March 14th, 2011

ETM 530 / 630: Decision Making In Engineering and Technology Management

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Winter 2011 Team 5 Project Paper

Selecting an Engineering Manager Using a Hierarchical Decision Model

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Abstract

Selection of an Engineering Manager can be a complex undertaking with financial and organizational risk associated with a poor selection. The subjective nature of selecting Engineering Managers is characterized by stress and uncertainty. To mitigate these effects, a Hierarchical Decision Model (HDM) was utilized for this study to rank Engineering Manager Candidates.

The HDM utilized pairwise comparison surveys, expert data from three different Industry groups, desirability curves, candidate profiles and constant sum method for data processing. Data was processed for each Industry expert group separately and as a combined expert group. The ranking results reflected the influence of Industry expert groups and identified inconsistencies in the data created by the expert data.

Part I: Introduction

Introduction

The traditional decision process for the selection of an Engineering Manager is usually based on the following phases:

- Review of the Candidate's Resume
- Review of the Candidate's References
- The Interview Process
- Selection of Finalist Candidates
- Ranking of Candidates and Offers of Employment

This process seeks to evaluate the candidate based on tangible and intangible criteria. Tangible criteria includes experience and education. The evaluation of the tangible criteria, such as technical experience, is verified during the reference check and interview phases. For most companies there is a benchmark level of experience and specialization required. The evaluation of intangible criteria, which includes criteria for presence, leadership, communication skills, health (vitality & fitness), etc., is also verified during the reference check and interview stages, but is subjective in nature. The evaluation of the intangible criteria is dependent on the interviewer's perception of the candidate during the interview phase. Thus there is more uncertainty in the decision process for the evaluation of the intangible criteria, such as personal attributes, than for the tangible criteria.

Manager Selection Criteria

We conducted a literature search for data and information on Engineering Manager Selection. The US Bureau of Labor Statistics (USBLS) offers an Occupational Employment Statistics for Engineering Managers (11-9041.00), which includes qualification categories such as knowledge, skills, abilities, work styles and education. Within these categories individual importance values were assigned to sub-qualifications. These importance factors were rated by Engineering Managers. [1] From the data:

Table 1: Selected Qualification Data

Selected Qualification Data from US Bureau of Labor Statistics (USBLS) Engineering Managers (11-9041-00)			
Qualification	Sub-qualification	Importance Factor	% Respondents
Knowledge	Engineering & Technology	95%	NA[1]
	Sales & Marketing	49%	NA[1]
	Economics & Accounting	47%	NA[1]
Skills	Speaking	75%	NA[1]
	Writing	72%	NA[1]
	Management of Personnel Resources	69%	NA[1]
	Management of Financial Resources	53%	NA[1]
Abilities	Oral Comprehension	78%	NA[1]
	Oral Expression	78%	NA[1]
	Written Comprehension	78%	NA[1]
	Written Expression	72%	NA[1]
Work Styles	Dependability	88%	NA[1]
	Leadership	81%	NA[1]
	Persistence	81%	NA[1]
Education[2]	Bachelors	NA[1]	68%
	Masters	NA[1]	24%
	Doctoral or Professional Degree	NA[1]	8%

Notes: (1) Not Available

(2) Degree type not included in data. Notes indicate that degrees were usually in the Sciences, Computer Science or Engineering)

The data from this table includes qualification criteria for experience such as technical, managerial, marketing & financial and for education (type of academic or professional degree). Qualification criteria for personal attributes are also included such as communications skills, leadership and work ethic (dependability & persistence). From the Engineering and Technology Management program coursework at Portland State University, additional information for personal attributes is available.

ETM 520 Engineering Management, Nature Leadership Theory course material, defined the attributes and qualities of natural leaders. Physical attributes of a leader were given as health, vitality and endurance. Character attributes included integrity, stability and work ethic. Personal attributes of personal magnetism, ability to inspire and tact were also given. Fit with corporate culture was also mentioned as a factor in the effectiveness of a leader / manager. [2]

From the USBLS data, Academic information and Experts, the criteria and sub-criteria were determined for Engineering Manager Selection. The experts included Engineering Managers surveyed and the authors. The Engineering Managers surveyed also vetted the list.

