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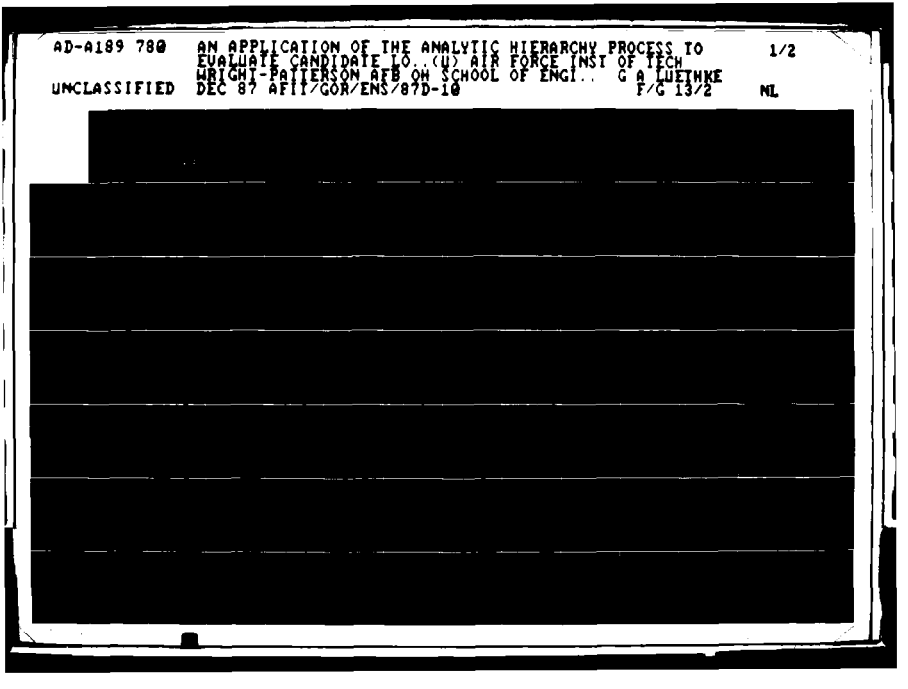

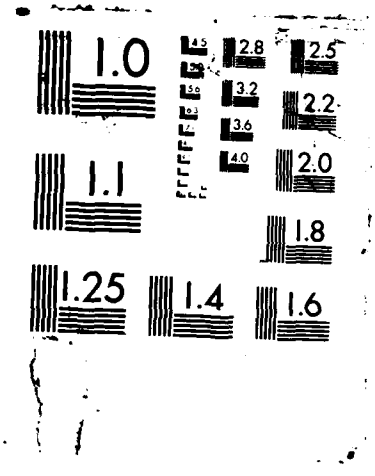
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AN APPLICATION OF THE ANALYTIC HIERARCHY PROCESS TO EVALUATE CANDIDATE LOCATIONS FOR BUILDING MILITARY HOUSING

THESIS

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Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
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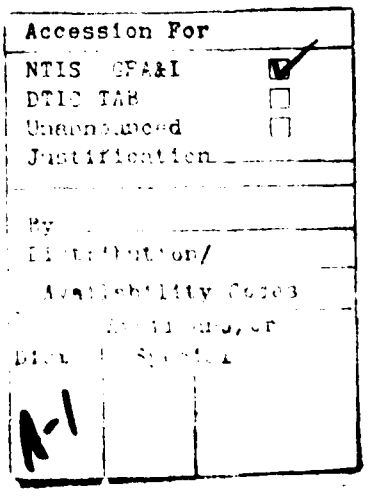

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Abstract

This study was supported by the Defense Housing Agency (DHA) and was an application of the Analytic Hierarchy Process (AHP) to the decision of where to build military family housing.

