USING THE ANALYTIC HIERARCHY PROCESS IN GROUP DECISION MAKING FOR NUCLEAR SPARE PARTS

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Abstract
The Analytic Hierarchy Process (AHP) is an established decision method used to synthesize judgments and select the best alternative. The AHP literature extensively discusses both theory and case studies for judgments made by one person. However, instances exist when the judgments of a group of individuals are needed for accurate knowledge representation and robust decision making. One such instance is spare parts processes for nuclear electricity plants. Elicitation of group knowledge is necessary because each work group may have different experiences and attitudes towards spare parts management. This paper presents an interview protocol used for group knowledge elicitation using AHP for nuclear spare parts inventory management. Inconsistencies in the data and challenges in AHP group aggregation are examined. A numerical example of employee responses is included. This research benefits the engineering manager by presenting a methodology to collect a range of knowledge across work groups. The authors' overall decision tool supports existing corporate culture while striving for continuous process improvement.

Key Words
Analytic Hierarchy Process (AHP), group decision making, spare parts inventory, electric utilities

Introduction
Approximately 20% of the U.S. electricity is generated through the use of nuclear power (DOE, 2010). Most plants in the U.S. are aging, and construction of new plants is being considered (NEI, 2010). Nuclear power itself is inexpensive to generate, but plants have both high capital and operations and maintenance costs. One such cost is spare parts inventory for the plant. Spare parts inventory has reached all time highs at some facilities, and operators typically purchase parts in the name of plant safety (Scala et al., 2010). However, plants have built-in safety systems to shut down the plant and prevent catastrophe if an issue occurrs and the plant becomes compromised in some way; in essence, parts are kept in stock to prevent revenue loss from off-lining the plant due to a mechanical failure (Scala et al., 2009a). Furthermore, public perception of nuclear power has always been risk-averse (Mullet et al., 1998). Any small or routine de-rate can cause media coverage and public concern, damaging the company's reputation. As a result, spare parts tend to be stockpiled in inventory.

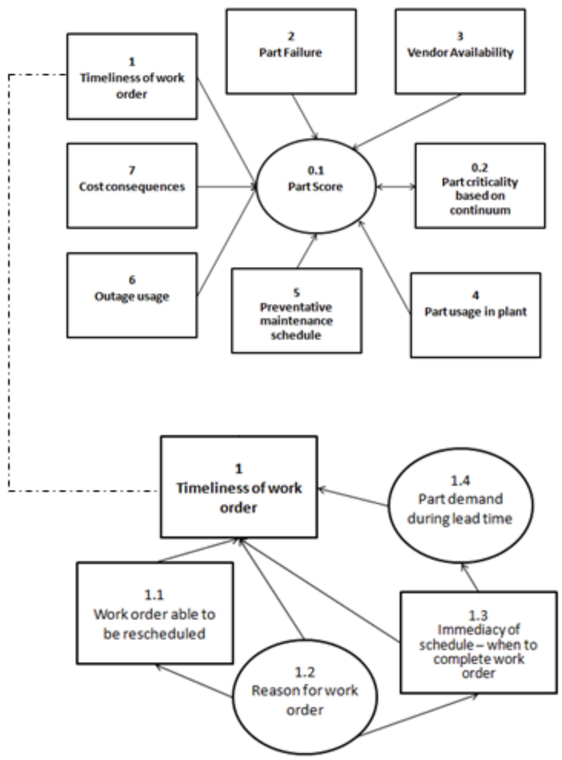
Furthermore, deregulation has changed the way utility companies do business. Before deregulation, companies received full recovery of costs of doing business plus a rate of return. Spare parts are a cost of doing business, so incentive did not exist for companies to reduce inventory. Now that a majority of states are deregulated, utilities are no longer guaranteed recovery for their costs and must operate like other competitive U.S. businesses. A shift in thinking and operating is needed, which can be difficult for the utilities' aging workforce (Scala et al., 2009b).