Table 2: Engineering Manager Selection Criteria

Engineering Manager Selection Criteria & Sub-Criteria		
Criteria	Sub-criteria	Source
Experience	Managerial	USBLS
	Technical	USBLS
	Marketing	USBLS
	Finance	USBLS
Education	Academic Degrees	USBLS
	Industry Training / On the Job Training (OJT)	USBLS
	Professional Certificate (and Degrees)	USBLS
Personal Attributes	Presence	Academic & Experts
	Communications Skills	USBLS
	Leadership	USBLS
	Work Ethic	USBLS
	Fit with Corporate Culture	Academic & Experts
	Health Fitness	Academic & Experts

Manager Selection Decision Models

The selection of an Engineering Manager involves subjective decisions regarding tangible and intangible criteria to include experience, education and personal attributes. The process is characterized by uncertainty and stress. Selection of an Engineering Manager can be a complex undertaking with financial and organizational risk associated with a poor selection. The literature contains information on methodologies to select and rank R&D project selection, Henriksen & Traynor [3], but is silent on the application to personnel selection. One of the methodologies reviewed by Henriksen & Traynor [3] is Decision Analysis models. These models include: Multi-attribute utility theory, decision trees, risk analysis, analytical hierarchy process, scoring and check lists, and probabilistic decisions models. [3]

Many companies use simplified decision models such as Go / No Go and Scoring. Go / No Go involves elimination of candidates and a subjective ranking of the remaining candidates. Go / No usually devolves to the hiring manager and can create internal disagreement among the involved management when consensus cannot be reached.

Scoring involves a preplanned system of point assignment to evaluate and rank the candidates. Elements of Go / No Go may still be present to eliminate candidates, who do not meet minimum acceptable standards, such as technical knowledge. A drawback of simple scoring is that relative weights for different major criteria may not be incorporated and that scoring may be seen as an individual's opinion, not part of a larger consensus. A requirement of most organizations is for the use of a system which is easily used and understood.

To overcome these drawbacks a Hierarchical Decision Model (HDM) may be employed to evaluate ranking of alternatives (candidates). An HDM is a multi-criteria approach, which evaluated relative weights of subjective decisions to reach a ranking of the alternatives. This paper will explore the use of a Hierarchical Decision Model to rank Engineering Management candidates.

Hierarchical Decision Models require that criteria be established for the evaluation of alternatives. These criteria can be single level or multiple levels, containing sub-criteria or even sub-sub-criteria. The relative weights of the criteria can be determined by subjective Pairwise comparison for each level among each grouping. Likewise the sub-criteria may be used to subjectively rank the major criteria against each other and then the associated sub-criteria. The relative weights for the HDM criteria were determined from the pairwise comparison data and processed using Portland State University's ETM Department PCM software. The pairwise comparison data may be found in the Appendix.

The alternatives (candidates) are assigned base values for each of the sub-criteria. The base values (years of experience, etc.) are evaluated by desirability matrix for each criteria and are assigned a relative values for evaluation by the model. The desirability matrix values were determined by Pairwise comparison surveys of the experts.

Part II: Model Construction

Evaluation criteria

Incorporating the Engineering Manager Selection Criteria into the Hierarchical Decision Model we have:

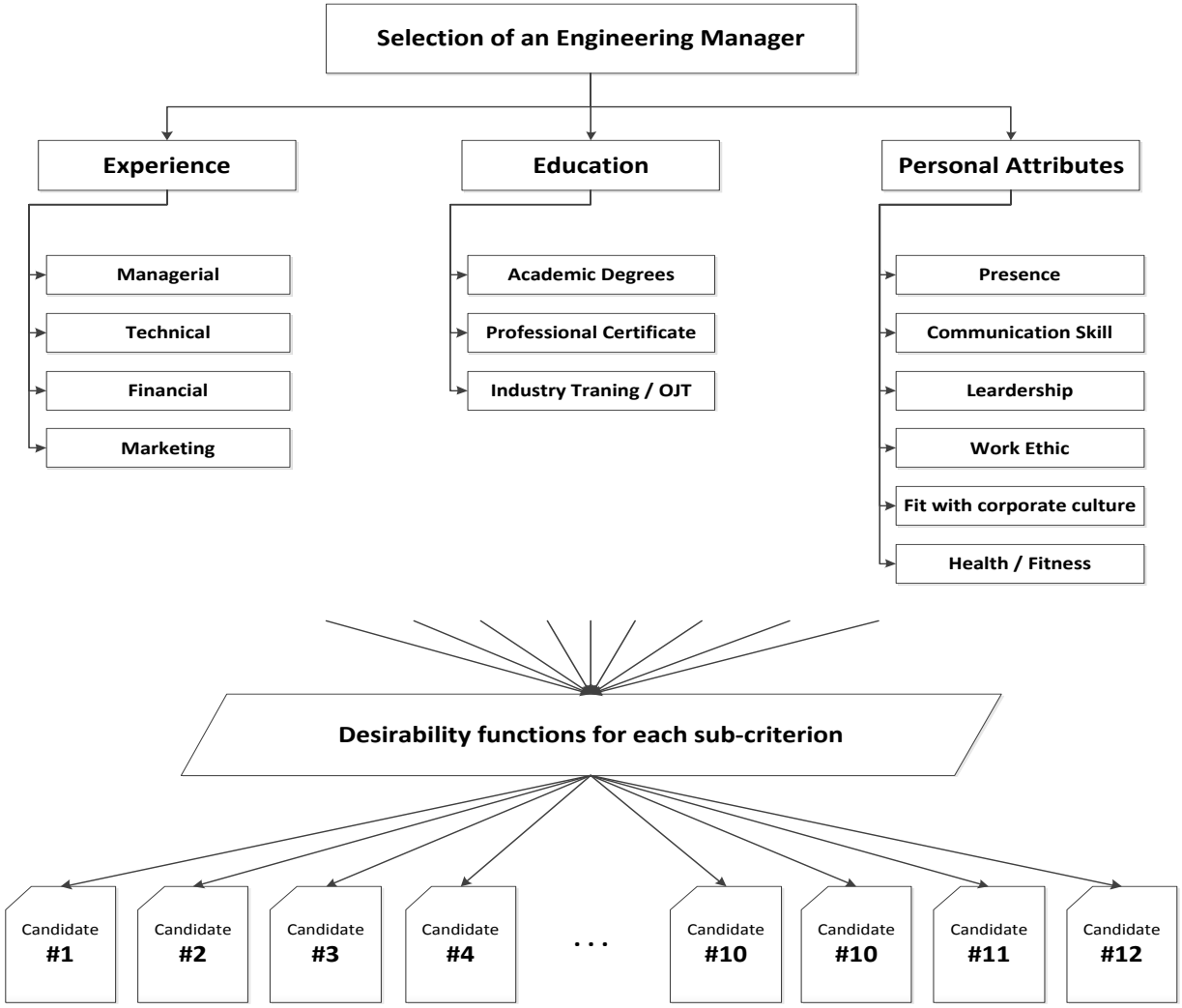


Figure 1 Hierarchical Decision Model

After we defined the decision criteria, we specified the range of each sub-criterion to develop desirability functions. For 4 types of experience criterion and industry training/OJT of education criterion, we decided to set them 15 years range with continuous data in order to take into account the variance of candidates' experience. On the other hand, for the rest of 8 sub-criteria, we defined the discrete categories such as 'BS-MS-Ph.D,' 'High-Medium-Low' to deal with their qualitative characteristics.

Evaluation of Candidates

Lastly, 12 virtual candidates were generated as decision alternatives based on the specified categories of sub-criteria. In this process, we tried to balance the type of candidates in order to avoid one-sided analysis. Hence, we generated 4 candidates for each 3 different types: academic, experienced and mixed of the two. Table 3 shows detail information of 12 candidates.

Table 3: Candidates

Candidate #		1	2	3	4	5	6	7	8	9	10	11	12
Experience	Managerial	0	0	1	0	0	5	0	13	0	8	0	8
	Technical	5	0	7	0	13	15	0	3	13	0	8	0
	Financial	0	0	0	9	0	0	8	3	0	13	0	13
	Marketing	0	8	0	0	0	0	8	13	3	13	8	13
Education	A. Degree	BS	BA	MS	MA	Ph.D	MS	BA	BS	MS	MA	Ph.D	Ph.D
	Certificate	0	0	1	1	0	0	1	0	1	3	0	3
	IT/OJT	2	2	1	2	5	3	1	3	0	1	0	0
Personal Attributes	Presence	M	H	L	L	M	H	M	L	M	M	M	H
	Comm skill	H	H	M	L	M	M	H	M	H	M	M	H
	Leadership	M	H	M	L	H	M	L	M	H	M	M	M
	H/Fitness	H	H	H	M	L	H	H	H	M	H	L	M
	Work ethic	H	H	M	H	M	H	H	H	H	M	H	M
	Fit w CC	M	H	M	M	M	M	M	L	M	H	M	H

Experts Organization

To prioritize criteria and candidates, we selected total 11 experts from three different areas: consulting company (3 from M+W Group), research-focused firm (4 from Bonneville Power Administration), and manufacturing-oriented focused (4 from Samsung Electronics). All of them are either currently working as a senior engineering/project manager or have related experience in those positions. Evaluation process was conducted via e-mail survey with constant-sum method format for pairwise comparison.

Part III: Model Implementation

Based on the Hierarchical Decision Model (HDM) defined in the previous section, we combined the survey results and computed them utilizing PCM software. Following figure represents 4 stages of this process. Separated pairwise comparison results for each expert group are also provided to highlight the different perspectives between them.