There are currently many military installations that have a deficit of housing. However, Congress has appropriated enough money for future construction that should reduce the current housing deficit to about 1 to 2% of its present value. One decision to be made then is where to place the housing so that the needs of the installation and the personnel are met. This study used the AHP to help in the decision of where to build the housing. To do this, a hierarchy was developed that modeled the decision to be made. This hierarchy included the criteria relevant to the decision of where to build military housing. To get these criteria, the experts from the Army, Navy, and Air Force were interviewed to get their inputs as to the housing needs of the military personnel. Next, the hierarchy was evaluated at Wright-Patterson AFB to show how the AHP works. To evaluate the hierarchy at Wright-Patterson AFB, an assumption had to be made that Page Manor, a large military housing complex, was going to be relocated. After the assumption was made, candidate locations for the relocation had to be determined. Four locations were found to be suitable for the type of construction needed to build the number of units required. Then, all the criteria were related through pairwise comparisons to get the relative importance of the criteria to the overall goal of deciding where to build the housing units. The hierarchy was then synthesized to get the relative ranking of the alternatives.

The conclusion of this study was that the AHP would be a good decision aid at the installation level housing offices. The AHP forces the decision maker to evaluate the relative importance of all the criteria before making a final decision.

AN APPLICATION OF THE ANALYTIC HIERARCHY PROCESS TO EVALUATE CANDIDATE LOCATIONS FOR BUILDING MILITARY HOUSING

I. Introduction

The purpose of this study is to use the Analytic Hierarchy Process (AHP) to support the decision of where to build military housing. The decision of where to build housing is a multiple criteria decision making (MCDM) problem because of the many attributes that can be associated with housing, such as proximity to work, cost of utilities, condition of local neighborhood, etc.

Background

The Department of Defense believes that everyone should have decent housing and is actively trying to adequately house all military personnel within CONUS and overseas (5). In his 1986 Annual Report, Robert A. Stone, Deputy Assistant Secretary of Defense (Installations), said that he had one objective, "To ensure that we have the excellent installations we need to carry out defense missions effectively in peacetime and war" (28:1). Having an excellent installation includes having adequate housing for all personnel. But currently, 15 to 20 percent of all military personnel are either paying too much for housing, living too far from the installation, or living in substandard housing (5).

When a military person gets transferred to a new installation, he or she is often faced with the problems of finding acceptable housing, that is, housing that is

affordable, housing that is near the installation, or housing that is considered to be in sufficient condition. There are many areas, especially on the East and West coasts of the United States, where housing is very expensive near the installation. The high cost of housing may force personnel to take housing that is either substandard but affordable, or too far from the installation to be practical.

Some installations do not have enough housing and are not close enough to a community to rely fully on the community's housing assets. There are many installations located near communities that do not have enough adequate housing to house all the personnel assigned to that installation. The lack of adequate housing forces personnel to live in substandard housing or to choose acceptable housing that is too far from the installation. The Defense Housing Agency (DHA) is trying to solve this problem by providing housing at all installations that currently have a deficit of housing (2,4,5,18,19,25).

When an installation cannot adequately and affordably house all their personnel within a reasonable distance of the installation there is said to be a deficit of housing at that installation. A deficit is defined as the difference between the number of housing units required to house all personnel adequately and the available assets in the community (9:96). An asset is a housing unit that meets the criteria of acceptability (9:96). There are currently six criteria that are used to determine whether a housing unit will be considered an asset. The criteria [21:Enclosure 1] are as follows:

1. It is within a one-hour commute by privately-owned vehicle during rush hour and no further than 30 miles from the installation.
2. It is structurally sound and does not pose a health or safety hazard.
3. It has hot and cold running water, a shower or bath, and at least one flushable toilet.
4. It has a heating system where the climate requires one.

5. It has electrical service.

6. It has the minimum number of bedrooms to assure no more than two dependents share a room .

The above criteria do not take affordability into account. The current position of the DoD is that no military member should have to pay more than 30 percent over the housing allowance for living expenses (21:1).

One area of concern by the DHA is that all the relevant criteria are not being taken into account when the deficit is being determined at a particular installation (5). The six criteria for acceptability stated above are the main criteria currently used for deciding whether a housing unit is considered an asset. In defining the deficit, housing requirements must be matched against current military housing assets, current available community housing assets, and housing starts. The Defense Housing Agency would like some way to make the relevant criteria more dependent on the installation. For instance, one community might have such a varied geography that using the standard 30 mile radius and 1 hour commute time might not be feasible. This could turn a housing area in the community that is currently counted toward assets into an area not considered acceptable for military personnel to live (2,4,5,18,19,25).