The authors are undertaking a large research project to improve spare parts inventory management at U.S. nuclear power plants. The goal of the project is to develop a spare parts inventory model that mitigates the risk of revenue loss from off-lining the plant. Employee knowledge is a crucial component to the model, and the authors have partnered with a Fortune 200 utility holding company as a case study. One aspect of the model is to synthesize employee knowledge across all plant work groups, not just the supply chain group. The Analytic Hierarchy Process (AHP) is an excellent decision making tool for such synthesis, and the authors are employing it along with influence diagrams to build a spare parts inventory decision model. A decision tool, such as AHP, is needed in this situation because traditional forecasting models for inventory are not appropriate, as the demands for spare parts are extremely small and intermittent (Scala et al., 2009a). Further discussion regarding spare parts demands and the corresponding inventory problem can be found in (Scala et al., 2009a; 2009b; 2010).

Motivation
The authors have constructed an influence diagram to capture all relevant factors and forces in the spare parts problem at the case study company (Scala et al., 2010). The influences form a basis to consider the problem beyond traditional supply chain concepts. The considerations and thought process by every group that

makes spare parts decisions in the plant are represented in the influence diagram. A copy of the high-level influence diagram is shown below in Exhibit 1 along with detail from the Timeliness of Work Order group. Further discussion along with a complete list of influences in each group can be found in (Scala et al., 2010).

Exhibit 1. High-level Influence Diagram and Detail for Timeliness of Work Order Group (Scala et al., 2010).



Because the authors are considering relevant influences across work groups, group judgment of the influences on the diagram is needed. One employee's perspective is simply not enough for knowledge representation and robust decision making. Employees have limited overall plant knowledge but detailed experience within their work groups. Spare parts management is a systematic problem throughout the entire plant and is not isolated to one group. Varied information from multiple employees and work groups is needed to represent what is really happening in the process. Furthermore, incorporating the perspectives of many employees in various groups will help to record the employees' unwritten knowledge accumulated over years of work experience. As employees retire and leave the company, the corresponding spare parts knowledge will not be lost.

The AHP is an excellent way to capture and synthesize qualitative knowledge, even from a group. The AHP is a decision tool developed by Thomas Saaty (1980). It supports decision making by synthesizing pairwise comparisons of decision attributes across alternatives and calculating priorities (Saaty, 1980; 1990). Because the model involves pairwise comparisons, qualitative items can be compared, judged, and ranked. This feature lends itself to spare parts management and process influences. Overall, the AHP supports both an engineering management perspective of spare parts and the integration of the process among multiple work groups at a nuclear plant, demonstrating the effects of decision making beyond the typical supply chain and plant maintenance groups.

The Analytic Hierarchy Process and Group Decision Making

The main construction of the AHP is a hierarchy with the goal of the analysis at the top, a listing of decision attributes in the middle tiers, and a bottom tier of decision alternatives. Pairwise comparisons between each set of alternatives or attributes on the level below are made with respect to the attributes in the next highest level. For example, if a problem has three attributes and five alternatives, pairwise comparisons between all five alternatives would be done three times, one time each with respect to the first attribute, then the second attribute, and finally the third attribute. Pairwise comparisons involve selecting which item is more important with respect to the attribute and then stating how much more important the item is over the other item. The pairwise comparisons are then synthesized through the use of linear algebra, and priorities for each attribute are given. The priorities are normalized to sum to one, and the priority with the highest value is said to be the best alternative (Saaty 1980; 1990).

The AHP has been used in a wide variety of applications. Such applications include politics, technology, marketing, material handling, conflict resolution, and medicine and are summarized in Zahedi (1986), Vargas (1990), and Vaidya and Kumar (2006). The AHP has also been used as a forecasting tool, as reviewed in Vaidya and Kumar (2006), including for forecasting inventory (Korpela and Tuominen, 1997). However, to our knowledge, the AHP has not been used until now in spare parts inventory forecasting and management.

The AHP can also be used to synthesize group judgments. In this situation, individuals perform pairwise comparisons, and the set of comparisons are aggregated into one combined set of judgments. The geometric mean is typically used to aggregate judgments, as it preserves the axioms of the AHP

(Aczél and Saaty, 1983). Typically, the geometric mean of the judgments is taken without question or testing; see examples in Liberatore and Nydick (1997) and Armacost et al. (1999). However, Saaty and Vargas (2007) recently introduced the concept of dispersion around the geometric mean. Based on this development, the geometric mean can no longer be automatically used without first performing a statistical test for dispersion around the mean. Too much dispersion, a form of variance, around the mean introduces variability in the model and violates Pareto Optimality, meaning the group is homogeneous in some paired comparisons and heterogeneous in others (Saaty and Vargas, 2007). Because group homogeneity needs to be preserved in the AHP, the geometric mean can now only be used provided that dispersion is not violated.

