100

Kristen John
HW # 3 - Problem 1
Due: 2-8-08

Analytical Hierarchy Process

Selecting the Way to the Moon

Figures of Merit: Crew Safety, Program Cost, Schedule, Extensibility
Concepts: EOR, LOR, Nova Direct

Prioritization Matrix	Crew Safety	Program Cost	Schedule	Extensibility
Crew Safety	1	6	4	7
Program Cost	1/6	1	1/6	1/2
Schedule	1/4	6	1	8
Extensibility	1/7	2	1/8	1
Sum Each Column	1.5595	15.0	5.2917	16.5
Normalize				
Crew Safety	0.6412	0.4000	0.7559	0.4242
Program Cost	0.1069	0.0667	0.0315	0.0303
Schedule	0.1603	0.4000	0.1890	0.4848
Extensibility	0.0916	0.1333	0.0236	0.0606

Final Score

0.555
0.059
0.309
0.077

✓

Q: Are the resulting weightings and order what I expected?
A: They are simliar to what I expected. I definitely felt that Crew Safety and Schedule were important (at least during the times of Apollo). So I was not surprised to see Cost and Extensibilty as low priority. However, I did not expect Crew Safety to be that much higher than Schedule.

✓

Crew Safety	EOR	LOR	Nova Direct
EOR	1	2	(1)
LOR	1/2	1	1/2
Nova Direct	(1)	2	1
Sum Each Column	2.5000	5.0	2.50
Normalize			
EOR	0.4000	0.4000	0.4000
LOR	0.2000	0.2000	0.2000
Nova Direct	0.4000	0.4000	0.4000

why did you rank NOVA equal to EOR on crew safety?

0.400
0.200
0.400

✓

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Program Cost	EOR	LOR	Nova Direct
EOR	1	1/4	1/2
LOR	4	1	3
Nova Direct	2	1/3	1
Sum Each Column	7.0	1.5833	4.5

Normalize

EOR	0.1429	0.1579	0.1111
LOR	0.5714	0.6316	0.6667
Nova Direct	0.2857	0.2105	0.2222

0.137
0.623 ✓
0.239

Schedule	EOR	LOR	Nova Direct
EOR	1	1/4	5
LOR	4	1	7
Nova Direct	1/5	1/7	1
Sum Each Column	5.2	1.3929	13.0

Normalize

EOR	0.1923	0.1795	0.3846
LOR	0.7692	0.7179	0.5385
Nova Direct	0.0385	0.1026	0.0769

0.252
0.675 ✓
0.073

Extensibility	EOR	LOR	Nova Direct
EOR	1	2	1/3
LOR	1/2	1	1/4
Nova Direct	3	4	1
Sum Each Column	4.5	7.0	1.5833

Normalize

EOR	0.2222	0.2857	0.2105
LOR	0.1111	0.1429	0.1579
Nova Direct	0.6667	0.5714	0.6316

0.239
0.137 ✓
0.623

[redacted] = 0.5553 × | 0.4000 | + 0.0588 × | 0.1373 | + 0.3085 × | 0.2521 | + 0.0773 × | 0.2395 | = [redacted] ✓
| 0.2000 | | 0.6232 | | 0.6752 | | 0.1373 |
| 0.4000 | | 0.2395 | | 0.0726 | | 0.6232 |

[redacted]

Q: Do your results agree with agree with the decision made by Apollo?
A: Yes. LOR had the higher rank, which was chosen for Apollo. However, the numbers for the three concepts are very close, and with slight adjustments in my matrices, the rankings switch places. This sensitivity in the ranking is possibly due to the high priority I placed on crew safety, along with the small differences in weightings for the crew safety pairwise comparisons. According to Apollo sources, the mission safeties were "essentially equal", so it was expected to have small differences in crew safety weightings. However, the extremely high emphasis on crew safety in the prioritization matrix causes these slight adjustments to make significant changes in the final ranking.

good.

o.k. ✓

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HW# 3 – Problem 2
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Vision for Space Exploration: Figures of Merit

1) Schedule

Meaning: Complete "Vision for Space Exploration" activities within specified time frames.
Rationale: Completing the activities by a designated time frame is necessary, not only because it is a presidential directive, but also because it keeps the public interested in the space program. It is also important to keep on schedule, so that there is not too large of a gap between completing low earth orbit objectives (STS and assembly of ISS) and future destination objectives (Moon, Mars, and beyond). According to the directive, the schedule includes (but is not limited to) retiring the Space Shuttle and completing the ISS assembly by 2010, returning humans to the Moon by 2020, and to have space transportation capabilities to support human exploration missions by 2014.

