PORTLAND STATE UNIVERSITY

ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Selection of an Engineering & Technology Management Student Project

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Table of Contents

Introduction

The selection of a project from a large list of possibilities is a common problem in Engineering. This type of problem seems to be incessant in many organizations. In fact, it became a problem for our team when we were faced with a difficult decision of which topic to select for our team term project. There were four project alternatives that were brought to our first meeting. All of the projects seemed perfectly reasonable and could be used for the purpose of the class. However, the problem was that we were only able to select one project. This situation was identified as a good opportunity to be the project topic itself.

The purpose of this project is to use decision making methodologies in selection of one project from among four project proposals. Since our project covers the selection of a student project for ETM students, the result is the selection of a project proposal and not the continuation and completion of the selected proposal. To provide effective information on our decision, the Hierarchical Decision Model (HDM), algorithm and tools used for the project selection are studied. The proposed algorithm is mainly based on using the Pairwise Comparison Method (PCM), an Online Survey, Bibliometric Techniques, and Utility Curves.

This project aims to explore the use of PCM in conjunction with an HDM, and show how it can be a useful tool in decision making. An HDM was developed using a set of criteria and several Pairwise comparisons were used to rank the various alternatives. The decision model along with utilizing the PCM helped our team rank the alternatives in order of our preferences. In this paper, the methodology will be explored and an explanation of the decision making process leading to the final decision will be included in detail.

Project Proposal Descriptions

In addition to creating an effective algorithm for project selection, it is also necessary to develop a process for the selection of which projects to use to ensure appropriateness and consistency when evaluating the alternatives. In order to be certain that the alternatives were carefully selected, the team only considered projects that the team members thought had some relevance and were in subject areas in which they had some background experience. Based on these criteria the team members came up with four project proposals for consideration:

<u>Project #1</u>: Deciding between fuel source technologies for a fleet of vehicles for a business.

<u>Project #2</u>: Selection of nuclear reactor technology for use in large scale power generation.

<u>Project #3</u>: Selection of technology for mercury emission control for a local pulp and paper mill.

<u>Project #4</u>: A decision between continuing use of the current eLearning Content Delivery system (Blackboard) or switching to an alternative system.

A detailed proposal of each project can be seen in Appendix A. Figure 1 presents a list of the potential alternatives of each project.

Figure 1: Technology alternatives for each one of the four project proposals.

Hierarchical Decision Model (HDM)

The team constructed the HDM, presented in figure 2, based on discussion and evaluation of potential criteria to rank, in a relative sense, important characteristics and criteria for requirements to complete the decision process for each of the unique proposals.

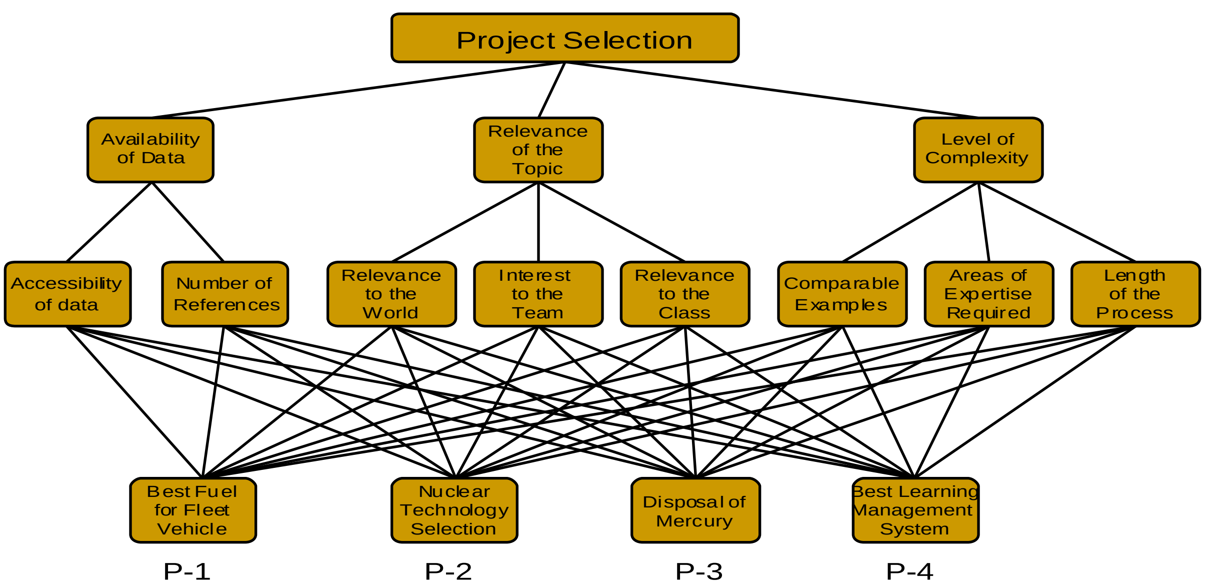

Figure 2: Hierarchal Decision Model used for the project.

Decision Model Criteria and Collection of Data

A critical task in the decision process was selecting the criteria to be used. Discussion among team members was quite lively regarding the details of the sub-criteria but it was relatively easy to select the three top level criteria. To the team, being able to get relevant data related to each proposal was one of the first things that came to the forefront. The team thought it was quite reasonable to believe that if we were truly interested in the project topic, the team would go forward with heightened enthusiasm making the project easier to complete. The team discussed a reasonable description for general interest—relevance. Knowing that the proposals that were under evaluation were quite varied in scope and detail; it seemed logical to consider the complexity of the topic. Prior knowledge and understanding of the proposal was viewed as a significant benefit by the team. If there was no prior knowledge, then large amounts of research and learning had to occur before the project was to be completed. These discussions led to the selection of the top tier on the decision hierarchy, Availability of Data, Relevance of the Topic and Level of Complexity.

Each of these criteria was then further broken down into sub-criteria. The selection of the sub-criteria led to the liveliest discussions among team members. The challenge of the task was to select areas that could be measured (quantified) and that would correlate with the perception of the team for each project proposal. It was also important to select sub-criteria that contributed to each main level criteria. In selecting the sub-criteria, a related discussion ensued that the values generated reflected the perceptions of the team.

To evaluate the model the team utilized internal Constant Sum Pairwise Comparison Models (PCM) [1], Internet and Database Searches, an online Class Survey and the judgment of the team members. The data was then used to rank the four proposals in terms of relative. The details of the evaluation can be found in Appendix A.

To support the first criteria, Availability of Data, two sub-criteria were identified: Accessibility of Data to the Team and Number of Available References. To quantify these criteria a ranking methodology was developed and employed. Specifically, Accessibility of Data was rated with a numerical ranking system developed by the team. The numeric scale ranged from one to five with five representing the project with the most accessible data. The rankings themselves are simply the team's numerical assessment of how often similar projects to those being compared are being done in the United States. Logically the more frequent these projects occur, the greater the number of examples to research and the greater the amount of literature will be available. The team had the fortune to be generally knowledgeable of the proposals as two of the proposals originated at team member's workplace and the other two were topics that had been previously researched by other team members so the team felt comfortable with the rankings and the justifications presented to the rest of the team.

With respect to the rating of the Number of References a bibliographic search technique was employed. For each proposal, three search terms were chosen. Each of the search terms were used as keywords to search readily available pertinent databases that can be accessed through most research libraries. The numbers of database hits were summed and were used to rank the proposals. The details of these searches are included in Appendix B.

The next criteria, Relevance to the Topic, had three sub-criteria to support it; Relevance to the World, Relevance to the Class and Interest to the Team. To quantify the Relevance to the World the same three search terms used for the Number of References bibliometric search were used again. To quantify the Relevance to the World the search terms were used in three different web search engines; Yahoo, Google and MSN. The number of hits was then summed and averaged (see Appendix B for details). To quantify the Interest of the Team, another internal Pairwise Comparison was done by the team to generate relative importance. The Relevance to the Class sub-criteria was addressed by using an online survey sent to the class. The survey was created and delivered on surveymonkey.com, a free online survey tool. The results were tabulated and a relative rank for the sub-criteria was created.

The last criteria on the first level of the hierarchy, Level of Complexity, also had three sub-criteria. They were; Comparable Examples, Numbers of Areas of Expertise, and Length of the Decision Process. To quantify these sub-criteria, the team did research to locate examples of other groups or organizations who were faced with the decision present by each proposal. The team created a ranking system for Comparable Examples, this system was created based on the findings of research and team members experience and knowledge of the topics [2-14]. The next sub-criteria to evaluate was the Number of Areas of Expertise. If the proposal were actually to be undertaken, unquestionably subject matter experts would be involved. For example, for the Mercury Emissions Project, an individual knowledgeable of regulatory issues would surely be needed as well as other experts knowledgeable in the specific chemical compounds that may be emitted as well as someone to represent the public health of the community as well as other potential experts from other fields. The number of general areas of expertise for each project was listed and counted for each proposal based on the team knowledge of the topics. Full details can be found in Appendix B. The last sub-criteria, Length of the Decision Process, was based on the teams knowledge and understanding of the decision behind each proposal. Similar 'knowledge judgments' have been used by other teams in the past and have proven to the valuable [15]. A value based on a ranking scale was assigned to each one of the individual proposals. The raw data used for this ranking was based on the team's collective judgment and knowledge of the projects. It is important to note that the accuracy of this judgment is not nearly as important as the relative scaling of these numbers as the end goal of the exercise is to look for differentials between what was examined. All the data collected to evaluate the four projects against each sub-criterion is available in Appendix A.