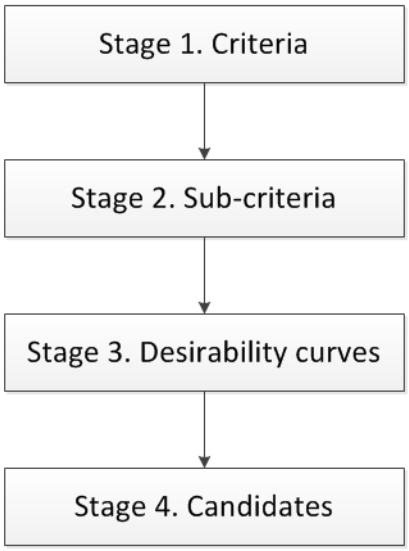


Figure 2: Evaluation flow chart

Criteria

For the first stage, 3 criteria were evaluated with respect to the decision object. Fortunately, 11 experts showed allowable level of inconsistency (all of them were less than 0.02). Weights of each criterion from three different expert groups are shown in the Table 4 with mean values.

Table 4: Weights of Criteria

Criteria / Expert group	Experience	Education	Personal Attributes
M+W Group	**0.41**	0.27	0.32
BPA	0.31	**0.38**	0.32
Samsung Electronics	0.30	0.26	**0.45**
Mean weight	0.34	0.30	**0.36**

Sub-criteria

For the second stage, 13 sub-criteria were evaluated with respect to each criterion in the same manner. By the way, one of experts from M+W group was excluded because of insufficient consistency (0.26, others showed less than 0.04) in personal attributes sub-criterion. Thus, mean weight was calculated from 11 pairwise comparisons. Table 5-7 shows these results.

Table 5: Weights of Sub-criteria (Experience)

Criteria / Expert group	Experience			
	Managerial	Technical	Financial	Marketing
M+W Group	0.32	**0.39**	0.17	0.13
BPA	**0.35**	0.29	0.17	0.19
Samsung Electronics	0.21	0.26	0.20	**0.32**
Mean weight	0.29	**0.31**	0.18	0.21

Table 6: Weights of Sub-criteria (Education)

Criteria / Expert group	Education		
	Academic Degree	Professional Certificate	Industry training/OJT
M+W Group	**0.54**	0.20	0.26
BPA	**0.57**	0.13	0.30
Samsung Electronics	0.33	**0.36**	0.31
Mean weight	**0.48**	0.23	0.29

Table 7: Weights of Sub-criteria (Personal Attributes)

Criteria / Expert group	Personal Attributes					
	Presence	Communication skill	Leadership	Work ethic	Fit with corporate culture	Health/ Fitness
M+W Group	0.13	**0.23**	0.19	0.18	0.13	0.14
BPA	0.16	0.20	**0.24**	0.19	0.06	0.15
Samsung Electronics	0.11	0.20	0.14	0.13	**0.24**	0.18
Mean weight	0.13	**0.21**	0.19	0.17	0.14	0.16

Desirability Curves

For the third stage, desirability functions of 13 sub-criteria were generated. For the discrete data such as academic degree and professional certificate, we conducted pairwise comparisons on each category and made it cumulative pattern. On the other hand, we came up with regression curves for rest of 5 sub-criteria with 4 points (0, 5, 10 and 15) from pairwise comparison in order to deal with continuous data type. Following figures are showing these desirability functions.

Table 8: Desirabilty Curves (Experience)