To decrease the number of personnel inadequately housed, housing assets must be bought, built, or rented by the government which requires funding. However, before housing can be acquired, an actual housing deficit must be defined at an installation and money appropriated to alleviate the deficit (5). Currently, each service (Army, Navy, Air Force) uses a different method of defining the deficit.

The Army has developed their own process to define the deficit. Their method is called the Segmented Housing Market Analysis (SHMA) and is currently being tested to see if it is feasible (4,5,25). The SHMA process is a detailed look at the

community and its projected economic future to project how assets will be altered by changes in the community's economic situation.

The Navy uses a sample survey process which they developed. The survey is given to military personnel and evaluates the suitability of a person's current housing status by asking how far they live from the installation, how long it takes them to drive to work, and the amount they pay for rent (2,6). A deficit is then derived from the survey. However, if the survey shows a deficit of housing, the Navy performs a detailed market analysis of the area to further define the nature of the deficit (19). The market analysis is similar to the Army's SHMA process but not as detailed.

The Air Force uses the sample survey process that the Navy developed to determine the deficit. However, the deficit calculated from the survey is the number reported as the actual deficit. The Air Force feels that no further definition of the deficit is needed (2).

The DHA would like to have one standard process for defining the deficit that is flexible enough to be used at all installations and will be able to detect small deficits so that corrective action can be taken (5). In spite of the need for continuity between the services for a better method of defining the deficit, there has been great success in getting money appropriated to increase housing assets at installations where there is currently a deficit. By FY 1991, it is estimated that housing assets will have increased to the point where the number of personnel inadequately housed will be 1 to 2 percent of the current deficit (5).

Justification for Study

Since monies have been appropriated to acquire housing assets, one problem is to decide where to build the housing. In deciding where to build, many criteria must be taken into account to ensure that the housing built today will not only be adequate today but will remain adequate for military personnel in the years to come.

The complexity of deciding where to build housing can be summarized by a quote from Daniel Mandelker and Roger Montgomery in a book on housing in America.

> Housing denotes an enormously complicated idea. It refers to a whole collection of things that come packaged together, not just four walls and a roof, but a specific location in relation to work and services, neighbors and neighborhood, property rights and privacy provisions, income and investment opportunities, and emotional or psychological symbols and support [16:1].

The decision of where to build housing is obviously a multiple criteria decision making problem. Cost, access and proximity to the installation, neighborhood, aesthetics, and schools are some of the criteria that must be considered. These criteria are general in nature and must be further defined making the problem more complex. For example, cost could be broken out into subcriteria of initial cost, maintenance cost, and a 20 or 30 year present worth of the cost to build in a certain area. In addition, the relative importance of each of the criteria must be taken into account.

The Analytic Hierarchy Process (AHP) lends itself to problems of several criteria that are further broken down into more specific subcriteria or levels. The AHP allows the decision maker to model a decision by using a hierarchy that contains the relevant criteria to the decision in a logical fashion so that the relative importance of the criteria can be judged.

Problem Statement

The Defense Housing Agency is actively trying to adequately house all military personnel. To achieve this, housing assets must be built so that housing is affordable, within a reasonable driving distance to the installation, appealing, and in acceptable areas in the surrounding communities. Deciding where to build housing requires that candidate locations be evaluated on several criteria to ensure the housing will meet the needs of the installation and the personnel today and in the future.

Research Questions

The most important step in using the Analytic Hierarchy Process is making sure the hierarchy models the decision to be made (23:35). This process involves making sure that all relevant criteria are included in the hierarchy and that the criteria are logically placed within the hierarchy (23:35-36). Therefore, there are two main research questions needed to complete this study before the hierarchy is put into practice.

1. What are the relevant criteria in selecting the location to build military housing?
2. Once developed, is the hierarchy logical in its representation and does it model the decision to be made?

