damage/defect free products. They also gave examples demonstrating scoring of departments within the organization on each of these four criteria by managerial subjective assessment, as well as using a more metric-driven model. Furthermore, they gave ranges for relative weight importance (which could be used for alternative multicriteria models⁷ such as HIPRE).⁸

In this study, data for relative criteria importance was given in ranges. We present the extremes below in development of SMART weights in Table 4.11:

The last two criteria have fairly consistent weights, so we chose weight of 0.21 for Correctness and 0.14 for Damage-defect free products. The first two had quite a range, as each extreme had a different first selection. Using the maximum weight for the first and subtracting 0.35 as the weight for the third and fourth ranked criteria, weights were generated. Using on-time delivery as the most important criteria yielded a weight for completeness outside the extreme weights, so we raised that weight to 0.29, lowering the weight for on-time delivery to 0.36. No adjustment was necessary to keep weights within range for the set of weights assigning completeness the greatest weight as shown in Table 4.12:

Table 4.11 Case 5 Weight development

Criteria	Mean	weights	Extreme1	weights	Extreme2	Weights
On-time delivery	100	0.317	100	0.402	50	0.215
Completeness	90	0.286	66	0.265	100	0.429
Correctness	75	0.238	50	0.201	50	0.215
Damage-defect free	50	0.159	33	0.133	33	0.142
	315		249		233	

Table 4.12 Case 5 Weights

Criteria	On-time first	Completeness first
On-time delivery	0.36	0.22
Completeness	0.29	0.43
Correctness	0.21	0.21
Damage-defect free	0.14	0.14

Table 4.13 Case 5 Value calculation with subjective scores

	weights	Procurement	Warehouse	OrderCycle	Manufact.	Trans.
On-time delivery	0.36	0	0.5	1	0.5	0
Completeness	0.29	0	0.5	1	1	1
Correctness	0.21	1	1	1	1	0.5
Defect free	0.14	0.5	1	1	1	0
Value scores		0.28	0.675	1	0.82	0.395

Gaudenzi and Borghesi gave two sets of scores to evaluate risks within their departments. Scores based on managerial input as well as a model used by Gaudenzi and Borghesi are demonstrated with both sets of weights generated above. Scores here are presented in a positivist perspective, with 1.0 representing the best performance. Therefore low resulting scores are associated with the most problematic departments.

The first set of value scores reflect weights emphasizing on-time delivery, with manager subjective scores shown in Table 4.13:

The scores themselves highlight where risks exist (0 indicates high risk, 0.5 medium level risk). The value scores give something that could be used to assess overall relative performance by department. Order cycle has no problems, so it has to score best. Manufacturing seems to have their risks well under control. Procurement and transportation departments are more troublesome.

The second set uses the same weights, but scores based on model inputs (see Table 4.14):

The implications are similar, except that the warehousing department shows up as facing much more risk.

We can repeat the analysis using weights emphasizing completeness. Using managerial subjective scores (Table 4.15):

This set of weights gives the transport department a better performance rating, but otherwise similar performance to the earlier analysis.

Finally, we use the model scores for weights emphasizing completeness (Table 4.16):

Here the warehouse department appears to face the greatest risk, followed by the procurement department.

The Guadenzi and Borghesi article presents an interesting application of multiple criteria analysis to something akin to business scorecard analysis, extending it to provide a potential departmental assessment of relative degree of risk faced.

Value Analysis

This application differs, because its intent is to provide a balanced scorecard type of model. This can be very useful, and interesting. But value analysis applies only to

Table 4.14 Case 5 Value calculation with model inputs

	Weights	Procurement	Warehouse	OrderCycle	Manufact.	Trans.
On-time delivery	0.36	0	0	1	0.5	0
Completeness	0.29	0	0	1	1	1
Correctness	0.21	1	1	0.5	1	0.5
Defect free	0.14	1	0.5	1	1	0
Value scores		0.35	0.28	0.895	0.82	0.395

Table 4.15 Case 5 Value calculations emphasizing completeness and subjective scores

	Weights	Procurement	Warehouse	OrderCycle	Manufact.	Trans.
On-time delivery	0.22	0	0.5	1	0.5	0
Completeness	0.43	0	0.5	1	1	1
Correctness	0.21	1	1	1	1	0.5
Defect free	0.14	0.5	1	1	1	0
Value scores		0.28	0.675	1	0.89	0.535

Table 4.16 Case 5 Value calculations emphasizing completeness with model scores

	weights	Procurement	Warehouse	OrderCycle	Manufact.	Trans.
On-time delivery	0.22	0	0	1	0.5	0
Completeness	0.43	0	0	1	1	1
Correctness	0.21	1	1	0.5	1	0.5
Defect free	0.14	1	0.5	1	1	0
Value scores		0.35	0.28	0.895	0.89	0.535

hierarchical development, because Gaudenzi and Borghesi apply AHP to performance measurement.

Conclusions

The cases presented here all applied multiple criteria models. This type of model provides a very good framework to describe specific aspects of risk and to assess where they exist, as well as considering their relative performance. The value scores might be usable as a means to select preferred alternatives or as performance metrics. Through value analysis, they can direct attention to features that call for the greatest improvement.

Value analysis can provide useful support to decision making by first focusing on hierarchical development. In all five cases presented here, this was accomplished in the original articles. Nonetheless, it is important to consider over-arching objectives, as well as means objectives in light of over-arching objective accomplishment.

Two aspects of value analysis should be considered. First, if scores on available alternatives are equivalent on a specific criterion, this criterion will not matter for this set of alternatives. However, it may matter if new alternatives are added, or existing alternatives improved. Second, a benefit of value analysis is improvement of existing alternatives. The score matrix provides useful comparisons of relative alternative performance. If decision makers are not satisfied with existing alternatives, they might seek additional choices through expanding their search or designing them. The criteria with the greatest weights might provide an area of search, and the ideal scores provide a design standard.

Notes

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