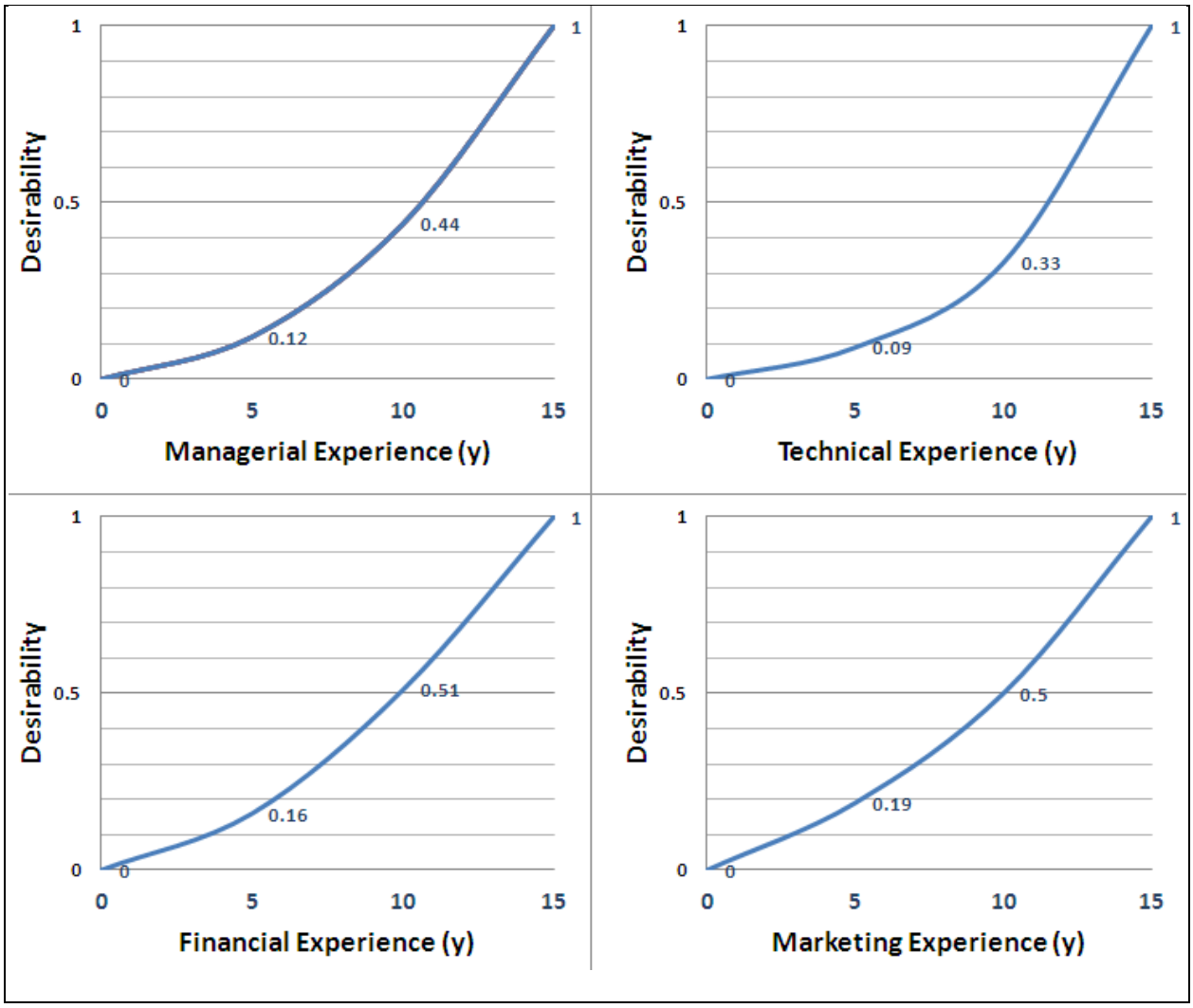


Table 9: Desirability Curves (Education)