If all the relevant criteria are placed logically into a hierarchy, and the hierarchy models the decision to be made, then the hierarchy should be able to help in the decision making process.

Overview

Chapter II is a summary of the current literature pertaining to housing with a brief description of the Analytic Hierarchy Process and a simple example of how the AHP works. Chapter III is a detailed description of the hierarchy and methodology used in this study. The results of the research are then given in Chapter IV and the conclusions and recommendations are discussed in Chapter V.

II. Literature Review

Overview

This chapter has four main sections with the first section being a discussion of housing problems in the United States followed by a discussion of human needs in housing. The last two sections will discuss decision making in general and the Analytic Hierarchy Process.

Some Housing Problems and Research in the United States

This section will describe some of the housing problems in the United States and some of the research that has been done in the housing area. Most of the literature focuses on the plight of the poor people in America trying to find adequate housing at an affordable cost.

At the turn of the century, in his book titled, *The Modern City and its Problems*, Frederick C. Howe, noted that the small town did not have many housing problems (11:273). He stated that there were usually enough houses and no slums or congestion in the small town, but when a town reached 1/4 to 1/2 million people, housing problems began to appear (11:273). The cause, he said, was high land value and lack of good transportation (11:276). Since land was so expensive, investors built large tenement buildings to get a return on their large investment. The high buildings created congestion. Transportation was a problem since the buses and trolleys did not reach out to the suburbs because it was not profitable, and as a consequence, the transportation companies unconsciously promoted congested cities (11:276). Howe points out that the move to alleviate the congestion problems met with resistance because there was more money in holding land for speculation than building houses to reduce the congestion (11:276).

The housing problems of the past are still around today and trying to fix these problems often creates new problems such as: who should get the next available housing unit or where to relocate people while existing housing is being fixed.

Public housing authorities throughout the United States must decide how to assign tenants to available housing units (14:832). However, as Edward H. Kaplan points out in an article titled, "Tenant Assignment Policies with Time Dependent Priorities," most public authorities use a fixed priority policy which leads to long waiting times for some families (14:1). Kaplan points out that a weighting system could be used that "state(s) the relative costs of waiting for different groups of applicants" (14:1). The applicant with the highest waiting cost would be given the next available housing unit (14:1).

Another problem facing public housing authorities is the rehabilitation of large tenements (13:5). While renovating these housing projects, there must be provisions made for those currently in the building to be renovated (13:5). Kaplan has developed a scheduling algorithm that tries to minimize project duration and does not allow for vacancies to become negative to ensure that the families are always housed (13:8). He points out that, to his knowledge, no public housing authority is currently attacking the problem of relocation planning (13:6).

Human Needs in Housing

If the military is going to try to adequately house all its personnel, it must understand human needs in housing. Shelter is the basic use of housing, but when a person is going to spend much of his or her time at home, the house must provide more than a roof (5). The home should be a place of entertainment, relaxation, safety, and privacy (6:17). To do this, housing should be provided to be:

1. Aesthetically pleasing
2. In a safe neighborhood

3. Close to work
4. Affordable
5. Close to schools
6. Close to entertainment
7. Close to shopping (4:17).

If these items are taken into account when choosing a location, not only are the physical needs taken care of, but the psychological aspects will also be addressed (5). There are many other intangibles that a home should provide a human being, and the military will only be successful in their housing projects when the intangibles are taken into account (5).

When dealing with many intangibles, it is often hard to make a sound decision that takes into account all factors. The following two sections will discuss decision making in general and the Analytic Hierarchy Process, a tool to help in the decision making process.

Decision Making

> Most of us believe life is so complicated that in order to solve problems we need more complicated ways of thinking. Yet thinking even in simple ways can be taxing [19:4].

Most decisions involve a complex system of inter-connected and inter-related elements in which logical deduction is often the easiest path to a solution (23:4,6). However, in the decision making process, if a person can clearly state his or her ideas, whether the ideas are logical or not, he or she can often persuade others to make a certain decision without considering all the relevant criteria (23:6,7).

