LATHE SELECTION USING ANALYTIC HIERARCHY PROCESS AND INFORMATION AXIOM

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Abstract: Selection of appropriate equipment, place, or employee is a problem that needs consideration by industry, as capacities develop and efficiencies become more valued over the recent decades. Several decision-making techniques have been developed and applied to many different areas to evaluate their reliability. This study focuses on the application of a hybrid decision-making technique of Analytic Hierarchy Process and Information Axiom to solve the problem of lathe selection. Results show that appropriate machine tools can easily be selected within a short time using this approach.

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Introduction

It is often difficult to select one option among many, especially with multiple selection criteria. Selecting the correct option becomes a problem for companies because the consequences of selection are directly related to profit. To ease the process, various techniques have been developed.

One of the oldest and simplest techniques is Analytic Hierarchy Process (AHP). Saaty (1980) developed this technique to solve complex decision problems. The main aim was to define and normalize the importance of criteria to form a single criterion for comparing alternatives. Later, different researchers proposed new techniques, such as TOPSIS, PROMETHEE, ELECTRE, and VIKOR.

As techniques were developed, they were applied to many different areas: education, engineering, government, industry, management, manufacturing, personal, political, social, and sports (Alias, Hashim, & Samsudin, 2008). A machine selection problem is where one needs to choose an alternative with the best attributes considering the comparison criteria. Studies on machine selection problems are broadly classified into categories, such as product design, manufacturing process, flexible manufacturing system, machine tool, material handling system, and robotic (Kentli & Uçak, 2011).

Yurdakul (2004) used the AHP technique to resolve the machine tool selection problem. He selected the best vertical machining center among five alternatives, considering the cost of items (material, labor, and factory overheads). Çimren, Budak, and Çatay (2004) designed software using the same technique to identify the best machining center among 236 alternatives, considering reliability, precision, and cost. Tsai, Cheng, Wang, and Kao (2010) selected the best 4-axis CNC machining center among three alternatives, considering reliability, cost, maintenance and service, safety and environment, and space.

Hybrid techniques have been developed to improve accuracy of applied techniques, for example, fuzzy AHP to handle uncertainty in extracting information from users or experts. Ayağ and Özdemir (2006) selected the best CNC vertical turning center among 19 alternatives. Önüt, Kara, and Efendigil (2008) used a hybrid fuzzy AHP and fuzzy TOPSIS technique and selected the best CNC machining center among four alternatives considering cost, operative flexibility, installation easiness, maintainability and serviceability, productivity, compatibility, safety, and user friendliness. Dura'n and Aguilo (2008) selected the best CNC turning center among three alternatives, considering flexibility, operation easiness, reliability, quality, implementation easiness, and maintainability. Moreover, Dağdeviren (2008) combined PROMETHEE with AHP and selected the best milling machine, considering price, weight, power, spindle, diameter, and stroke. Guan, Wang, & Tao (2009) selected the best machining processes for a product, considering cost, quality, and operation time, using a hybrid technique of GA and AHP.

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The previously mentioned techniques calculate importance weights considering only expert opinion. This could lead to varying results because it relies on surveys or interviews from varying experts, who each have individual experience in the area. Thus, other information is needed in the system for more robust results. Therefore, an Information Axiom combined with the AHP has been used to accomplish this aim (Tarcan, 2005). A few applications of this combination are found in literature, for example, Kentli and Akbaş (2011) applied the technique to a machine selection problem. This study aims to apply the same approach to the problem of lathe selection.

Hybrid Technique of AHP and Information Axiom

The AHP ranks alternative solutions by prioritizing requirements with the pairwise comparison involving expert opinion to define the priorities. More specifically, the problem is systematically divided into data of interrelated elements, which are normalized prior to comparing and ranking the data. Having multiple criteria complicates the problem in that an alternative with low ranking in some criteria may inadvertently be selected as best choice. The AHP method involves six steps as shown in Figure 1 (see Annex).

The use of the Information Axiom of axiomatic design aims for information content calculated from numerical values of the products' properties. The product with the lowest information content is deemed the best. Unlike the AHP, the Information Axiom uses certain and constant values rather than values that change from person to person. However, the Information Axiom treats all criteria in the design problem with equal importance, which may not be the case. The Information Axiom is used to evaluate the weights of the criteria, and the comparison of alternatives is then performed using AHP.

For a given design, the information content can be obtained for different applications, according to Kar (2000), as follows:

$$IN = C[(m_s - m_d)^2 + \sigma_s^2]$$

$$IS = C[m_s^2 + \sigma_s^2]$$

$$IL = C[(m_s - m_d)^2 + \sigma_s^2]^{-1}$$

where "IN" is the information content for nominal-the-best design, "IS" for smaller-the-better design, and "IL" for larger-the-better; while "C" is a proportional constant that depends on the design specifications, "m_s" the mean of the system range, "m_d" the mean of the design range, and "σ_s" the variation of the system range.

Selecting Best Lathe

As the case study, a lathe selection problem was chosen. Data found in literature were used in the study to compare results of lathes (Athawale & Chakraborty, 2010). The capital cost was important, as starting the process with less expenditure provides an opportunity to produce the same product at a lower price. Also, having a CNC lathe capable of different products allows for greater gain in a competitive market. Thus, several different tools (for tool capacity, maximum machining diameter, and maximum machining length) and rapid processing (for spindle speed range, rapid traverse rate of X, and Z-axis) were used as comparison criteria. Data used in the study are shown in Table 1 and the comparison matrix in Table 2 (see Annex).