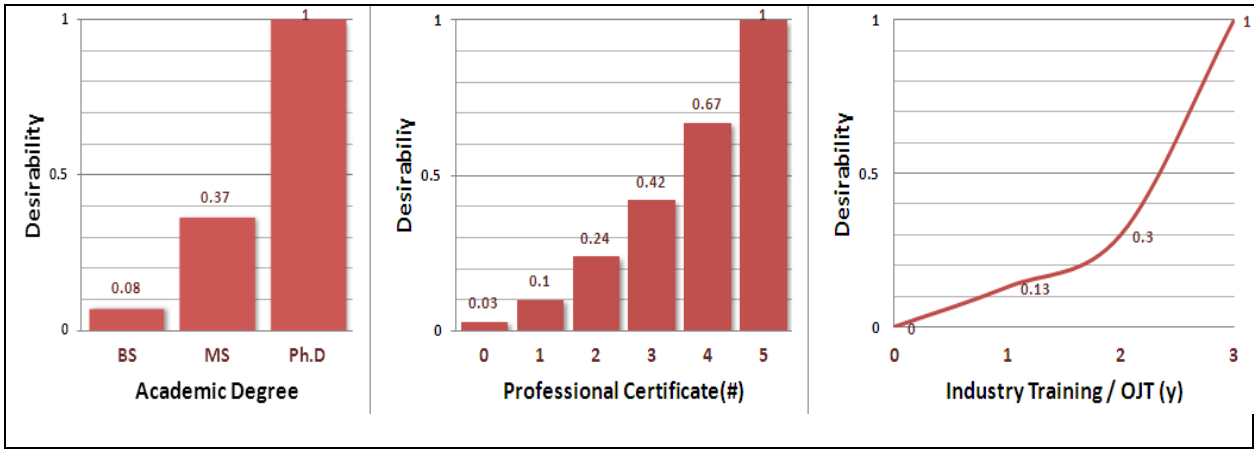
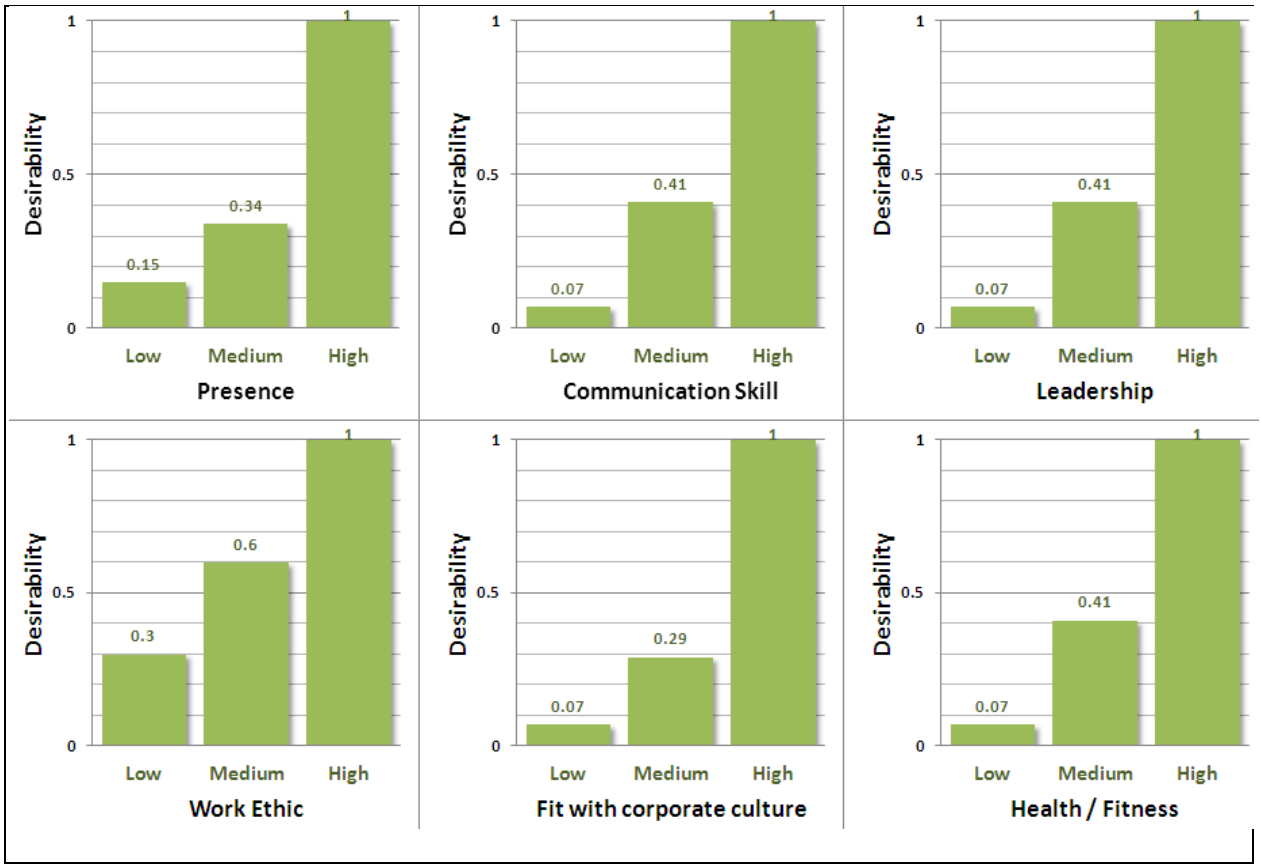


Table 10: Desirability Curves (Personal Attributes)



Candidates

For the last stage, 12 candidates were prioritized based on the weights and desirability functions in terms of each criterion. In other words, each candidate was assigned normalized numerical value by this process, which makes it possible to compare their qualitative as well as quantitative qualification information with others. For example, candidates #1 were to be assigned his/her final value of 0.297 by summation of 0.010 (from 5 years of technical experience), 0.040 (from 2 years of OJT and BS degree) and 0.247 (from 3 high level of communication skills, health/fitness and work ethic and 3 medium level of presence, leadership and fit with corporate culture.) Following table shows the results of this process.

Table 11: Final Weights

	Overall	M+W Group	Samsung Electronics	BPA
Candidate #1	0.297	0.303	0.305	0.283
Candidate #2	0.427	0.415	0.440	0.426
Candidate #3	0.225	0.233	0.223	0.221
Candidate #4	0.181	0.173	0.215	0.155
Candidate #5	**0.478**	**0.504**	0.427	**0.503**
Candidate #6	0.454	0.473	0.443	0.446
Candidate #7	0.304	0.297	0.338	0.278
Candidate #8	0.429	0.409	0.452	0.427
Candidate #9	0.358	0.376	0.356	0.340
Candidate #10	0.413	0.385	0.456	0.397
Candidate #11	0.213	0.206	0.245	0.189
Candidate #12	0.442	0.417	**0.485**	0.425