2) Program Cost

Meaning: Complete research, development, and operations within specified budgets.
Rationale: The presidential directive explicitly states that the United States will implement an "affordable human and robotic program" for exploration. In addition, the current NASA budget is not as high as it used to be (as compared to the Apollo era), and more spending limits are set in place by Congress.

3) Technological Achievements

Meaning: Develop innovative technologies, knowledge, and infrastructure to increase extensibility of missions.
Rationale: It is necessary to accomplish certain technological achievements in earlier missions in order to "extend humanity's reach to the Moon, Mars, and beyond" for future human exploration activities. It is also important to make certain technological achievements in order to further science and to answer fundamental questions about Earth, stars, other planets, and the solar system.

4) Mission Safety/Success

Meaning: Return crew safely for manned missions and successful landings/deployments for robotic missions.
Rationale: For manned exploration missions, such as STS, ISS, and the crew exploration vehicle, it is crucial to return every astronaut home safely. As mentioned in the directive, past Apollo and Shuttle losses are harsh reminders of the "inherent risks of space flight", and that in preparing for future human exploration, it is essential to "advance our ability to live and work safely in space". As for robotic missions, it is imperative to complete the missions' objectives, whether it be landing a rover successfully on the surface of Mars, delivering necessary supplies to the Moon, or successfully deploying a telescope.

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Evaluation of the Analytical Hierarchy Process

As mentioned in the class slides, if there is an article about a topic entitled "Response to the Response to the Response", then the topic is not as widely accepted as some might hope. The Analytical Hierarchy Process (AHP) is commonly used by mathematicians, scientists, and engineers in the decision making process. Some swear by it, while others are thoroughly opposed to it. Either way, it is important to note that the true value of AHP often lies not in the final rankings, but in the "insight gained" throughout the process.

The greatest advantage to AHP is that it provides a method of comparing both quantitative and qualitative criteria. It also provides a way to preference each idea to the next. The AHP user will define Figures of Merit (FOM) which are "metrics by which a stakeholder's expectations will be judged in assessing satisfaction with a product or system." AHP forces the user to individually weight each FOM's significance over every other FOM. In addition, the AHP user must identify each of their concepts or alternatives, and weigh each of them versus each other. Overall, AHP is an important tool because it compels the user to not only list what their FOMs and concepts are, but to truly understand their significance by going through the process.

Unfortunately for T.L. Saaty, the AHP is not accepted by everyone. One flaw in particular is the issue of rank reversal. As noted by R.D. Holder in *Some Comments on the Analytical Hierarchy Process,* "the fallacy of rank reversal of candidates may occur if either a

new candidate is introduced or an existing candidate is removed." In experimenting with my AHP matrices for *Selecting the Way to the Moon*, I noticed this rather distasteful phenomenon. cool. :) For example, one would think that if the teacher likes John better than Tom, even if Wally comes into the picture, the teacher will still like John better than Tom! But that is not always true with AHP. The details of this flaw are discussed in detail in papers between Saaty and Holder. Another issue brought up by Holder and other critics is the use of a linear scale as opposed to a multiplicative or exponential scale. A major flaw with AHP is that it is very subjective. Two users could analyze the same FOMs and concepts and get completely different rankings. This may be a good thing if the decision being made only affects that single user. However, if there are many stakeholders trying to come up with one final decision, this could be a problem. Another issue with AHP is the potential for misunderstanding or misusing AHP. For instance, say there is a budget cap of $1000. Option A is $800, while Option B is $900. Some would weight them as "neutral", because neither of them exceeds the cap. However, another might "moderately prefer" Option A over Option B, because Option A is less likely to exceed the cap if the numbers are to increase. Another issue with AHP is that it is a complicated process and simpler processes exist (like Pugh Matrices) to accomplish the same objective.

good comment, but you lose some fidelity when you go to some of these simpler methods

In the *1995 Systems Engineering Handbook*, NASA suggests the use of AHP in the decision-making process. It is also important to note that the handbook states that "if the wrong weights, objectives, or attributes are chosen, the entire process may obscure the best alternative." ✓ This shows that NASA recognizes the potential for error in the system. The handbook also states that "individual evaluators may tend to reflect biases" and that "the results, therefore, may

depend on the mix of evaluators". This essentially says that NASA recognizes that AHP is subjective. As mentioned before, I feel that AHP is important because of the "insight gained along the way." Overall, I would not recommend AHP as a method of making a *final* decision, because it is often more important to "rely on engineering judgment and experience rather than a formalized tool". I think it is a good tool to use along the way because the serious thought that must go in to evaluating each FOM and concept is helpful and necessary. Some feel that the prioritization matrix is the greatest strength of AHP, and I agree that it is extremely useful in determining the significance of FOMs. When used correctly, AHP can be a valuable tool in the process of decision-making.

excellent observation!