A number of these numerical ratings used a Utility Curve as a method to normalize and scale the raw data so that comparisons between different sub-criteria could be done reasonably [16]. For example, the results of the bibliometric database searches and the number of areas of expertise needed to complete each individual project would be expected to have a substantially difference orders of magnitude. A method to compare these numbers in a fair and reasonable manner was needed. To accomplish this task, the team generated Utility Curves for many of the sub-criteria used. The curves were defined by the team and can be found in Appendix B.

Assumptions of the Model

There were many assumptions made in the presented HDM that should not be discounted when coming to a final decision. First, the weights of the criteria were chosen by the team members. We did not seek external professionals on the subject at hand to help the team members with the data. Next, the team members chose databases for the availability of data. The sub-criteria under availability of data called Number of References was rated by using three search terms that were generated by the team then searched in three databases that were also chosen by the team. Research was not done to determine the optimal database for each topic would be but the assumption is that these databases would result in good comparison values for references in the four topics of interest. We again used the same search terms for the sub-criterion Relevance to the World under the criterion Relevance of the Topic. It was assumed that the chosen databases would result in reasonable comparison values for the relevance to the world. Another assumption that applies to both searches was that overall number of hits from the searches has the same percentage of actual results pertaining to the topic versus non related topics. The reference and hit data were not analyzed to see if the results were actually relevant to the topic and therefore the actual percentage is unknown.

Another assumption made by the team was that the results from the survey monkey in the sub-criterion Interest to the Class under the criterion Relevance of the Topic was representative of the whole class. In all actuality, we may have received different results if all surveys from the class were submitted instead of the 19 that were actually submitted.

Lastly, the sub-criteria Areas of Expertise Required under the criteria Level of Complexity were chosen by the team member with the most knowledge of the topic. In reality, the team member who chose the number of areas of expertise required may have overlooked an area that someone with more in depth knowledge of the topic would have known. In other words, no professional project managers in these topics were consulted to get the data used in the model.

HDM Results

A number of different calculation tools were used to determine the relative weights for the pairwise comparisons of the decision model. These tools provided a way to assign numerical values to each project when evaluated for each criterion of the second level of the HDM. Table 1 presents a summary of the numerical values assigned to each project for each criterion.

The values shown in Table 1 were utilized to calculate the relative weights in every comparison. For the detailed procedure about these calculations, go to Appendix A of this report. These relative weights were fed into the PCM software to determine the weights of each project in each criterion in the second level of the HDM. Table 2 presents a summary of the numerical results.

Table 1: Numerical values assigned to each project to calculate relative weights.

Availability of data			
Criterion	Accessibility of the data to the team	Number of references	
Project	Points	Utility	
P-1	3	0.83	
P-2	3	1	
P-3	5	0.75	
P-4	5	0.68	
Relevance of the topic			
Criterion	Relevance to the world	Interest to the team	Relevance to the class
Project	Utility	Relative weights assigned by team members	Points
P-1	0.74		206
P-2	1		278
P-3	0.42		200
P-4	0.75		323
Level of complexity			
Criterion	Comparable examples	Areas of expertise required	Length of the process
Project	Points	Points	Points
P-1	5	1	5
P-2	1	5	2
P-3	3	3	3
P-4	5	1	4

Table 2: PCM software results for the pair wise comparisons.

Availability of data - 0.38			
	Accessibility of the data to the team - 0.71	Number of references - 0.29	
Project	Weights for criterion	Weights for criterion	
P-1	0.19	0.26	
P-2	0.19	0.31	
P-3	0.31	0.23	
P-4	0.31	0.21	
Relevance of the topic - 0.35			
	Relevance to the world - 0.3	Interest to the team - 0.42	Relevance to the class - 0.28
Project	Weights for criterion	Weights for criterion	Weights for criterion
P-1	0.26	0.19	0.21
P-2	0.34	0.3	0.27
P-3	0.15	0.23	0.2
P-4	0.26	0.27	0.32
Level of Complexity - 0.27			
	Comparable examples - 0.21	Areas of expertise required - 0.49	Length of the process - 0.3
Project	Weights for criterion	Weights for criterion	Weights for criterion
P-1	0.36	0.39	0.39
P-2	0.07	0.08	0.08
P-3	0.21	0.13	0.23
P-4	0.36	0.39	0.31

The final step to determine the final selection of a project was a simple series of multiplications following the hierarchical relationships provided by the HDM. Table 3 presents the final results of these calculations. Figure 3 shows the same results in a graphical form.

Table 3: HDM final results

Values for the final selection	
First level	Final weights
Availability of data	0.38
Number of references	0.35
Level of complexity	0.27
Second level	
Accessibility of the data to the team	0.27
Number of references	0.11
Relevance to the world	0.11
Interest to the team	0.15
Relevance to the class	0.1
Comparable examples	0.06
Areas of expertise	0.13
Length of the process	0.08
Third level	
P-1	0.26
P-2	0.21
P-3	0.23
P-4	0.3

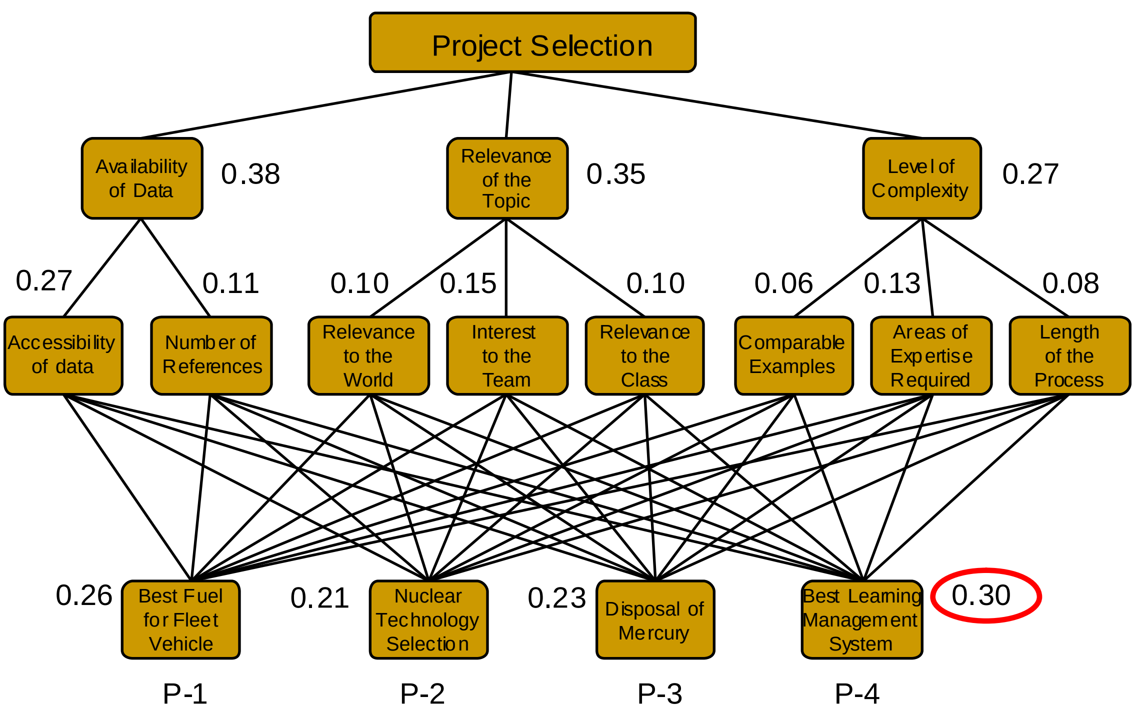

Figure 3: Final results

Analysis of Results

Based on the scores from the HDM model, the projects are ranked from highest to lowest P4, P1, P3, and P2. This ranking is primarily dependent on the weighting applied to the first level criteria by the team using the PCM described previously. From the weightings one can conclude that the most important criterion for this team, in terms of project selection, is the availability of the data followed by the relevance of the topic. However the complexity of the project is weighted lowest suggesting that the team is not intimidated by a complex project as long as there is data available and it is relevant. To explore the sensitivity of the model to different weightings a simple analysis was performed by varying the weightings among the first level criteria. Table 4 summarizes the results for scenarios where one criterion is weighted very heavily (0.9) while the other two share the remainder (0.05). From this simple analysis it can be seen that if availability of data is the most important criterion P4 is still the preferred project however the ranking order changes. When relevance is the most heavily weighted criterion P2, the nuclear energy project, comes out with the highest score suggesting it is a very relevant topic. Finally when complexity is felt to be most important the fleet vehicle project, P1, is the preferred project.

Table 4: Effect of Different First Level Criteria Weighting.

		Most Important First Level Criterion		
Criterion	**Actual (Team PCM weights)**	**Availability of Data**	**Relevance**	**Complexity**
Availability of Data	0.38	0.90	0.05	0.05
Relevance	0.35	0.05	0.90	0.05
Complexity	0.27	0.05	0.05	0.90
Project Ranking	P4-P1-P3-P2	P4-P3-P2-P1	P2-P4-P1-P3	P1-P4-P3-P2

As described previously the selection of the first level criteria weightings by PCM imparts the team's preferences to the model. Similarly, the use of a PCM to rank the second level criteria and a PCM to rank the relevance of the projects to the team also imparts the team's preference. In most situations model bias is to be avoided or at least understood and defended. In the case of this project bias is to be expected and is actually a positive feature. The selection of a team project is a problem of preference which is bias. By using results from PCM's performed by the team this model brings the teams preference or bias to the problem of selection of a project. What this means is that any team that might use this model would come up with different weightings and necessarily different rankings. While the results of this model are not meant to be generalized, the methodology of using an HDM model to utilize subjective preferences and measureable criteria to select a project could be applied to other topics by other teams.