Part IV: Recommendations & Conclusions

Results Discussion

Data Results

Table 12 – Weighting Results

		Overall	Consulting	Samsung	BPA
C	Experience	0.34	**0.41**	0.30	0.31
	Education	0.30	0.27	0.25	**0.37**
	Personal Attribute	**0.36**	0.32	**0.45**	0.32
Ex	Managerial	0.29	0.31	0.21	**0.35**
	Technical	**0.31**	**0.39**	0.26	0.29
	Financial	0.18	0.17	0.21	0.17
	Marketing	0.22	0.13	**0.32**	0.19
Ed	Academic Degree	**0.48**	**0.54**	0.33	**0.57**
	Professional Certificate	0.23	0.20	**0.36**	0.13
	Industry Traning / OJT	0.29	0.26	0.31	0.30
PA	Presence	0.13	0.13	0.11	0.16
	Communication Skill	**0.21**	**0.23**	0.20	0.20
	Leadership	0.19	0.19	0.14	**0.24**
	Work Ethic	0.17	0.18	0.13	0.19
	Fit with corporate culture	0.14	0.13	**0.24**	0.06
	Health / Fitness	0.16	0.14	0.18	0.15

Table 13 - Prioritized Ranking for Engineering Manager Candidates

	Overall	Consulting	Samsung	BPA
Candidate #1	0.297	0.303	0.305	0.283
Candidate #2	0.427	0.415	0.440	0.426
Candidate #3	0.225	0.233	0.223	0.221
Candidate #4	0.181	0.173	0.215	0.155
Candidate #5	**0.478**	**0.504**	0.427	**0.503**
Candidate #6	0.454	0.473	0.443	0.446
Candidate #7	0.304	0.297	0.338	0.278
Candidate #8	0.429	0.409	0.452	0.427
Candidate #9	0.358	0.376	0.356	0.340
Candidate #10	0.413	0.385	0.456	0.397
Candidate #11	0.213	0.206	0.245	0.189
Candidate #12	0.442	0.417	**0.485**	0.425

Key Elements for Manager Selection

Overall, the model ranked candidate #5 as the highest with a composite score of 0.478. Candidate five's qualifications are shown:

Table 14: Candidate 5 Qualifications

Candidate #5	
Education	
OJT	5
Degree	Ph.D
Certifications	0
Experience	
Managerial	0
Technical	13
Financial	0
Marketing	0
Interview Composite Scores	
Prescence	Medium
Communication Skills	Medium
Leadership	High
Health/Fitness	Low
Work Ethic	Medium
Fit with Corporate Culture	Medium

The candidate ranked high in technical management experience – from table 12 it is shown that this is the most important experience sub-criterion (weight = 0.31) and a high desirability value of 13 years. The candidate also has a PhD; this degree corresponds to the highest value on the desirability curve for the education criteria. As well, a degree was the highest rank under education (weight = .48).

Effect of Industry on Weighting

Our team was comprised of individuals from consulting, research and development, and high-tech, manufacturing environments. The focus of this analysis was to solicit input from experts in each of these areas to complete the pair-wise comparisons. At the start of the project our team hypothesized that we would see differences in how the criteria and sub-criteria were ranked among the focus areas. The results of the model closely matched our initial hypothesis.

Effect of Industry: High Tech, Design Consulting Environment:
M+W Group: USA

M+W Group USA is part of the M+W Corporation of Stuttgart, Germany. M+W designs and manufacturers HVAC equipment, provides High Tech Design Consulting and Construction Management Services worldwide.

Many consulting firms require engineers to be registered/licensed, and therefore a formal degree is required as part of the licensing process. This requirement is reflected in the education criteria ranking – an academic degree is ranked highest among the sub-criteria (academic degree, professional certificate, industry training/OJT) with a value of 0.54; this is the second highest score in the report. As explained to the experts who completed the pair-wise comparison a PE license was not considered a certificate, else we would have expected the professional certificate to be ranked the highest.

It is interesting to note that of the primary criteria (education, experience, and personal attributes) that experience, NOT education, was ranked highest. One of the pair-wise comparison had an inconsistency value of > 0.1. In the interest of time the team did not ask the person to retake the survey and chose to consider the results with this data point. The inconsistency (0.26 for personal attributes) did not affect the outcome of how the HDM model ranked the criteria or sub-criteria; this was determined by running the model with the data point and without – the results were the same. However, it cannot be assumed that this would be the case for all HDMs and the results of pair-wise comparisons should be below 0.1.

The HDM identified candidate #5 as the best for M+W Group. Do candidate #5's qualifications satisfy the HDM criteria? Candidate #5 has 13 years of technical experience, medium communication skills, and a PhD. The technical experience criterion is met. However, when we look at other candidates who had high communication skills, they did not have technical experience or advanced degrees. Therefore, candidate #5 was the best choice. The model identified the best candidate based on the criteria!