Psychologists and brain researchers have shown that persuasion and personal preferences normally have a greater influence on the decision making process than logical deduction (23:7).

Behaviorists have developed some theories on explaining human nature (23:7). Instinct–drive theory states that many human actions are based on instinct. These actions include seeking food, mating, avoiding pain, etc. However, this theory does not account for most human behavior (23:7). Reason–impulse theory states that human action is based on suggestion, habit, or other irrational thinking and rarely is logic a factor (23:7,8). Dynamic field theory states that humans act in a dynamic field of environmental factors and that decisions are based on what would be most beneficial to humans wants or needs (23:8).

It would seem that a complex decision process is needed with all the theories on human nature and the forces that drive human decisions. However, as Saaty points out in his book, *Decision Making for Leaders*, what is needed is not a more complicated way of thinking but a process by which complex decisions can be handled in a simple manner (23:4). This method of handling decisions should be able to handle inter–related elements without having to struggle with the problem of human nature (23:4,5).

The AHP allows complex decision making to be handled in a simple, systematic, and effective way.

The Analytic Hierarchy Process

To begin the discussion on the Analytic Hierarchy Process, a simple example will be illustrated first, followed by a more detailed discussion on the steps of the process.

Example The following example describes the process of purchasing a new automobile using the AHP to aid in ordering the preferences of the automobiles. The buyer has narrowed her choice down to three cars: a Buick Somerset, a BMW 318i, and a Mazda 626. She now wishes to make a rational choice based on the following criteria: cost, utility, comfort, maintenance costs, appearance, and resale

value.