Results

Table 3 (see Annex) shows the comparison of the lathes. Ranking of seven selected CNC lathes are shown from seven criteria perspectives. As a result, VTURN 16 was chosen as the best candidate. The least-preferred choice was EX-106. Possibly, the rapid traverse rate values were ineffective in the selection, as the best had the minimum and the least-preferred had the maximum value.

Conclusion

A hybrid methodology (AHP with Information Axiom) was successfully applied to a lathe selection problem. The study showed that this methodology can be applied for robust results. The results indicate that VTURN 16 lathe was the best choice, though consideration of different criteria (e.g., maintenance cost and weight) could alter this outcome. Comparison with literature showed similar results to those obtained in this study.

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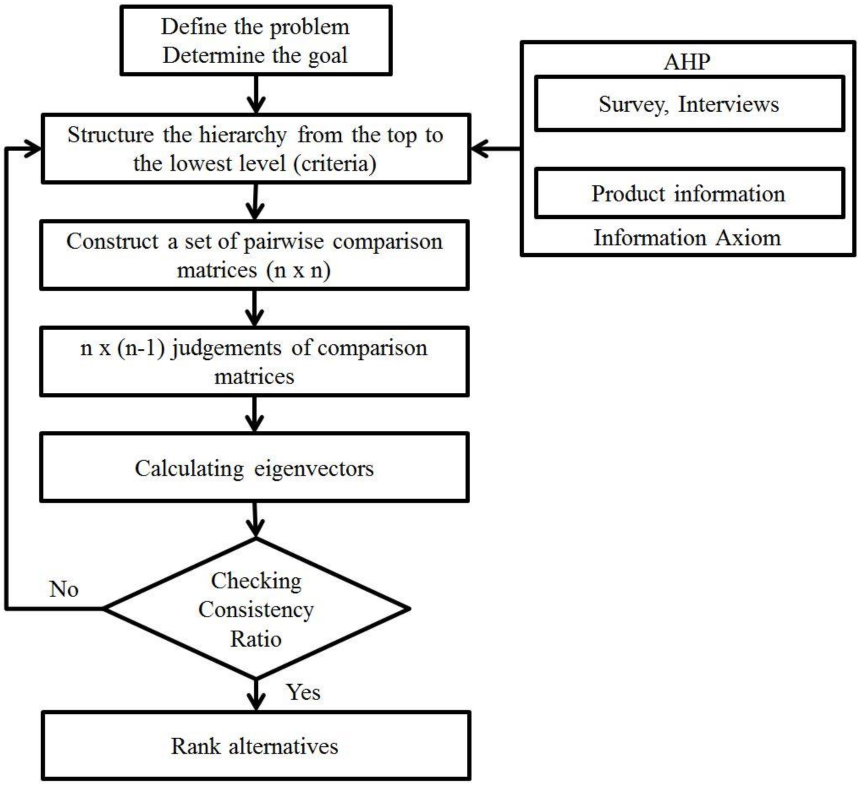
Annex

Figure 1: Schematic representation of the hybrid approach



Source: Authors

Table 1: Data of lathes

Lathes	CC (Capital Cost) million USD	SS (Spindle Speed Range)	TC (Tool Capacity)	TX (Rapid Traverse Rate of X-Axis)	TZ (Rapid Traverse Rate of Z-Axis)	MD (Max. Machining Dia.)	ML (Max. Machining Length)
YANG ML-5A	1.20	5590	8	24	24	205	350
EX-106	1.32	4950	12	24	30	240	340
VTURN 16	1.10	5940	12	12	15	230	600
FEMCO HL-15	1.20	5940	12	12	16	150	330
ECOCA SJ20	1.18	3950	8	24	24	250	330
TOPPER TNL-85A	1.20	3465	8	20	24	264	400
ATECH MT-52S	1.38	4752	12	20	24	235	350

Source: Authors

Table 2: Pair-wise comparison matrix of lathe criteria

Criteria	CC	SS	TC	TX	TZ	MD	ML	Priority Vector
CC	1	1	1	1/2	1	1/2	1	0.1143
SS	1	1	1	1	1	3	2	0.1815
TC	1	1	1	1	2	2	2	0.1793
TX	2	1	1	1	1/2	1/3	1	0.1273
TZ	1	1	1/2	2	1	1/2	1/2	0.1154
MD	2	1/3	1/2	3	2	1	1	0.1620
ML	1	1/2	1/2	1	2	1	1	0.1202

Source: Authors

Table 3: Ranking matrix

Lathe models	CC	SS	TC	TX	TZ	MD	ML	Σ
YANG ML-5A	0.0177	0.0245	0.0029	0.0257	0.0183	0.0085	0.0087	0.1064
EX-106	0.0076	0.0235	0.0419	0.0409	0.0559	0.0321	0.0101	0.2117
VTURN 16	0.0499	0.0420	0.0414	0.0039	0.0039	0.0253	0.0930	0.2595
FEMCO HL-15	0.0197	0.0299	0.0294	0.0028	0.0038	0.0024	0.0051	0.0931
ECOCA SJ20	0.0224	0.0078	0.0030	0.0260	0.0185	0.0238	0.0047	0.1061
TOPPER TNL-85A	0.0251	0.0031	0.0041	0.0227	0.0260	0.0361	0.0314	0.1486
ATECH MT-52S	0.0025	0.0122	0.0277	0.0169	0.0193	0.0191	0.0091	0.1068

Source: Authors