Effect of Industry: High Tech, Manufacturing Environment:
Samsung Electronics, South Korea

Samsung Electronics is the world's largest maker of computer memory chips and other electronic gadgets, headquartered in Seoul, South Korea. As a general rule, Asian cultures are more sensitive to fitting in with the corporate culture, "...interpersonal relationships and social interactions are more valued..." [4] [5] This statement is reinforced when we look at the segmented model results. Samsung experts ranked personal attributes (0.45), specifically, fit with corporate culture (0.24) as the highest. The outcome of Samsung's ranking is further

supported by the appointment of Gee Sung Choi as CEO in 2009 – his motto of "generating only ideas that can be sold" suggests a strong marketing influence on their corporate culture.

The HDM identified candidate #12 as the best for Samsung. Do candidate #12's qualifications satisfy the HDM criteria? Candidate #12 has a high fit with corporate culture, 13 years of marketing experience, and 3 professional certifications. There is another candidate that also meets the criteria, candidate #10. This required looking at the next highest weighted personal attribute score, communication skills. Candidate 12 had high and candidate #10 had medium. Therefore, candidate #12 was the best choice. The model identified the best candidate based on the criteria!

Effect of Industry: Research and Development Environment:
Bonneville Power Administration (BPA), Portland, OR

The Research and Development group at BPA manages a portfolio of near/medium/long term projects with the objective of producing financial benefits to BPA, and ultimately deliver value to the Pacific Northwest electric system. The projects address technology roadmap gaps in the areas of energy efficiency, transmission, and others. Due to the breadth of knowledge required analyze complex concepts, it is logical that formal education was ranked highest among the criteria and, within the education sub-criteria, overwhelmingly an academic degree was the top choice (0.57); in fact of all the rankings in this report it was the highest.

The HDM identified candidate #5 as the best for BPA. Do candidate #5's qualifications satisfy the HDM criteria? Unlike M+W Group, BPA ranking of the weighted criteria was different (education, personal attributes, and experience). Candidate #5 has a PhD, high leadership, and 0 years of managerial experience! As mentioned above, the academic degree scored very high (0.57). The other two candidates with a PhD scored lower on the leadership criteria and only one had managerial experience. Since the personal attributes criteria ranked higher than the experience criteria it was appropriate to recommend candidate #5 - the model identified the best candidate based on the criteria!

Conclusions

Overall the objective of the project was to demonstrate the process of using a hierarchical decision model combined with desirability curves to select an engineering manager. It is assumed that when the model is practically applied within an organization, pertinent criteria will be used; the purpose was to demonstrate a technique but not with absolute values.

Model Validity

Looking at the segmented scores (e.g. scores within the individual industry) the model provides valid results. However, the combined results seem to be skewed by Samsung's high weighting

of personal attributes; personal attributes ranked second for both consulting and research and development organizations.

However, it is unlikely that when the model is practically applied, an organization would solicit experts from industries where there are not similar experiences or backgrounds (e.g. a research and development organization would not solicit experts from an environmental engineering firm) to complete a pair-wise comparison, with the objective of ranking criteria. This may not be a consideration but should be stated nonetheless based on the perceived impact on the results in this project.

Recommendations

Model Application

The results of the model are not comprehensive. Rather it provides a ranking of candidates based on criteria established by an organization making the selection. Other factors may need to be considered before a final candidate is selected to possibly include body language during an interview, veteran's preference, diversity quotas, etc.).

The team recommends the following qualifying statement when applying the model: the pair-wise comparisons should be completed within the same or relatively similar industries to reduce bias and promote consensus.

Future Research

It is feasible to consider a similar model being used for any type of decision process such as those presented in the Winter 2011 ETM 530 course (stove selection, camera or bicycle selection) or extending to industry applications. Currently, the model has been adapted to rank project managers in consideration for a performance award.

Specifically, in the course of completing this project the team considered other items for future research to include the following:

1. Analyze the results using experts from the same industry (e.g. all consulting, or high tech MFG, etc.). The data suggests a strong cultural bias when we examined the Samsung results and the impact can be seen on the combined scores for the main criteria: Samsung weighted personal attributes as almost .50, relative to experience and education. Both consulting and research and development ranked personal attributes as second but valued experience and education more. Research and personal discussion attribute Samsung's scores to cultural biases.

Part V: References

[1] US Bureau of Labor Statistics, *Occupational Outlook Handbook, 2010 – 2011,* Section 11-9041.00: Engineering Managers

[2] Kocaoglu, D.F. *ETM 520: Management of Engineering & Technology Lectures, Natural Leadership Theory,* Engineering and Technology Management Department, Portland State University, Fall 2010

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Part VI: Appendix