Another method of AHP group aggregation has been developed by Basak (1988) and Basak and Saaty (1993). This method takes a statistical approach to the AHP and advocates putting the judgments into groups and then testing for the homogeneity of the groups. However, Basak (1988) and Basak and Saaty (1993) do not provide direction on how to place the judgments into groups nor direction on which group is best to use for the overall aggregated judgments. The method is not practical to use.

For this research, the authors proceeded with group knowledge elicitation due to its many benefits to and uses in the spare parts problem, while considering dispersion around the geometric mean. The following sections outline the interview protocol used in group elicitation, examples of employee responses, and discussion regarding both aggregation of the judgments and open research questions.

Interview Protocol

The influence diagram for the spare parts process contained 34 total influences which were first placed into groups according to case study company work functions that had collective knowledge of a group of similar items (Scala et al., 2010). A team of analysts at the case study company verified the influences to correspond with the knowledge areas. Seven overall groups of influences were constructed; see Exhibit 2 for a list and description of groups. The manager or leader of each work group was then asked to provide the contact information for five employees that could make the AHP pairwise comparisons between the items in the group. Some work groups have overlapping functionality, so some managers were asked to provide contact information for multiple groups. Also, some employees had overlapping knowledge and were asked to make comparisons for multiple groups. In total, 25 employees were contacted for the pairwise comparison interviews. The various knowledge areas and work locations of these employees aimed to capture multiple opinions and perspectives to the spare parts process as well as various approaches to work.

Exhibit 2. List and Description of Influence Groups.

Influence Group	**Description**
Timeliness of work order	Refers to when the work order can be completed and the associated parts that will be required to complete the work order.
Part failure	Refers to the various indicators that could predict an imminent or future part failure.
Vendor availability	Refers to the ability of vendors to supply spare parts when needed and the ease with which they can be procured.
Part usage in plant	Refers to the volume and frequency with which a spare part is installed / used in the plant.
Preventative maintenance (PM) schedule	Refers to activities associated with PM, corresponding maintenance rules, and how parts are selected to be included on a PM work order.
Outage usage	Refers to the parts requested for use during plant outage and when the related work orders can be carried out.
Cost consequences	Refers to system-wide costs incurred if the plant has to be off-lined or de-rated.

The AHP was used in the pairwise comparison interviews. Employees were asked to make pairwise comparisons between each possible pair of influences in the group, selecting which of the two items was more important in the spare parts process and stating how much so by using Saaty's Fundamental Scale of

Absolute Numbers (Saaty, 1980; 1990). The basic scale ranges from odd numbers one to nine, corresponding to qualitative descriptions of importance. In an attempt to simplify the scale, provide clarity, and prevent inconsistency in responses, nine was not an option for employees in this process. Eliminating nine from the scale prevents extreme values and helps to keep the comparisons homogeneous. If nine is used in one comparison, then all other pairwise comparisons in that group need to have values less than nine, or they all have to be nine. Nine is the most extreme value on the scale, and nothing can exceed it (Vargas, 2010). However, the authors adhered to the relational importance defined by Saaty for values one to seven. Exhibit 3 depicts the ratio scale for values one to seven on the Fundamental Scale and the corresponding explanations for those numbers (Saaty, 1980; Saaty, 1990). Respondents were sent a list of the items to compare along with a description of the influence group from Exhibit 2 approximately two to three business days before the interview. Employees were also provided with an example of making pairwise comparisons when buying a car – such an example is easy to understand for those who are not familiar with pairwise comparisons or the AHP process. Employees interviewed were geographically dispersed over six work locations in two states, so a phone interview process was most appropriate. The phone interview lasted approximately fifteen to twenty minutes, and the respondents' judgments were recorded in the SuperDecisions software, which is a widely accepted software package for Analytic Hierarchy Process / Analytic Network Process analysis (www.superdecisions.com).

Exhibit 3. Ratio Scale Values and Corresponding Descriptions (Saaty, 1980; Saaty, 1990).