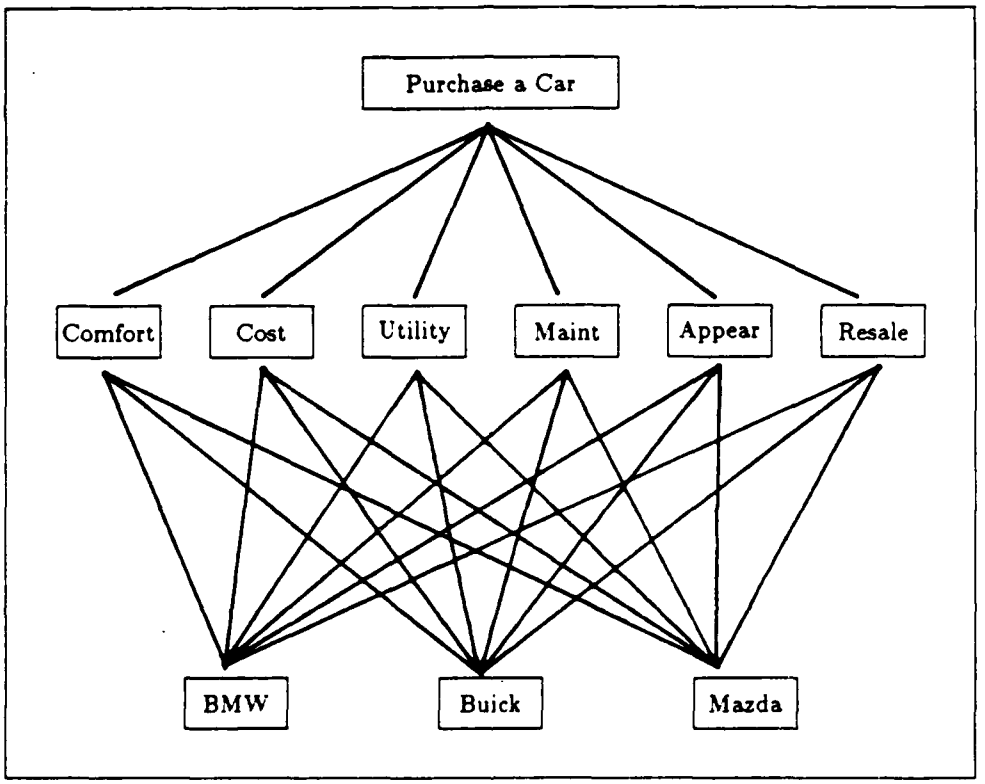


Figure 1: A Hierarchy for Purchasing a Car

To help in her decision, she builds a hierarchy found in Figure 1. She then performs pairwise comparisons on the criteria to evaluate the relative importance of each criteria to the purchase of a new car. Figure 2 shows how the comparisons are made and input into a matrix. A representative question asked when making comparisons might be: Cost is how much more important than maintenance when buying a car? The answer in this case is that cost is weakly more important than maintenance, so a 3 is put in the first row, second column. The AHP uses a 1-9 scale to make all comparisons with 1 being equivalence, 3 being weak, 5 being strong, 7 being very strong, and 9 being absolute (23:78). Even numbers are used when a

compromise is needed between two judgments (23:78). This process is repeated for each combination of criteria until the matrix is complete, however, only the upper right portion of the matrix needs to be evaluated because the lower left is just the reciprocal of the upper right portion.

Buy a Car	Co	Ma	Ap	Cm	Ut	Re
Co	1	3	3	5	7	9
Ma	1/3	1	1	3	5	7
Ap	1/3	1	1	3	4	6
Cm	1/5	1/3	1/5	1	3	4
Ut	1/7	1/5	1/4	1/3	1	3
Re	1/9	1/7	1/6	1/4	1/3	1

Co–Cost
Ma–Maintenance
Ap–Appearance
Cm–Comfort
Ut–Utility
Re–Resale Value

Figure 2: Matrix of Comparisons on Purchasing a Car

Cost	Buick	BMW	Mazda
Buick	1	5	3
BMW	1/5	1	1/3
Mazda	1/3	3	1

Comfort	Buick	BMW	Mazda
Buick	1	1/5	1/3
BMW	5	1	3
Mazda	3	1/3	1

Figure 3: Car Comparisons on Cost and Comfort

She must now see how each car performs on each of the criteria. This process will require 6 matrices but only two matrices will be shown. Figure 3 shows how the cars performed on cost and comfort. The cost matrix says that the Buick is strongly better than the BMW on cost and weakly better than the Mazda. The comfort matrix says that the BMW is strongly better on the BMW than the Buick and weakly better than the Mazda.

After all comparisons are made, the matrices must be synthesized to calculate the relative weights of each criteria and to get an overall ranking of the cars based on the criteria. Table 1 contains all the weights with the overall ranking of the cars in the last column. The table shows that, using the criteria defined earlier and using the weights given, the Buick has the highest ranking followed by the Mazda and the BMW.

Table 1: Weights of Criteria

	Co	Ma	Cm	Ut	Ap	Re	
Overall	0.423	0.204	0.093	0.051	0.191	0.029	Ranking
Buick	0.275	0.064	0.010	0.005	0.016	0.002	0.372–1st
BMW	0.045	0.017	0.059	0.035	0.135	0.019	0.310–3rd
Mazda	0.112	0.123	0.024	0.011	0.040	0.008	0.318–2nd

Description The AHP is a flexible tool that gives the decision maker the ability to model a complex system into a hierarchy of relevant criteria to aid in his decision making process (23:5). The AHP allows him to make assumptions and deal with large, complex systems, in a logical fashion (23:5). However, when building the hierarchy, the experts on the subject should be relied upon to help structure the hierarchy so that the AHP can assess the problem through the most experienced hands (24:4).

A simple but typical hierarchy can be seen in Figure 1 which is a hierarchy for purchasing a car. The purpose of building a hierarchy is to be able to evaluate the impact of the criteria on the overall decision (24:4). The basic approach to building a hierarchy is first to determine what needs to be done or to set a goal (24:16). In Figure 1, the goal is to purchase a new car. The second step is to generate a set of alternatives that will satisfy the goal (24:16). In Figure 1, the alternatives are to purchase a BMW, a Buick, or a Mazda 626. The last step is to decide on the relevant criteria that are important and will relate the alternatives to the goal

(24:16). The relevant criteria in Figure 1 are Comfort, Cost, Maintenance, Utility, Appearance, and Resale. However, two people might come up with very different criteria for buying a car. The AHP is very easily adaptable to people having varying attitudes toward the goal (23:23).