Recommendations to the Decision Maker

In the case of the HDM presented in this report, the bias of the team did not negatively affect the outcome of the decision since the purpose was to select a project of that best fitted the interests and preferences of the team. However, there are some recommendations regarding bias that can be made to a decision maker in regards to a HDM that requires more objectivity. If possible use the expertise of people that have no interest in the outcome of the decision to determine the weights of your model criteria or create a systematic and consistent methodology to do it. This will minimize influence of personal biases. It is beneficial if the team has access to the proper expertise to evaluate the model criteria. This is crucial for decisions that require deep knowledge of specific topics where only the appropriate opinions of experts can provide a way to select and evaluate the criteria of the HDM. This is particularly important for complex topics such as nuclear energy where team members may not have a complete understanding of the topic. Teams should minimize bias by making the pairwise comparisons as objective as possible. The use of ranking systems and other ways to assign numerical values to each option being evaluated. While the first level criteria weighting can and should be done based on team preference the second level criteria should be evaluated on objective data if at all possible. This type of scoring can be done using ranking, scoring or utility curves. Reevaluate your decision model periodically. As a team becomes more familiar with the topics it may be necessary to adjust the sub-criteria.

Lessons Learned

Since our team has to propose four projects to show the processes for decision making project, understanding all projects is required for our team. To cover all four projects, finding the best criteria becomes the biggest problem. It requires a good understanding of the topics being compared to choose appropriate criteria for a specific HDM. The diversity of topics did not allow the team to gather the same type of relevant data for all four projects. The availability of data in essential to apply PCM consistently, it was not easy for the team to consistently evaluate our criteria for the different projects. Also, the expertise for particular project is important. Some members of the team may be professional in specific field which might be suitable for some projects. Thus, level of perception might be different between team members.

The relevance of information for each project options, which are illustrated in this project, is difficult to set in the same flow. Including the numbers of data available from different database websites, we have to think about the consistency for each database websites that we will use as a reference in some criteria. Moreover, the conditions, as key words or phrases, give the difficulties to our team when we try to make the criteria to cover all aspects. In order to clarify the understanding of doing this project, we have to show the appropriate criteria for making a decision of choosing projects in this paper. Therefore, the difficulties of finding data and making criteria to be consistent are the most challenge for our team to do this project.

Biases appear to be one of key factors since there are different specific fields. It is obvious that team members or classmates weight the criteria or project options unequally. Because we are not the experienced managers who are capable of weighting the scores for particular criteria, some members tend to score the projects based on individual feelings. As the result, the scores could be differently assessed from the way they are supposed to be.

Finally, PCM is an excellent tool that facilitates the decision making process and it provides the best option that reflects all the different relationship of a HDM.

Conclusion

Using team selected criteria an HDM model was constructed to assist with the decision of what project to choose from a list of four proposals. By using PCM in conjunction with the HDM model the team an evaluated the model and came to the final conclusion that Selection of a Learning Management System was the preferred project. The use of PCM to make a selection among different alternatives requires the use of appropriate criteria and sub-criteria. The results show that the selected criteria and sub-criteria led to the Selection of a Learning Management System as the option with the highest score in the HDM. Even though this option did not have the highest score in all criteria, the weight distribution of the HDM led to this option as the best decision. While in most cases every effort should be made to minimize bias, when constructing and evaluating models, in this case bias (team preference) was built into the model and therefore the selection criteria reflect the team's true choice and the final project selection reflects the team. Because the model is specific to this particular team the model can not be generalized for all teams (other teams would not come to the same conclusion) however the methodology used to build and evaluate the model could be used by other teams or students to evaluate potential project choices.

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Appendix A

Project

Proposals

Project Proposal #1: Fleet Vehicle Fuel Options

The proposal on this topic would decide which type of fueling options should be selected for a business fleet vehicle application. The primary options to choose from are a traditional gasoline power train, a hybrid option or diesel. The diesel also has another sub-option to consider, biodiesel.

Primary considerations to consider while making this decision are related to costs, both initial and operating, and vehicle reliability. Given what could be described as a heightened environmental awareness and the trend of many companies positioning themselves and their products as environmentally friendly, the concept of marketing or public relation value of the decision would be evaluated. Another significant critierion for the decision would be the vehicle payload capacity, which would be expected to vary based on the needs a specific business.

Many companies have recently broached this decision in recent times as well as the actual development and hardening of hybrid technology so that real reliability data can be researched and reviewed as well as the availability of examples of companies making the fleet fuel decision.

Project Proposal #2: Nuclear Technology Selection

The proposed project "Nuclear Technology Selection" is a build on a previous project completed in Technology Assessment and Acquisition where a group of Engineering Management students first assessed what technology to select for an "always on" power source coming to the conclusion of nuclear power, then assessing which nuclear technology would be the best in Oregon. The "always on" power sources that were assessed were coal, natural gas, and nuclear. The criteria used was economical to the consumer, toxic waste produced, job creation, cost of construction, safest for people living within 50 miles, air pollution produced, reliance on foreign or imported energy sources, and capacity. Using those criteria the team came to the conclusion that Nuclear was the best technology for Oregon.

The next assessment was which nuclear technology to pick. We researched the current technologies and compared pressurized water, boiling water, pressurized heavy water, lead cooled, sodium cooled, and advanced gas cooled reactors. When choosing the technology the team had limited data due to the limited time they had to circulate a survey. Also, when the team analyzed the data they found an error in the way a particular question was asked which could have resulted in a skewed decision model.

This project would be a re-assessment of the types of nuclear technology that are out there to come to a better data driven decision. The team has ample amounts of data on nuclear technology but also know the data can be biased based upon who is assessing the technologies. The relevance of the topic is high because of the need for alternative energy in the United States. The complexity is also high due to the lack of knowledge that the group has on specific types of nuclear technologies.

Project Proposal #3: “A Pair Wise Comparison to Choose the Best Option for Mercury Emissions Control at a Local Pulp and Paper Mill”

Mercury emissions are a problem shared across the pulp and paper industry. The EPA’s Toxic Release Inventory of 2002 shows 646 lbs Hg per year released by the pulp and paper industry. Out of this total, 84% (544 lb) was air emissions, 14.6% (94 lb) was solid waste, and the remaining 1.4% (8 lb) was liquid waste. A local pulp and paper mill is experiencing mercury emissions problems at two different points in its process: (1) the flue gases from two power boilers; and (2) the final treated wastewater treatment plant (WWTP) effluent.

Studies done at the mill have determined that the cause of the mercury emissions is the current disposal method of WWTP sludge. The mill needs to find a long term solution to this problem in order to assure compliance with existing and expected environmental regulations. A pair wise comparison method can be used to help the mill choose the best technological option to control mercury emissions. The following list is an example of the criteria that can be utilized to make the comparisons: (a) the technology is transferable to the pulp and paper industry and can readily be adapted or retrofit to the existing equipment; (b) the technology requires as little capital as possible and offers acceptable pay back time; (c) operation and maintenance costs are minimal; (d) the efficiency of the current WWTP either improves or remains unaltered; (e) the new process is not detrimental to subsequent dewatering operations; (f) the technology preferably does not require additional air pollution control equipment; and (g) the technology is safe and durable.

Project Proposal #4: “A learning Management System for PSU”

A learning management system (LMS) is software used for delivering, tracking, and managing training. In many instances, corporate may purchase LMSs to automate the training of employees, or an institution could use it to enhance the online learning. While most systems are commercially developed, in which requires non-free software licenses and restrict access to their source code (eg. Blackboard, Angel), but there are also many free and open-source models (Moodle, Sakai) available.

Over the years, Portland State University purchased a license with commercial vendors (webCT, Blackboard), which cost the institution a great amount. Rather than sticking with the current LMS, should PSU go toward an open-source system? This project will focus on making the decision for which LMS to use: 1. Continue using the current LMS (Blackboard), 2. Move toward another commercial product (Angel), 3. Select an open-source LMS (Sakai) that is supported by a community of academic institutions and organizations, or 4. Invest in a completely open-source product (Moodle) which is currently used at many other leading Institutions.