Number	**Description**
1	*A* and *B* are *equally* important
3	*A* is *weakly* more important than *B*
5	*A* is *strongly* more important than *B*
7	*A* is *very strongly* more important than *B*

AHP inconsistency of employee answers was checked after the phone interview; employees were then contacted in a follow-up phone call to clarify answers and improve inconsistency. In the follow-up call, respondents were asked to reconsider the most inconsistent answers in order of most inconsistent to least inconsistent as indentified by the SuperDecisions software. Once a response was modified, the software's inconsistency analysis was re-run. The employee was then asked to reconsider the newest most inconsistent item and then so on as identified by SuperDecisions. In some instances, the employees chose to modify their responses. In other instances, the employees wanted to keep the previous answer. The authors did not force the employees to change their answers. However, respondents were asked to modify answers until either the AHP inconsistency ratio fell below 0.20 or until there were no more comparisons to modify. It was not always possible to improve the inconsistency ratio below 0.20 given that some employees did not want to modify highly inconsistent answers. The authors are aware that Saaty recommends an inconsistency ratio of .10 or less (Saaty, 1980; 1990). However, this is a guideline. Inconsistency is not error but rather variation in the data. Because the authors plan to combine the judgments, an inconsistency ratio for greater than 0.10 at the individual level does not degrade the results. The inconsistency of the combined judgments will be less than the greatest inconsistency in an individual judgment in that group (Vargas, 2010). Therefore, the authors aimed for inconsistency at 0.20 or lower to ensure reasonable results once the results were aggregated. Furthermore, some influence groups contain seven or eight items, causing quite a few (21 or 28, respectively) pairwise comparisons. It can be rather difficult for a decision maker to keep all the comparisons clear and consistent when making many judgments, so relaxing the inconsistency ratio to 0.20 or less is appropriate for the empirical data in this study.

Example of Employee Responses

To illustrate the interview process, an example of two employee responses in the Timeliness of Work Order group is outlined below.

The Timeliness of Work Order group is the first group of influences and is described in detail in Scala et al. (2010). There are four influences in this group and the corresponding pairwise comparisons for these influences are shown in Exhibit 4. Employee #15 is an online work week manager in the work management department at the case study company. His judgments along with synthesized AHP priorities and corresponding inconsistency ratio are shown in Exhibits 5 and 7. Employee #18 is an outage scheduling supervisor at the case study company. He provided the judgments shown in Exhibit 6, with AHP priorities and inconsistency ratio in Exhibit 8.

Note that the original inconsistency is high for both employees #15 and #18. The employees were asked to revise their judgments, and the revised outcomes are shown in Exhibits 9, 10, 11, and 12. Clearly, the follow-up phone call process provided

Exhibit 4. Pairwise Comparisons in the Timeliness of Work Order Group.

Column A	vs.	Column B
1.1 If work order is able to be rescheduled		1.2 Reason for the work order
1.1 If work order is able to be rescheduled		1.3 When to complete the work order (immediacy of schedule)
1.1 If work order is able to be rescheduled		1.4 Additional part demand during work order lead time
1.2 Reason for the work order		1.3 When to complete the work order (immediacy of schedule)
1.2 Reason for the work order		1.4 Additional part demand during work order lead time
1.3 When to complete the work order (immediacy of schedule)		1.4 Additional part demand during work order lead time

Exhibit 5. Employee #15 Original Judgments.

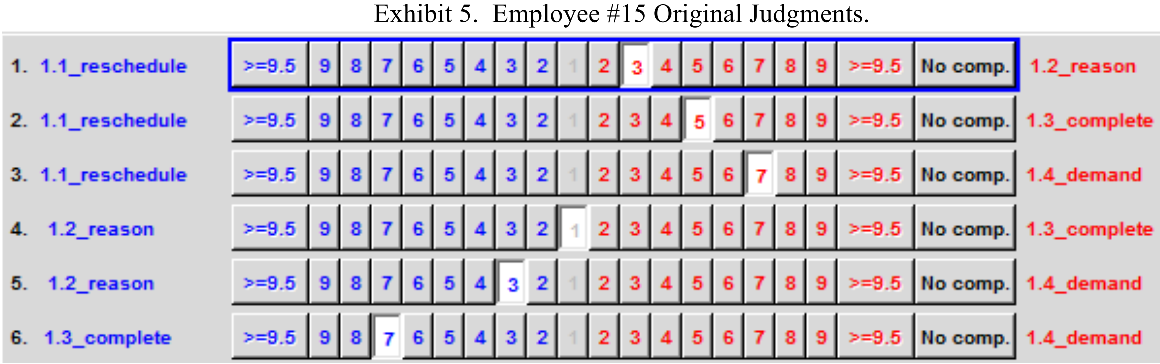


Exhibit 6. Employee #18 Original Judgments.

