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CLINICAL ENGINEERING TECHNOLOGY ASSESSMENT DECISION SUPPORT: A Case Study Using the Analytic Hierarchy Process (AHP)

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I. INTRODUCTION

This article describes a case study using the Analytic Hierarchy Process (AHP) to perform a microeconomic Health Technology Assessment (HTA) on neonatal ventilators for a women's health facility. AHP is a well-developed decision support tool that allows the user to design a clear hierarchical structure for decision-making and documents and weighs the trade-offs between different decision criteria and alternatives [1, 2]. AHP also has documented applications for product selection [3]. This study shows that AHP facilitates the interdepartmental interactions needed to evaluate an expensive technology in today's healthcare environment. Also, the AHP-based process accommodates the evolving knowledge and understanding of the hospital participants. Finally, the study documents show the how AHP allows resolution of the conflicting decision criteria and that a modern hospital must consider when making capital equipment decisions that affect medical care by pairwise comparisons of the importance of each criteria.

In this study, the decision weight for the cost criteria is different than documented in many other AHP-based purchasing decisions because of the implicit life-and-death nature of the tradeoffs. Although reducing the cost of healthcare delivery is desirable, the savings can be misleading if a wrong alternative increases the risk of patient injury, or death.

II. METHODOLOGY

The 500-bed, tertiary care hospital studied is a major trauma center and teaching institution in the suburbs of one of the top 10 US cities (by population). It is one of the few independent hospitals in the region. In 2000, it had one of the largest obstetrics programs in its region, with approximately 4400 deliveries. There were over 400 admissions to the 25-bed NICU, including neonates transferred from other area hospitals.

Ventilators for neonates range in price from $18,000-$40,000, and each one has very different features. Also, the ventilators have a very significant life-cycle cost of ownership due to supplies and maintenance requirements, which can dwarf the initial purchase price. The hospital needs to purchase two dozen or more units for a new NICU. When combined with 5 to 10 year life cycle costs of supplies, maintenance, and repairs, the purchasing decision for 24 neonatal ventilators becomes a million dollar commitment. In addition, competent clinical and technical training and support are needed for a decade or more for safe and effective patient care, so the staffing costs are significant. Because of the large overall investment that neonatal ventilators require, a senior clinical engineer (CE) and respiratory therapist (RT) agreed to be help build the AHP model for this study.

The Expert Choice 2000 implementation of AHP was chosen for this study because it provides a mixture of graphical tools that supplement the numeric computations. In the authors' prior research activities the graphics features proved to be a very valuable way of demonstrating to decision makers how the AHP model works and helps ensure buy-in and confidence in the AHP process.

The AHP model was designed and implemented in a series of six iterations of meetings with the CE and RT.

Table 1 Evolution of the AHP model

Iteration	Info Source*	Primary Criteria	Secondary Criteria	Additional Criteria		Rating Criteria
1	Authors, CE	4	19	0	0	19
2	CE	4	21	26	0	39
3	CE & RT	4	22	29	0	42
4	CE	4	23	33	0	46
5	CE	4	20	35	2	46
6	RT	4	20	35	2	46
AHP Hierarchy Level		Level 1	Level 2	Level 3	Level 4	"bottom"

Table 1 shows the iterative evolution of the AHP model. This table shows the individual whose input was used and the primary, secondary, and additional criteria categories that were created. This table also lists the total number of criteria and the total number of bottom-level criteria. (In this context, bottom-level criteria are those on which each alternative is evaluated).

Criterion weights were derived by having the CE and RT do pairwise comparisons of the importance of each criterion against every other criterion in the same group. After consideration of the large number of bottom-level criteria in the final model (46), and the potential number of alternative neonatal ventilators that could be considered (as many as a dozen or more), the authors believed that pairwise comparison of the alternatives for each criterion was not tractable. As a result, a rating hierarchy was used to evaluate alternatives. The rating approach differs from pairwise comparison of alternatives in that individual ratings weights can be defined for each criterion. Rating the alternate ventilators offered another advantage in that the hospital staff is familiar with the use of similar techniques like Apgar Scores for clinical assessments.

The first model (Iteration 1) was a prototype generated by one of the authors to bootstrap the discussion with the CE. The initial discussion with the CE resulted in an AHP model that had four criteria at the first level and 19 at the second level. The model was formulated by using published reports from ECRI's Health Devices Journal [4], and Product Comparison Reports[5], from manufacturer's specifications, and from online information from Amethyst Research's web site [6]. The CE was asked to look at the categories that had been prepared and contribute his initial reactions. He was asked to fill in the pairwise comparison matrix for the criteria to show him how Expert Choice worked. Five more iterations were needed for the CE and RT to agree that the design was complete.

In the final model, the top-level groups were Safety, Clinical Factors, Biomedical Engineering, and Cost, with decision weights of 0.32, 0.30, 0.22, and 0.16 respectively. The low (16%) weight of Cost in this hospital's model is considerably different that found in other business decision models that have been published [7], reflecting the relative importance of the other criterion categories in healthcare.

Lastly ventilator options were evaluated using the AHP model. Option 1 was the current production version of the incumbent ventilator, featuring digital displays and more flexible adjustments and alarms. Option 2 was one of the latest ventilator models available, and features a very flexible selection of many advanced operating modes and alarms. The hospital has successfully deployed a few of the Option 2 ventilators in the NICU and is very pleased with the results. Option 3 was the incumbent ventilator, a reliable but old (20+ years) design that is no longer in production. However, this unit has proved generally adequate and reliable for the hospital and can be purchased in used condition from other hospitals.

Table 2 Sample ratings for the ventilator alternatives

Criteria Category	Option 1	Option 2	Option 3
Daily maintenance requirements: Pre-use checkout	Simple	Very intensive	Simple
Alarm system unique sounds & prioritization	Minimal/ none	Large number	Minimal/ none
Responsive Valve Feature	Limited	Excellent	Limited
Factory support: Service documentation	Excellent	Limited availability	Excellent
Training program	No staff training	2 Staff Training	No staff training

Table 2 shows samples of the ratings that each of the neonatal ventilators was assigned. As can be seen, each criterion can have different rating descriptions, and each alternative is seen to have unique ratings in each criterion.

III. RESULTS

Options 1 and 3 were better than Option 2 for some criteria, but Option 2 turned out to be the best overall. When all of the 46 bottom-level (rating) criteria were evaluated, Option 2 had the highest overall score (.46), Option 1 was second (.31), followed by Option 3 (.23). In general, Option 3's obsolete design did not score well, and it was further damaged by the limited repair and service alternatives that remain. Although Option 1 was a newer design, it still lacks many of safety and clinical features that the RT and CE preferred. Option 2 is the best choice for the hospital unless a later revision of the model changes the weights of the bottom-level criteria.

IV. CONCLUSIONS

This case study showed how the AHP decision support technique can be applied to clinical engineering health technology assessment projects. AHP provides a structured method of organizing and documenting the decision process and takes into consideration the many tradeoffs that exist between alternate choices. When an AHP model is properly designed and implemented, it facilitates interdepartmental and interdisciplinary communication and results in a decision support tool that represents a consensus model. The AHP model can then be used to compare health technology alternatives and delivers a composite score for each alternative that identifies the best choice.

AHP produces a clinical engineering decision support tool for the hospital that identifies the best technology alternative for their specific need. Further, the model can be updated or adapted to different medical technologies whenever needed, so the development investment is not wasted.

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