Appendix B
Calculation
Tools

Project Criteria

The main project criteria identified for team 1 to choose among the projects being considered are the following:

C-1: Availability of data
C-2: Relevance
C-3: Level of complexity

A pairwise comparison was done by team 1 members to determine the relative importance of these criteria. The relative weights assigned by each member are shown below:

Roberto Artiga:

C-1	55	vs.	C-2	45

C-1	65	vs.	C-3	35

C-2	60	vs.	C-3	40

Marc Britton:

C-1	30	vs.	C-2	70

C-1	50	vs.	C-2	50

C-2	70	vs.	C-3	30

Bundit Chotivanawan:

C-1	70	vs.	C-2	30

C-1	60	vs.	C-3	40

C-2	40	vs.	C-3	60

Paul Nguyen:

C-1	60	vs.	C-2	40

C-1	70	vs.	C-3	30

C-2	60	vs.	C-3	60

Noah Third:

C-1	30	vs.	C-2	70

C-1	40	vs.	C-3	60

C-2	60	vs.	C-3	40

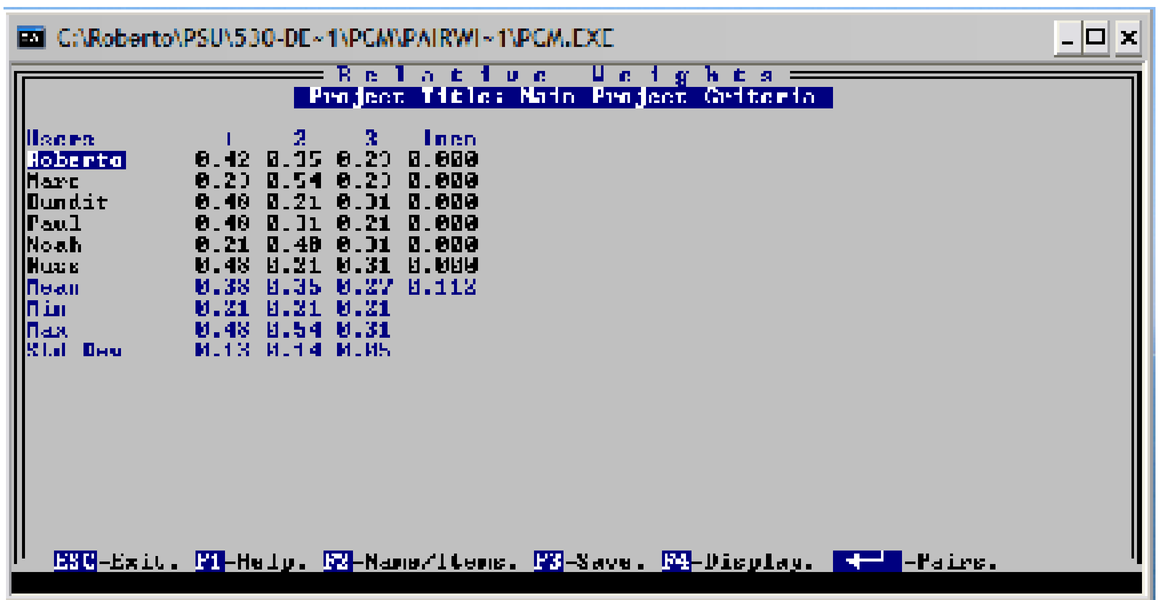
Russ Watt:

C-1	70	vs.	C-2	30

C-1	60	vs.	C-3	40

C-2	40	vs.	C-3	60

PCM software results:


C:\Roberto\PSU\530-DE~1\PCM\PAIRWI~1\PCM.EXE

Relative Weights

Project Title: Main Project Criteria

Users	1	2	3	Incn
Roberto	0.42	0.35	0.23	0.000
Marc	0.23	0.54	0.23	0.000
Dundit	0.48	0.21	0.31	0.000
Paul	0.48	0.31	0.21	0.000
Noah	0.21	0.48	0.31	0.000
Russ	0.48	0.21	0.31	0.000
Mean	0.38	0.35	0.27	0.112
Min	0.21	0.21	0.21	
Max	0.48	0.54	0.31	
Std Dev	0.13	0.14	0.05	

ESC-Exit. F1-Help. F2-Name/Items. F3-Save. F4-Display. ↵-Pairs.

Availability of data:

C-1: Accessibility of data to the team
C-2: Number of references

Roberto Artiga:

C-1	70	vs.	C-2	30

Marc Britton:

C-1	65	vs.	C-2	35

Bundit Chotivanawan:

C-1	75	vs.	C-2	25

Paul Nguyen:

C-1	70	vs.	C-2	30

Noah Third:

C-1	80	vs.	C-2	20

Russ Watt:

C-1	65	vs.	C-2	35

The relative weights for these two criteria were determined by averaging the six values available.

Weight of C-1 = (70 + 65 + 75 + 70 + 80 + 65) / 6 = 71
Weight of C-2 = 29

Relevance:

C-1: Relevance to the world
C-2: Level of interest to team members
C-3: Level of interest to the class

Roberto Artiga:

C-1	30	vs.	C-2	70

C-1	40	vs.	C-3	60

C-2	70	vs.	C-3	30

Marc Britton:

C-1	40	vs.	C-2	60

C-1	70	vs.	C-2	30

C-2	70	vs.	C-3	30

Bundit Chotivanawan:

C-1	55	vs.	C-2	45

C-1	60	vs.	C-3	40

C-2	60	vs.	C-3	40

Paul Nguyen:

C-1	40	vs.	C-2	60

C-1	40	vs.	C-3	60

C-2	55	vs.	C-3	45

Noah Third:

C-1	60	vs.	C-2	40

C-1	55	vs.	C-3	45

C-2	45	vs.	C-3	55

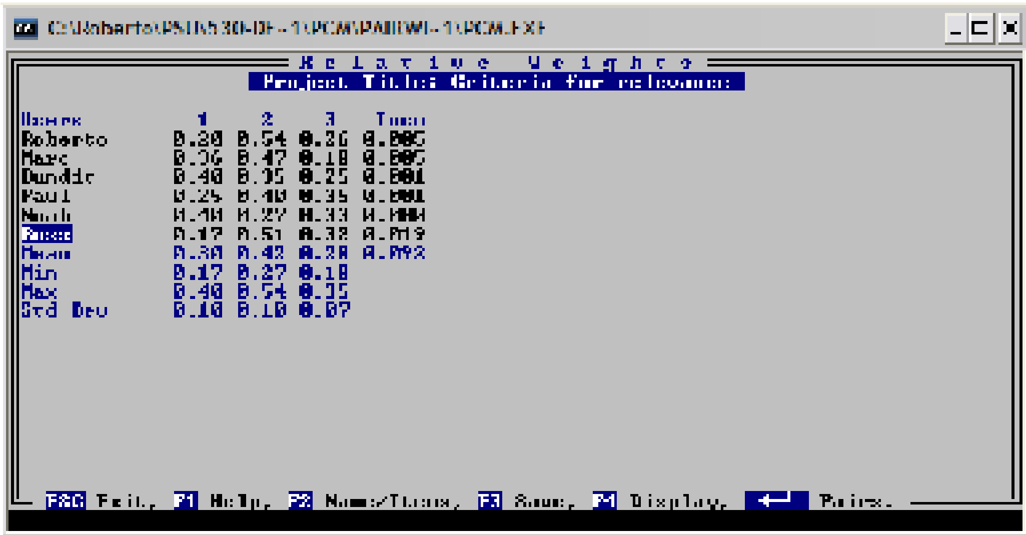
Russ Watt:

C-1	20	vs.	C-2	80

C-1	40	vs.	C-3	60

C-2	55	vs.	C-3	45

PCM software results



Level of complexity

C-1: Comparable examples
C-2: Areas of expertise require
C-3: Length of the decision process

Roberto Artiga:

C-1	20	vs.	C-2	80

C-1	30	vs.	C-3	70

C-2	75	vs.	C-3	25

Marc Britton:

C-1	40	vs.	C-2	60

C-1	55	vs.	C-2	45

C-2	60	vs.	C-3	40

Bundit Chotivanawan:

C-1	25	vs.	C-2	75

C-1	20	vs.	C-3	80

C-2	55	vs.	C-3	45

Paul Nguyen:

C-1	30	vs.	C-2	70

C-1	25	vs.	C-3	75

C-2	60	vs.	C-3	40

Noah Third:

C-1	30	vs.	C-2	70

C-1	55	vs.	C-3	45

C-2	75	vs.	C-3	25

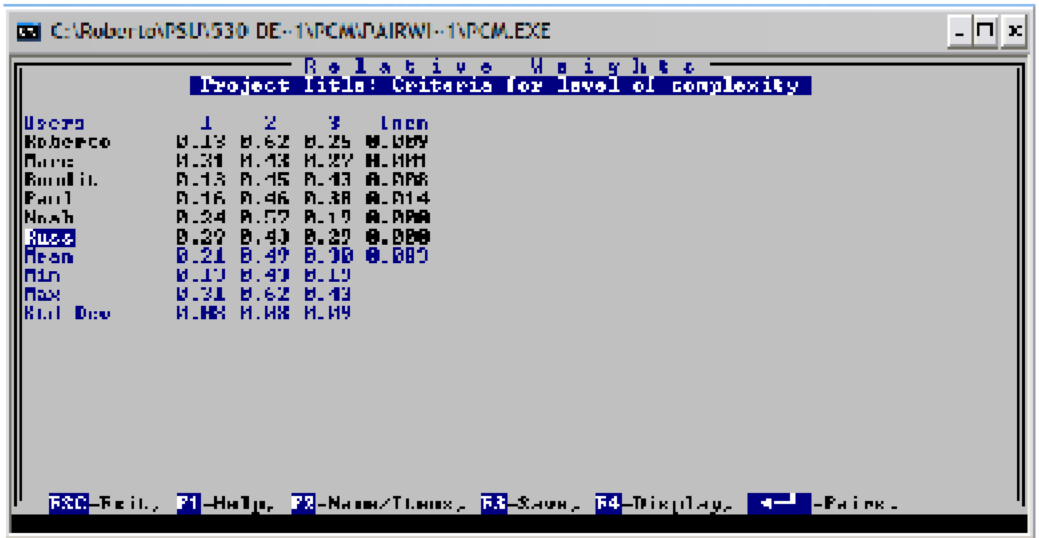
Russ Watt:

C-1	40	vs.	C-2	60

C-1	50	vs.	C-3	50

C-2	60	vs.	C-3	40

PCM software results:



C:\Roberto\PSU\530 DE~1\PCM\PAIRWI~1\PCM.EXE

Relative Weights

Project Title: Criteria for level of complexity

Users	1	2	3	Incn
Roberto	0.13	0.62	0.25	0.009
Marc	0.31	0.43	0.27	0.000
Rosalia	0.13	0.45	0.43	0.008
Paul	0.16	0.46	0.38	0.014
Noah	0.24	0.57	0.19	0.000
Russ	0.27	0.43	0.27	0.000
Mean	0.21	0.47	0.30	0.003
Min	0.13	0.43	0.19	
Max	0.31	0.62	0.43	
Std Dev	0.08	0.08	0.09	

ESC-Exit, F1-Help, F2-Names/Items, F3-Save, F4-Display, ↵-Pairs.