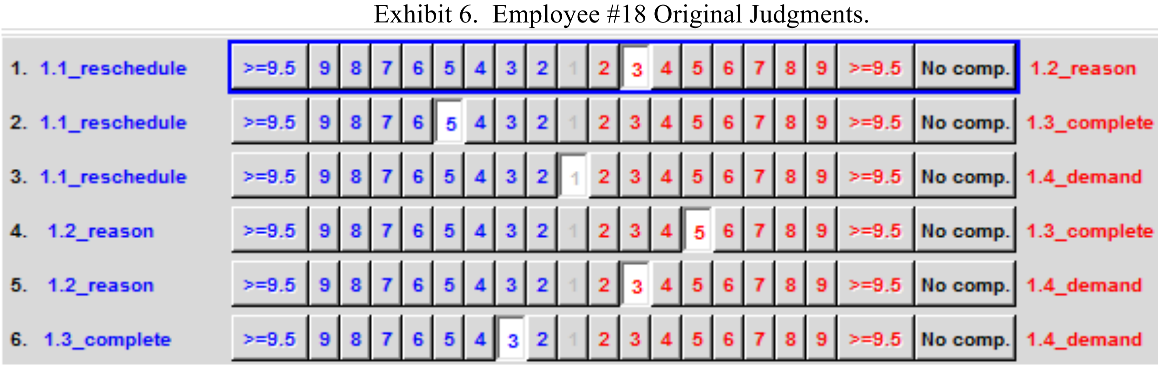


Exhibit 7. Employee #15 Original Priorities and Inconsistency.

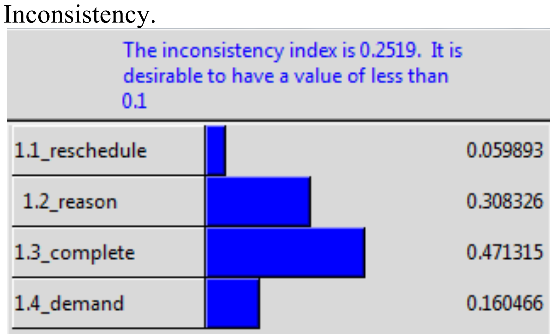


Exhibit 8. Employee #18 Original Priorities and Inconsistency.

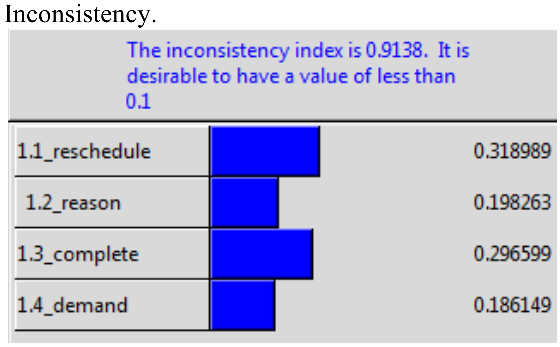


Exhibit 9. Employee #15 Revised Judgments.

Exhibit 10. Employee #18 Revised Judgments.

Exhibit 11. Employee #15 Revised Priorities.

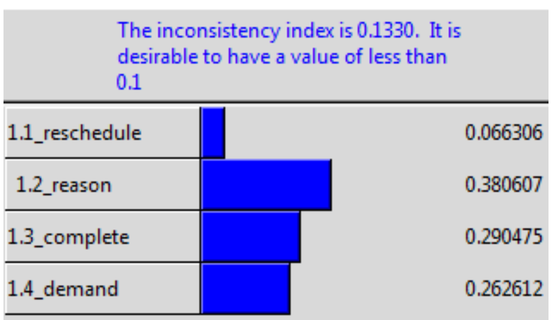
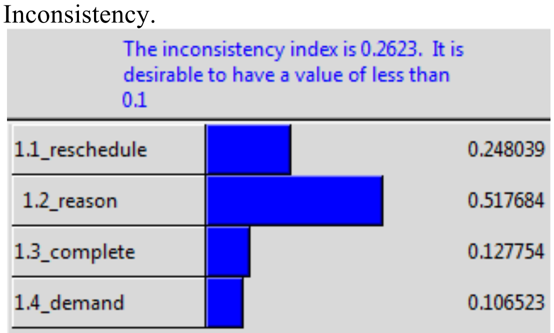