EMGT 530/630

Team 1

Accessibility of Data to the Team

P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

The following table shows the ranking system utilized by team 1 for the accessibility of data to the team for the four project choices:

Accessibility of the data to the team	
Category	Points
Easily accessible	5
Very accessible	4
Somewhat accessible	3
Difficult to access	2
Inaccessible	1

The four project options were ranked according to the above table as shown below:

Accessibility of the data to the team		
Project	Points	Justification
P-1	3	This is an imaginary project so it would be necessary for the team to require access to information of companies that have done similar projects.
P-2	3	Two team members worked on a similar project and therefore there is some information available and they also know people who have access to more information.
P-3	5	One of the team members works at the local pulp and paper mill so the data for this project is easily accessible.
P-4	5	One of the members of the team members works at PSU so the data for this project is also easily accessible

The relative weights for the pairwise comparisons were calculated using a rational relationship between each project giving higher value to the project with more access to information. The calculation procedure is shown below:

Weight of P-i = [(Points for P-i) / (# Points for P-i and P-j)] * 100
Weight of P-j = 100 – Weight of P-i

For instance:

Weight of P-1 = (Points for P-1) / (Points for P-1 and P-2)
Weight of P-1 = [(3) / (3+3)] * 100 = 50
Weight of P-2 = 100 – 50 = 50

Weights of projects for pair comparisons:

P-1	50	vs.	P-2	50

P-1	38	vs.	P-3	62

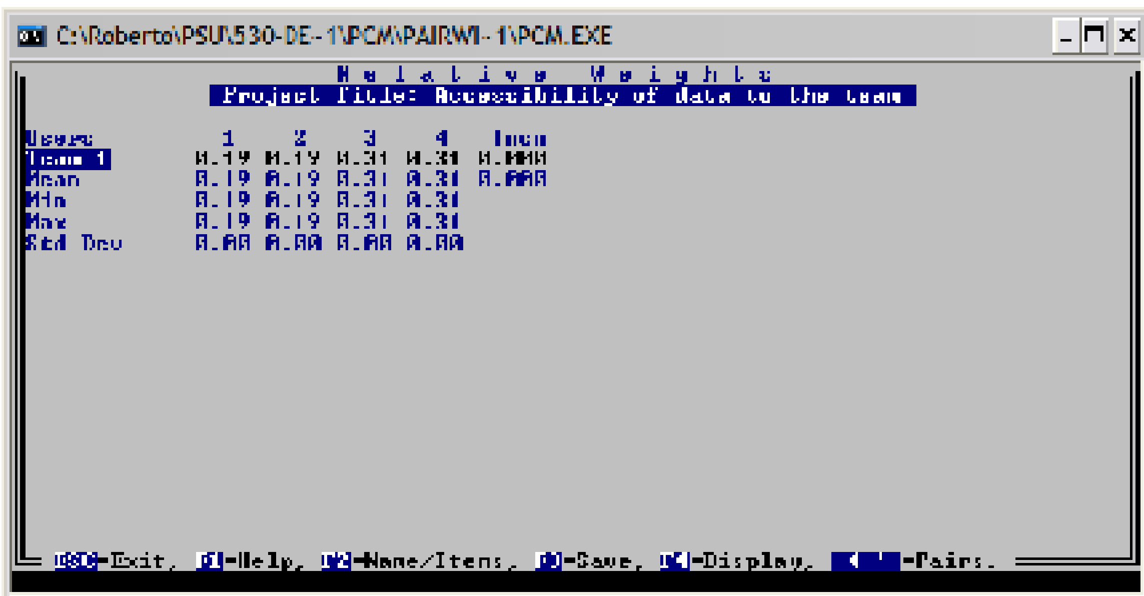
P-1	38	vs.	P-4	62

P-2	38	vs.	P-3	62

P-2	38	vs.	P-4	62

P-3	50	vs.	P-4	50

PCM software results:



EMGT 530/630
Team 1
Number of References

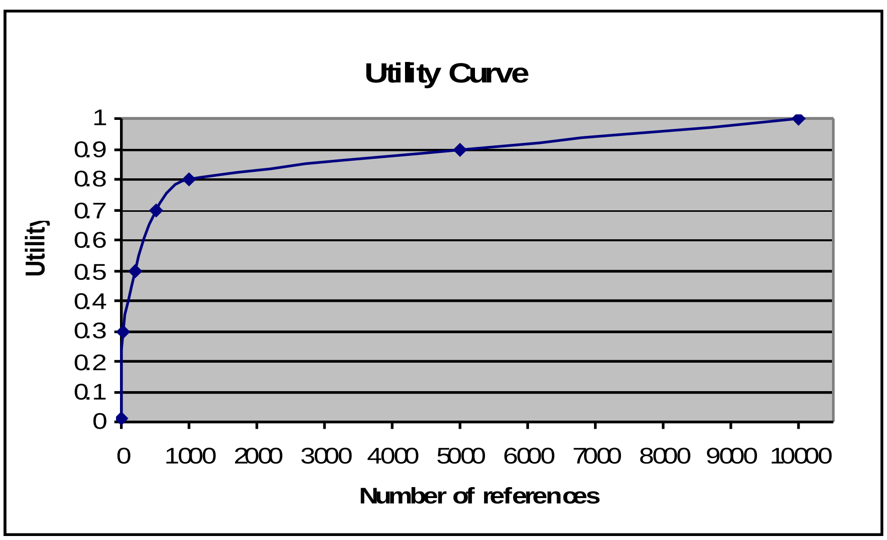
P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

The following table shows the number of references for each project (see appendix A for details):

Number of References	
Project	Number of hits
Fleet vehicles	2,257
Nuclear Technology	27,960
Mercury Emission Control	732
PSU Blackboard System	476

Team 1 created the following utility curve to compare the number of references:

Values for utility curve	
Number of hits	Number of hits
1	0.01
25	0.3
200	0.5
500	0.7
1000	0.8
5000	0.9
10000	1



The utility values for the number of references for each project are listed below:

Number of References	
Project	Utility
P-1	0.83
P-2	1
P-3	0.75
P-4	0.68

The above values were calculated using linear interpolation according to the next formula:

Utility of P-i = (Utility of P-i0) + (# of references of P-i - # of references of P-i0) * [(Utility of P-i1 – Utility of Pi0) / (# of references of P-i1 - # of references of P-i0)]

For instance:

Utility of P-1 = 0.8 + (2257-1000) * [(0.9-0.8) / (5000-1000)] = 0.83

The relative weights for the pairwise comparison were calculated using the above utilities as follows:

Weight of P-i = [Utility of P-i / (Utility of P-i and P-j)] * 100
Weight of P-j = 100 – Weight of P-i

For instance:

Weight of P-1 = [(0.83) / (0.83+1)] * 100 = 46
Weight of P-2 = 100 – 46 = 54

Weights of projects for pair comparisons:

P-1	46	vs.	P-2	54

P-1	53	vs.	P-3	47

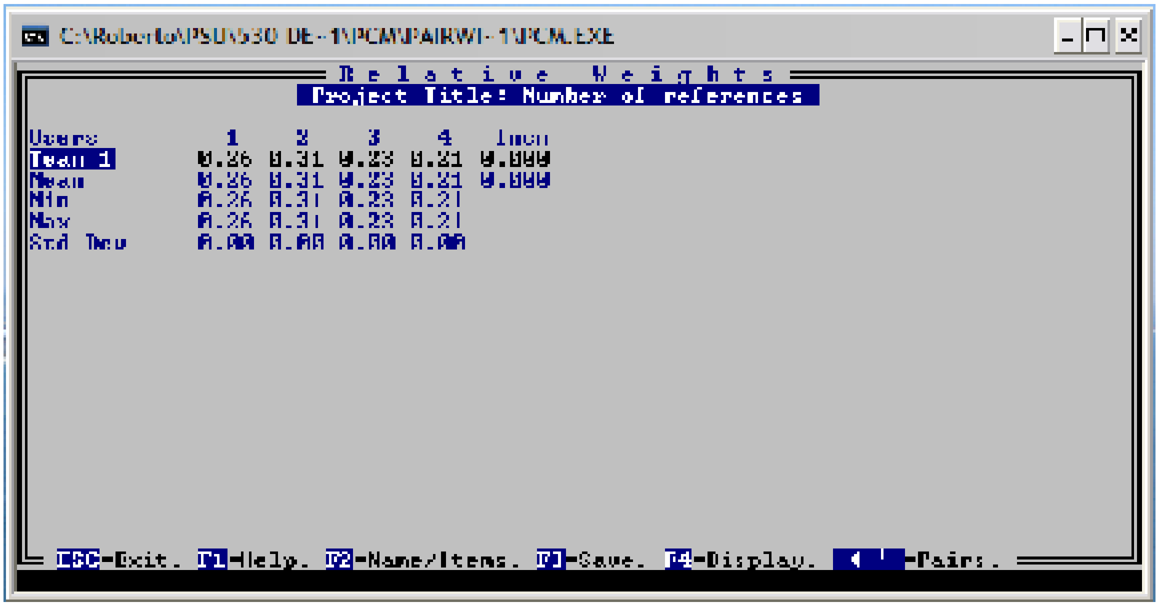
P-1	55	vs.	P-4	45

P-2	57	vs.	P-3	43

P-2	60	vs.	P-4	40

P-3	52	vs.	P-4	48

PCM software results:


C:\Roberto\PSU\530 DE~1\PCM\PAIRWI~1\PCM.EXE
Relative Weights
Project Title: Number of references
Users 1 2 3 4 Incn
Team 1 0.26 0.31 0.23 0.21 0.000
Mean 0.26 0.31 0.23 0.21 0.000
Min 0.26 0.31 0.23 0.21
Max 0.26 0.31 0.23 0.21
Std Dev 0.00 0.00 0.00 0.00
ESC-Exit. F1-Help. F2-Name/Items. F3-Save. F4-Display. -Pairs.

EMGT 530/630

Team 1

Relevance to the World

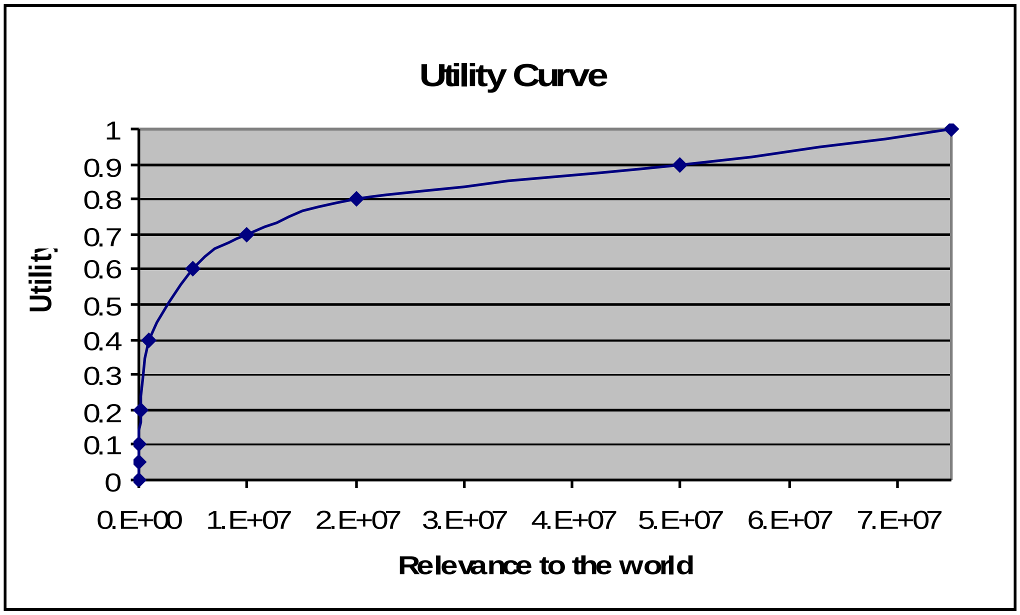
P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

The following table shows the results for the relevance to the world of each project (see appendix A for details):

Relevance to the world	
Project	Results
Fleet vehicles	13,660,000
Nuclear Technology	87,954,333
Mercury Emission Control	1,413,100
PSU Blackboard System	15,453,667

The following utility curve was created by team 1 to compare the relevance to the world of each project:

Values for utility curve	
Number of hits	Number of hits
0	0
5,000	0.05
25,000	0.1
100,000	0.2
1,000,000	0.4
5,000,000	0.6
10,000,000	0.7
20,000,000	0.8
50,000,000	0.9
75,000,000	1



The utility values for the relevance to the world for each project are listed below:

Number of References	
Project	Utility
P-1	0.74
P-2	1
P-3	0.42
P-4	0.75

The above values were calculated using linear interpolation according to the next formula:

Utility of P-i = (Utility of P-i0) + (# of references of P-i - # of references of P-i0) * [(Utility of P-i1 – Utility of Pi0) / (# of references of P-i1 - # of references of P-i0)]

For instance:

Utility of P-1 = 0.7 + (13,660,000-10,000,000) * [(0.8-0.7) / (20,000,000-10,000,000)] = 0.74

The relative weights for the pairwise comparison were calculated using the above utilities as follows:

Weight of P-i = [Utility of P-i / (Utility of P-i and P-j)] * 100
Weight of P-j = 100 – Weight of P-i

For instance:

Weight of P-1 = [(0.74) / (0.074+1)] * 100 = 46

Weight of P-2 = 100 – 46 = 54

Weights of projects for pair comparisons:

P-1	43	vs.	P-2	57

P-1	64	vs.	P-3	36

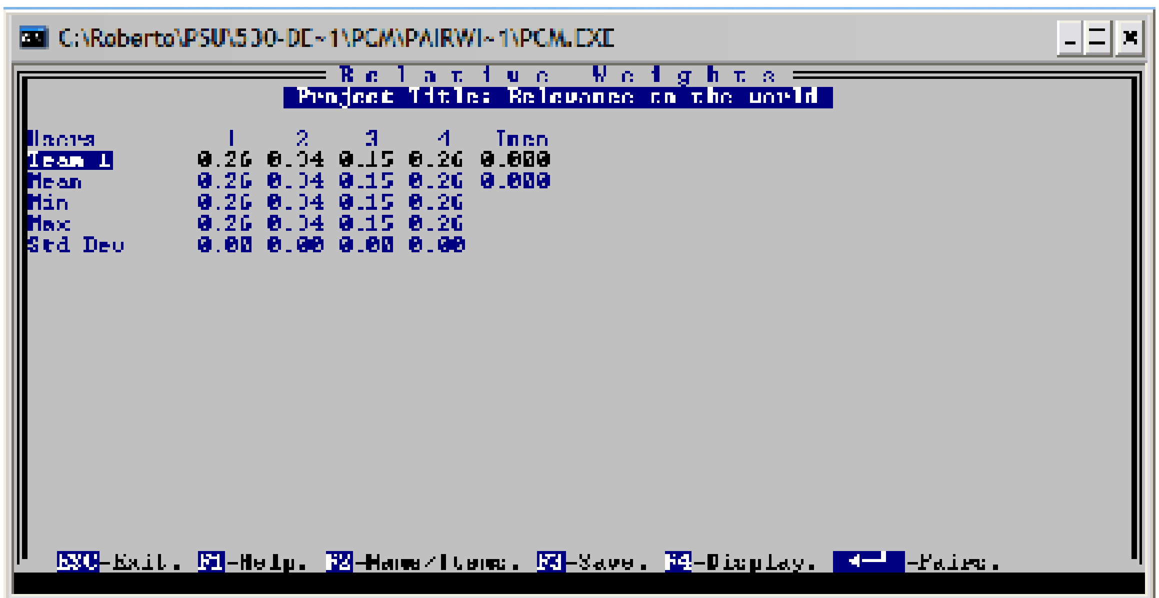
P-1	50	vs.	P-4	50

P-2	70	vs.	P-3	30

P-2	57	vs.	P-4	43

P-3	36	vs.	P-4	64

PCM software results:



EMGT 530/630

Team 1

Level of Interest to the Class

P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

Team 1 utilized Monkey Survey to do a survey among EMGT 530 students to determine the level of interest of the class in the four projects under consideration, a total of 19 students participated in the survey. The results of the survey are shown below:

Response Summary

Total Started Survey: 19
Total Completed Survey: 19 (100%)

Page: Group 1 Class Survey

1. Please help us with ranking the following four options with your level of interest. Ties are not allowed.

	Most Interesting	Somewhat Interesting	Minimally Interesting	Not at all Interesting	Response Count
Car selection for a business fleet of vehicles based on fuel type.	16.7% (3)	16.7% (3)	22.2% (4)	44.4% (8)	18
Options for a large-scale [illegible] electrical power generation.	23.5% (4)	52.9% (9)	17.6% (3)	5.9% (1)	17
Method used to control mercury emissions from a local pulp and paper mill.	5.9% (1)	23.5% (4)	35.3% (6)	35.3% (6)	17
Selection of a web-based education content delivery method for PSU (Blackboard or a Blackboard replacement).	55.6% (10)	16.7% (3)	22.2% (4)	5.6% (1)	18
				answered question	19
				skipped question	0

Team 1 assigned the following values to the four levels of interest included in the survey:

Levels of interest to the class	
Level	Points
Most interesting (MOI)	4
Somewhat interesting (SI)	3
Minimally interesting (MI)	2
Not at all interesting (NI)	1

The values of the levels of interest were combined with the percentages of the class survey for each one of them to determine total points assigned to each project according to the following formula:

Points of P-i = %MOI *4 + %SI *3 + %MI *2 + %NI *1
For instance:

Points of P-1 = 16.7*4 + 16.7*3 + 22.2*2 + 44.4*1 = 206

The total points for each project are presented below:

Level of interest to the class	
Project	Points
P-1	206
P-2	278
P-3	200
P-4	323

The relative weights for the pairwise comparisons were calculating using a rational relationship between the final points for each project given higher value to the project with more points. The procedure for these calculations is shown below:

Weight of P-1 = (Points for P-1) / (Points for P-1 and P-2) * 100
Weight of P-1 = [(206) / (206+278)] * 100 = 50
Weight of P-2 = 100 – 50 = 50

Weights of projects for pair comparisons:

P-1	43	vs.	P-2	57

P-1	51	vs.	P-3	49

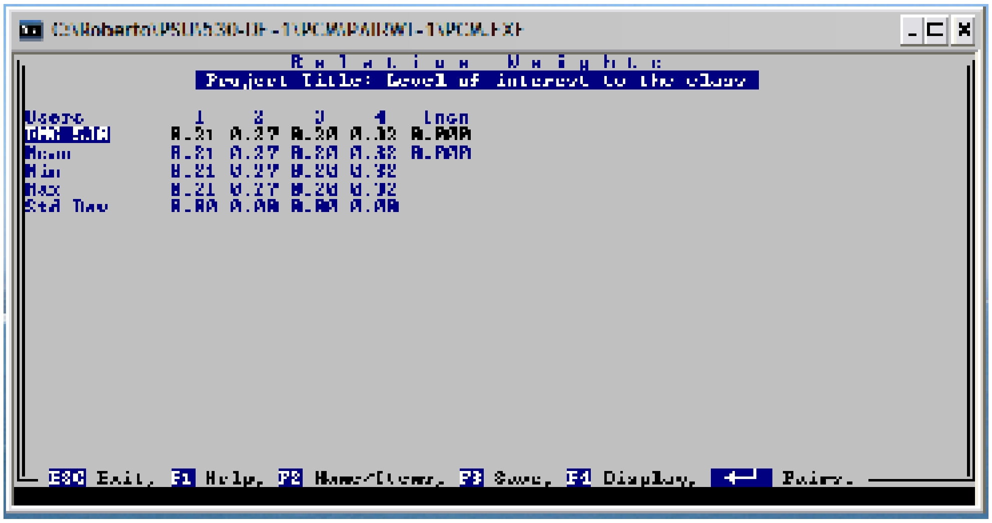
P-1	39	vs.	P-4	61

P-2	58	vs.	P-3	42

P-2	46	vs.	P-4	54

P-3	38	vs.	P-4	62

PCM software results:



EMGT 530/630

Team 1

Comparable Examples

P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

The following table shows the ranking system utilized by team 1 for the comparable examples to the four project choices:

Ranking of comparable examples	
Description	Points
Being done by most companies in the US	5
Often being done by companies in the US	4
Occasionally being done by companies in the US	3
Hardly being done by companies in the in the US	2
Not being done by companies in the US	1

The four project options were ranked according to the above table as shown below:

Number of Experts Available		
Project	Results	Justification
P-1	5	It is safe to assume that most companies do these analysis when they buy their fleet vehicles
P-2	1	No nuclear plants have been ordered since 1978 in the US, more than 100 reactors have been canceled, including all ordered after 1973. No units are currently under active construction; the Tennessee Valley Authority's Watts Bar 1 reactor, ordered in 1970 and licensed to operate in 1996, was the most recent U.S. nuclear unit to be completed.
P-3	3	In the US, the control of Hg in offgas from wastewater sludge incineration has not been widely practiced, and Hg emissions from sludge incineration are a small but measurable component of emissions inventories according to the USEPA.
P-4	5	Most schools have management learning systems in place

The relative weights for the pairwise comparisons were calculated using a rational relationship between each project giving higher value to project with more points. The procedure for the calculations is shown below:

Weight of P-i = [(# of examples for P-i) / (# of examples for P-i and P-j)] * 100

Weight of P-j = 100 – Weight of P-i

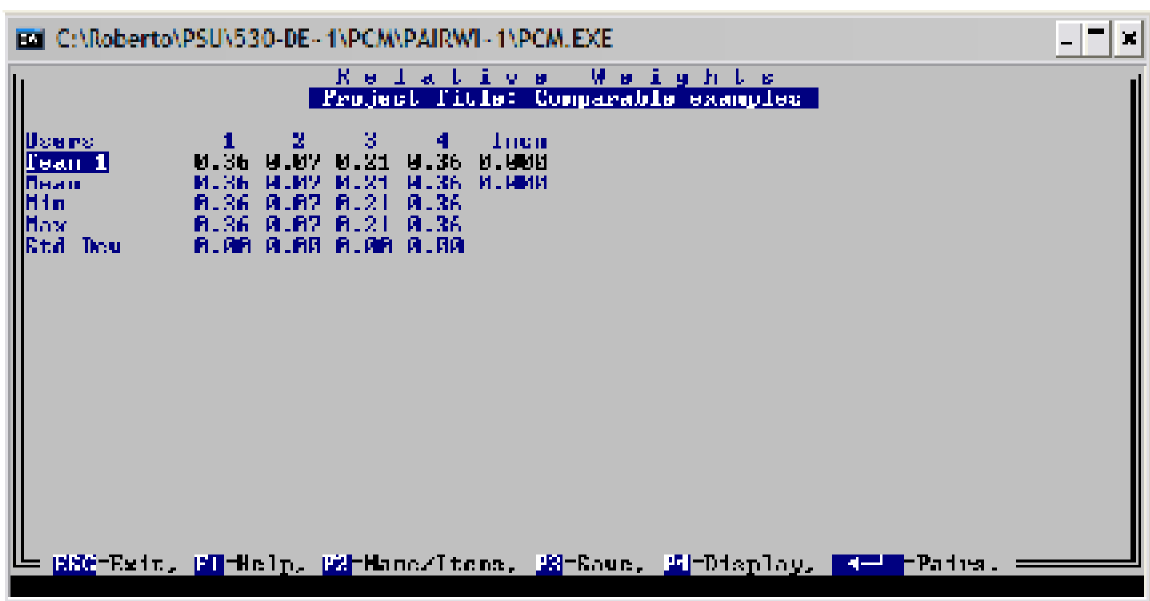
For instance:

Weight of P-1 = (# of examples for P-1) / (# of examples for P-1 and P-3)
Weight of P-1 = [(5) / (5+1)] * 100 = 83
Weight of P-2 = 100 – 50 = 17

Weights of projects for pair comparisons:

P-1	83	vs.	P-2	17
P-1	50	vs.	P-4	50
P-2	17	vs.	P-4	83
P-1	63	vs.	P-3	37
P-2	25	vs.	P-3	75
P-3	37	vs.	P-4	63

PCM software results:



EMGT 530/630
Team 1
Areas of Expertise Required

P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

The following table shows the number of areas of expertise identified by team 1 for each project (see appendix A for details):

Areas of expertise required	
Project	Results
P-1	1
P-2	5
P-3	3
P-4	1

The relative weights for the pairwise comparisons were calculated using a rational relationship between each project giving higher value to the project with the lower number. The calculation procedure is shown below:

Weight of P-i = [1 - (# of areas for P-i) / (# of areas for P-i and P-j)] * 100
Weight of P-j = 100 – Weight of P-i

For instance:

Weight of P-1 = [1 - (# of areas for P-1) / (# of areas for P-1 and P-2)] * 100
Weight of P-1 = [1 - (1) / (1+5)] * 100 = 83
Weight of P-2 = 100 – 50 = 17

Weights of projects for pair comparisons:

P-1	83	vs.	P-2	17

P-1	75	vs.	P-3	25

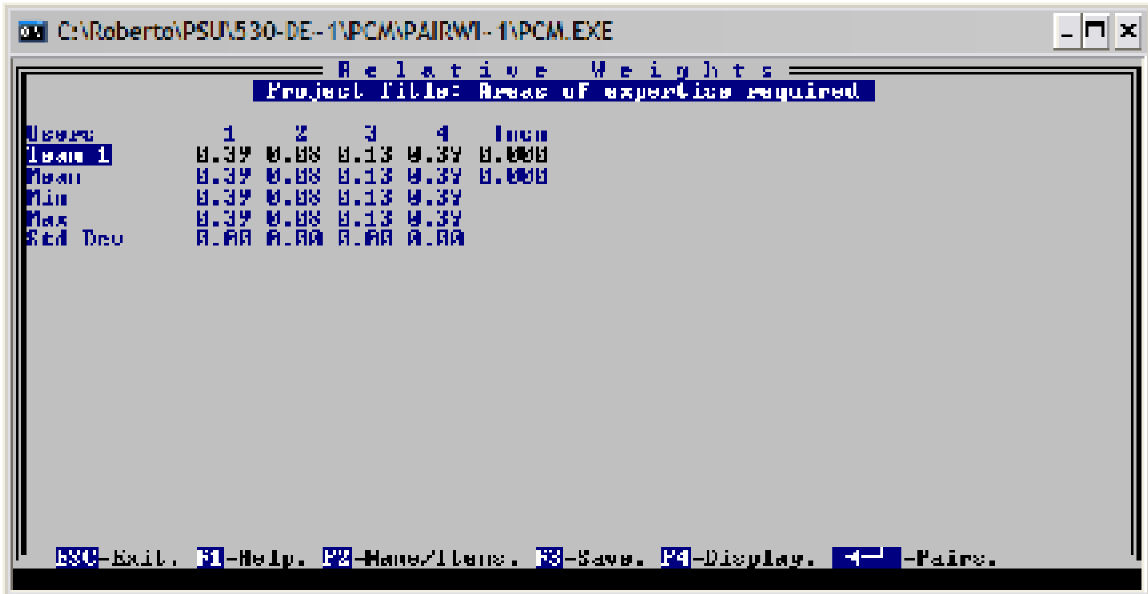
P-1	50	vs.	P-4	50

P-2	37	vs.	P-3	63

P-2	17	vs.	P-4	83

P-3	25	vs.	P-4	75

PCM software results:



EMGT 530/630

Team 1

Estimate Length of the Decision Process

P-1: Selection of fleet of vehicles based on fuel type
P-2: Nuclear technology selection
P-3: Mercury emissions control selection at a local pulp and paper mill
P-4: Selection of a learning management system for PSU

The following table shows the ranking system utilized by team 1 for the estimate time of the decision process for the four project choices:

Ranking for length of the decision process	
Description	Points
Less than 1 month	5
Less than 6 months	4
Less than 1 year	3
Less than 2 years	2
More than 2 years	1

The four project options were ranked according to the above table as shown below:

Length of the decision process		
Project	Results	Justification
P-1	5	The economic analysis for the selection of a fleet of vehicles based on fuel efficiency could be finished in less than a month
P-2	1	Based on the current situation of the energy sector in the US and the current environmental regulations the selection of nuclear technology can easily take more than 2 year
P-3	3	Based on existing data at the local pulp mill, it is very likely that the selection process for these project would take about between 6 months and 1 year
P-4	4	The team member than has been working in this projects considers that the selection process in these project would be from 1 to 3 months

The relative weights for the pairwise comparisons were calculated using a rational relationship between each project giving higher value to the project with the shorter time. The values were calculated as follows:

Weight of P-i = (# of weeks for P-i) / (# of weeks for P-i and P-j) * 100
Weight of P-j = 100 – Weight of P-i

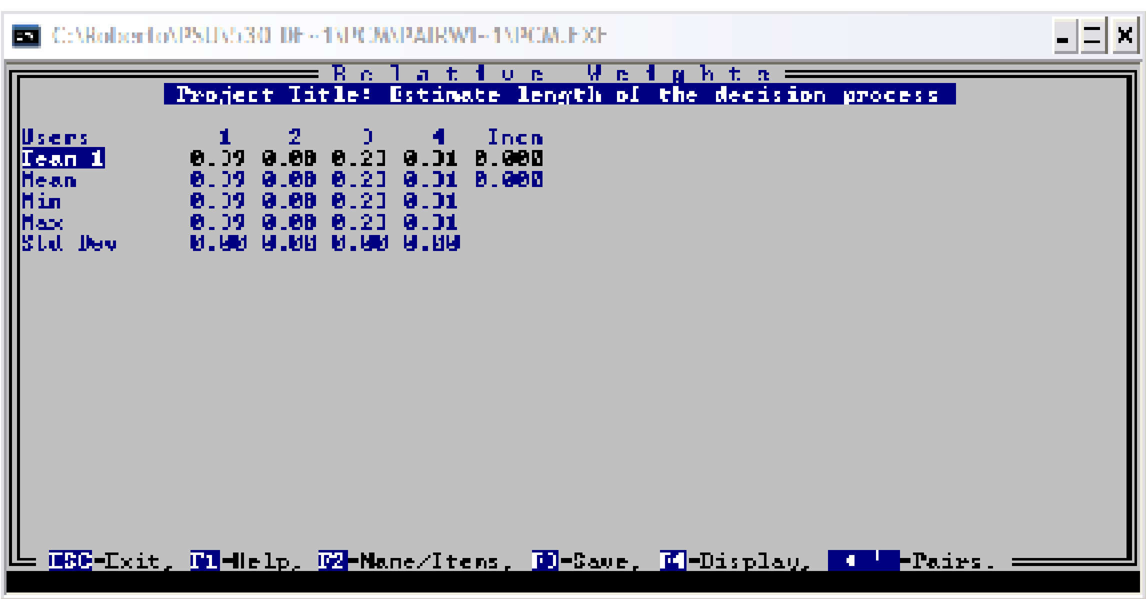
For instance:

Weight of P-1 = (# of weeks for P-1) / (# of weeks for P-1 and P-2) * 100
Weight of P-1 = (5) / (5+1) * 100 = 83
Weight of P-2 = 100 – 50 = 17

Weights of projects for pair comparisons:

P-1	83	vs.	P-2	17	P-1	63	vs.	P-3	37
P-1	56	vs.	P-4	44	P-2	25	vs.	P-3	75
P-2	20	vs.	P-4	80	P-3	43	vs.	P-4	57

PCM software results:



Appendix C
Database and Internet Searches Results

Project Proposal #1 "Selection of fleet of vehicles based on fuel type"

Availability of data

- Number of references

  First search: "diesel" "hybrid" "vehicles"

  ScienceDirect: 1,186 (Only journals for energy and environmental science from 1980 to present)
  Environmental Sciences and Pollution Management: 98
  Compendex: 444

  Second search: "diesel" "hybrid" "cost"

  ScienceDirect: 1,838 (Only journals for energy and environmental science from 1980 to present)
  Environmental Sciences and Pollution Management: 86
  Compendex: 336

  Third search: "diesel" "hybrid" "technologies"

  ScienceDirect: 2,076 (Only journals for energy and environmental science from 1980 to present)
  Environmental Sciences and Pollution Management: 28
  Compendex: 680

Relevance of the topic

- Relevance to the world

  First search: "diesel" "hybrid" "vehicles"

  Google: 559,000
  Yahoo: 19,100,000
  MSN: 5,590,000

  Second search: "diesel" "hybrid" "cost"

  Google: 341,000
  Yahoo: 9,630,000
  MSN: 3,210,000

  Third search: "diesel" "hybrid" "technologies"

  Google: 2,260,000
  Yahoo: 5,840,000
  MSN: 2,290,000

Project Proposal #2 "Nuclear technology selection"

Availability of data

- <u>Number of references</u>
  First search: Nuclear Technology Selection
    ScienceDirect: 8,317 (Only journals for energy and engineering from 1980 to present)
    World Nuclear Association: 49
    Compendex: 4588
  Second search: Nuclear Energy Technologies
    ScienceDirect: 29,156 (Only journals for energy and engineering from 1980 to present)
    World Nuclear Association: 189
    Compendex: 31,187
  Third search: Nuclear Energy Selection
    ScienceDirect: 8,346 (Only journals for energy and engineering from 1980 to present)
    World Nuclear Association: 55
    Compendex: 5,992

Relevance of the data

- <u>Relevance to the world</u>
  First search: Nuclear Technology Selection
    Google: 10,800,000
    Yahoo: 48,600,000
    MSN: 2,500,000
  Second search: Nuclear Energy Technologies
    Google: 27,500,000
    Yahoo: 115,000,000
    MSN: 17,600,000
  Third search: Nuclear Energy Selection
    Google: 753,000
    Yahoo: 38,600,000
    MSN: 2,510,000

Project Proposal #3 "Mercury emissions control selection at a local pulp and paper mill"

Availability of data

- <u>Number of references</u>
  First search: "pulp" "paper" "mercury"
    ScienceDirect: 1,161 (Only journals for chemical engineering and environmental science from 1980 to present)
    Environmental Sciences and Pollution Management: 108
    Compendex: 113
  Second search: "mercury" "emissions" "sludge"
    ScienceDirect: 1,437 (Only journals for chemical engineering and environmental science from 1980 to present)
    Environmental Sciences and Pollution Management: 36
    Compendex: 49
  Third search: "kraft" "pulp" "mercury"
    ScienceDirect: 258 (Only journals for chemical engineering and environmental science from 1980 to present)
    Environmental Sciences and Pollution Management: 16
    Compendex: 20

Relevance of the data

- <u>Relevance to the world</u>
  First search: "pulp" "paper" "mercury"
    Google: 187,000
    Yahoo: 1,850,000
    MSN: 480,000
  Second search: "mercury" "emissions" "sludge"
    Google: 263,000
    Yahoo: 750,000
    MSN: 336,000
  Third search: "kraft" "pulp" "mercury"
    Google: 165,000
    Yahoo: 116,000
    MSN: 92,300

Project Proposal #4 “Selection of a learning management system for PSU”

Availability of data

- Number of references

  First search: Blackboard learning system

  ScienceDirect: 736 (Only journals for computer science from 1980 to present)
  Compendex: 191
  The Chronicle: 16

  Second search: Sakai learning system

  ScienceDirect: 290 (Only journals for computer science from 1980 to present)
  Compendex: 84
  The Chronicle: 5

  Third search: Moodle learning system

  ScienceDirect: 15 (Only journals for computer science from 1980 to present)
  Compendex: 87
  The Chronicle: 3

Relevance of the data

- Relevance to the world

  First search: “Blackboard” “system”

  Google: 277,000
  Yahoo: 20,100,000
  MSN: 2,380,000

  Second search: “Sakai” “system”

  Google: 3,010,000
  Yahoo: 4,890,000
  MSN: 912,000

  Third search: “Moodle” “system”

  Google: 3,680,000
  Yahoo: 10,900,000
  MSN: 212,000