Exhibit 12. Employee #18 Revised Priorities and Inconsistency.



improvement in Employee #15's score, as his inconsistency ratio is now under 0.20. Employee #18 changed some answers but not enough responses to lower his inconsistency under 0.20. These are the best results the researchers could obtain for the individual respondents without forcing the participants to change answers. Taking this approach allows for the most consistent answers while preventing the data from being skewed or interfered with by a third party. The individual decision makers' perspectives and attitudes toward the current spare parts process are thus accurately reflected. However, the overall AHP process and hierarchy considers one set of judgments. The five sets of responses will need to be aggregated into one set of judgments. The researchers plan to use these aggregated responses in an inventory model to synthesize all influence groups and determine priority weights for individual influences. The following section describes the process of AHP aggregation and subsequent data limitations.

Group Aggregation

The revised judgments for the five decision makers in the Timeliness of Work Order group are shown in matrix form in Exhibit 13. Note that Employee #15 is the second entry in each set of judgments and Employee #18 is the third entry. Employee numbers 16, 17, and 14 are also included in this group. Before using the geometric mean to aggregate responses, the authors performed the dispersion test as outlined in Saaty and Vargas (2007) and found that all sets of judgments failed the test, implying too much dispersion around the geometric mean. Therefore, the geometric mean cannot be used, and another method of group aggregation is needed to aggregate the appropriate results for these data, as the Basak (1988) and Basak and Saaty (1993) method has too many limitations for practice. In theory, researchers should return to the decision makers to revise judgments when the geometric mean cannot be accurately used. However, the authors did follow-up with respondents and found that the employees did not always wish to modify their judgments. Therefore, dispersion could not always be improved. Due to the limitations and impracticality of the Basak (1988) and Basak and Saaty (1993) method, another method is clearly needed to address AHP group aggregation when dispersion around the geometric mean is violated and respondents are unwilling or unable to revise their judgments. The researchers are in the process of developing such a method through the use of principal components analysis (PCA). A principal component is a linear combination of optimally weighted variables to account for variance (SAS, 2007). The first principal component accounts for the maximum amount of total variance in the data by calculating an eigenvector (SAS, 2007). Use of PCA is expected to account for the variance around the mean while adhering to the typical use of eigenvectors for AHP prioritization.

Exhibit 13. Revised Judgments for All Respondents in the Timeliness of Work Order Group.

		Judgments			
	vs.	1.1	1.2	1.3	1.4
Judgments	1.1	1	3, 1/3, 1/3, 1/7, 1/5	1/3, 1/5, 5, 1/5, 1/5	3, 1/7, 1, 1/3, 5
	1.2		1	1/5, 1, 5, 1, 1/5	1/3, 3, 5, 5, 3
	1.3			1	5, 1, 3, 5, 1/7
	1.4				1

Conclusions and Future Work

Existing AHP aggregation methods in the literature expect decision makers to revise their judgments to reach consensus and prevent dispersion. However, this may not happen in actuality. If the decision makers were gathered together in one location, they could have possibly reached group consensus through discussion. However, the work locations were geographically scattered, preventing the employees from meeting together. As a result, the data collection was more of a questionnaire than discussion process, and dispersion was prevalent in the employee responses. This dispersion reflects both the varied employee work group backgrounds and experiences and what those groups deem to be important in their work. This is necessary to capture in the model, but a way to address the needed spread and dispersion of the judgments data is needed. The authors' ongoing research of using PCA to combine judgments and calculate AHP priorities aims to address this issue. Once the judgments are combined, the authors plan to use the aggregated priorities as weights for the influences in a corresponding inventory decision making model for spare parts.

This overall research benefits the engineering manager by developing an inventory decision tool that balances existing corporate culture with continuous improvement initiatives. The use of AHP and aggregation of group judgments allows for representation of the range of knowledge and expectations across work groups and locations. The proposed methodology collects the experiences of multiple employees and synthesizes their qualitative data into a set of priorities for the influences to the spare parts process. The varied employee opinions can be brought together in a format that represents the overall goals and needs of the case study company, while recording critical knowledge of employees on the verge of retirement or attrition. The process of identifying influences and weighing them through group aggregation of the AHP, whether or not dispersion around the mean exists, can be applied in a multitude of corporate settings and to a varied set of decision making needs, beyond spare parts. Such studies will capture corporate knowledge and balance corporate culture and decision making through continuous improvement and improved business practices.

References

Aczél, J., and Saaty, T. L., "Procedures for Synthesizing Ratio Judgements," *Journal of Mathematical Psychology, 27* (1983), pp. 93-102.

Armacost, Robert L., Jamshid C. Hosseini, and Julia Pet-Edwards, "Using the Analytic Heirarchy Process as a Two-phase Integrated Decision Approach for Large Nominal Groups," *Group Decision and Negogiation, 8* (1999), pp. 535-555.

Basak, I., "When to Combine Group Judgments and When Not to in the Analytic Hierarchy Process: A New Method," *Mathematical and Computer Modelling*, *10*:6 (1988), pp. 395-404.

Basak, Indrani, and Thomas Saaty, "Group Decision Making Using the Analytic Hierarchy Process," *Mathematical and Computer Modelling*, *17*:4-5 (1993), pp. 101-109.

Creative Decisions Foundation, "SuperDecisions Software for Decision Making," http://www.superdecisions.com/ (April 26, 2010).

Korpela, Jukka, and Markku Tuominen, "Inventory Forecasting with a Multiple Criteria Decision Tool," *International Journal of Production Economics, 45:*1-3 (1996), pp. 159-168.

Liberatore, Matthew J., and Robert L. Nydick, "Group Decision Making in Higher Education Using the Analytic Hierarchy Porcess," *Research in Higher Education, 38:*5 (1997), pp. 593-614.

Mullet, Etienne, Makhlouf Ben Bouazza, Véronique Dupont, and Anne Bertrand, "Risk Perception and Energy Production," *Human and Ecological Risk Assessment, 4*:1 (1998), pp. 153-175.

Nuclear Energy Institute, "Key Issues: Building New Nuclear Plants," http://www.nei.org/keyissues/newnuclearplants/buildingnewnuclearplants/# (May 1, 2010).

Saaty, Thomas L., "How to Make A Decision: The Analytic Hierarchy Process," *European Journal of Operational Research, 48* (1990), pp. 9-26.

Saaty, Thomas L., *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, McGraw-Hill (1980).

Saaty, Thomas L., and Luis G. Vargas, "Dispersion of Group Judgments," *Mathematical and Computer Modelling, 46* (2007), pp. 918-925.

SAS Institute Inc., "Chapter 1: Principal Components Analysis," 2007, http://support.sas.com/publishing/pubcat/chaps/55129.pdf (February 16, 2010).

Scala, Natalie M., Kim LaScola Needy, and Jayant Rajgopal, "Decision Making and Tradeoffs in the Management of Spare Parts Inventory at Utilities," *Proceedings of the 30th National Conference of ASEM,* Springfield, Missouri (October 14 – 17, 2009a).

Scala, Natalie M., Jayant Rajgopal, and Kim LaScola Needy, "Influence Diagram Modeling of Nuclear Spare Parts Process," *Proceedings of the 2010 Industrial Engineering Research Conference*, Cancún, Mexico (June 6-9, 2010).

Scala, Natalie M., Jayant Rajgopal, and Kim LaScola Needy, "Risk and Spare Parts Inventory in Electric Utilities," *Proceedings of the 2009 Industrial Engineering Research Conference,* Miami, Flordia (May 30 – June 3, 2009b), pp. 1351-1356.

United States Energy Information Administration, "Electric Power Monthly: April 2010," http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html (April 30, 2010).

Viadya, Omkarprasad S., and Sushil Kumar, "Analytic Hierarchy Process: An Overview of Applications," *European Journal of Operational Research*, *169* (2006), pp. 1-29.

Vargas, Luis G., "An Overview of the Analytic Hierarchy Process and its Applications," *European Journal of Operational Research, 48* (1990), pp. 2-8.

Vargas, Luis, Personal Communication, April 28,2010.

Zahedi, Fatemeh, "The Analytic Hierarchy Process – A Survey of the Method and its Applications," *Interfaces, 16*:4 (1986), pp. 96-108.

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Thank you for your interest in this research!

Here is some helpful information for citing the paper.

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