Being flexible is not the only advantage of the AHP. Saaty points out 10 advantages to the AHP:

1. Unity: The AHP provides a single, easily understood, flexible model over a wide range of unstructured problems.
2. Process Repetition: The AHP enables people to refine their definition of a problem and to improve their judgment and understanding through repetition.
3. Judgment and Consensus: The AHP does not insist on consensus but synthesizes a representative outcome from diverse judgments.
4. Tradeoffs: The AHP takes into consideration the relative priorities of factors in a system and enables people to select the best alternative based on their goals.
5. Synthesis: The AHP leads to an overall estimate of the desirability of each alternative.
6. Consistency: The AHP tracks the logical consistency of judgments used in determining priorities.
7. Complexity: The AHP integrates deductive and systems approaches in solving complex problems.
8. Interdependence: The AHP can deal with the interdependence of elements in a system and does not insist on linear thinking.
9. Hierarchic Structuring: The AHP reflects the natural tendency of the mind to sort elements of a system into different levels and to group like elements in each level.

10. Measurement: The AHP provides a scale for measuring intangibles and a method for establishing priorities [19:23].

Once the hierarchy is built, it must be evaluated numerically (24:15). This numerical analysis is performed by making pairwise comparisons of the criteria at each level of the hierarchy (24:15). When all comparisons have been made, the matrices are synthesized to determine the overall weights of the alternatives (23:79).

When pairwise comparisons are made, the entries are placed in a matrix as in Figure 4. This type of matrix is called a reciprocal matrix because $a_{ji} = 1/a_{ij}$ (24:18).

$$A = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{pmatrix}$$

Figure 4: Matrix of Pairwise Comparisons (24:17)

To get the pairwise comparisons, questions must be asked that relate one level of the hierarchy with the next higher level of the hierarchy (23:77). The way the questions are asked is a very important step in the process, and the question must relate the correct relationship between levels of the hierarchy (23:77). In the car example, the relative importance between Level 1 and Level 2 was the key to relating the two levels. The question asked relating Cost and Comfort was, "Cost is how much more important than Comfort in purchasing a car?" However, if the relationship between two levels is a probability that one criteria will affect the next higher level, the question to be asked should be, "How much more probable is Criteria 1 to have an affect than Criteria 2?"

When asking the questions, the decision maker is asked to place a value on the question from a scale of numbers from 1-9, with 1 being equality and 9 being extreme (24:22). A logical question might be, "Why not use another scale?" The answer is that, through many experimental tests, the 1-9 scale proved to be statistically more capable of measuring the humans mental capability to detect different degrees of strengths and weaknesses between objects (24:24).

Another consideration when making pairwise comparisons is the idea of consistency (23:82). The idea of consistency can be mathematically shown.

$$\text{If } A = 2B$$

$$\text{and } B = 2C$$

$$\text{then } A = 2(2C) = 4C.$$

These equations say that if A is preferred twice as much as B, and B is preferred twice as much as C, then A must be preferred 4 times as much as C. If A were not preferred 4 times as much as C, then the comparisons would be considered inconsistent (23:82). The AHP allows for inconsistency and provides a measure for it because it is very difficult to be consistent, even when there are only a few comparisons to be made (23:82,83). The consistency ratio (C.R.) is the deviation from consistency, the Consistency Index (C.I.), divided by the random consistency for a matrix of the same size (20:24-25). The consistency ratio is calculated as follows. Suppose that a $6x6$ matrix of pairwise comparisons has a C.I. of 0.111. The random consistency of a $6x6$ matrix of comparisons is 1.24 (24:24). Then the C.R. would be $0.111/1.24 = 0.90$. Saaty points out that a C.R. of greater than 0.10 is not good and the comparisons should be revised (23:83).

After all pairwise comparisons have been made, the whole process must be synthesized to obtain an overall set of priorities (23:79). The process consists of determining the priority of each criteria as related to the overall goal and then combining these priorities with the set of alternatives to get the weighting factors that will rank the alternatives (23:80-82).

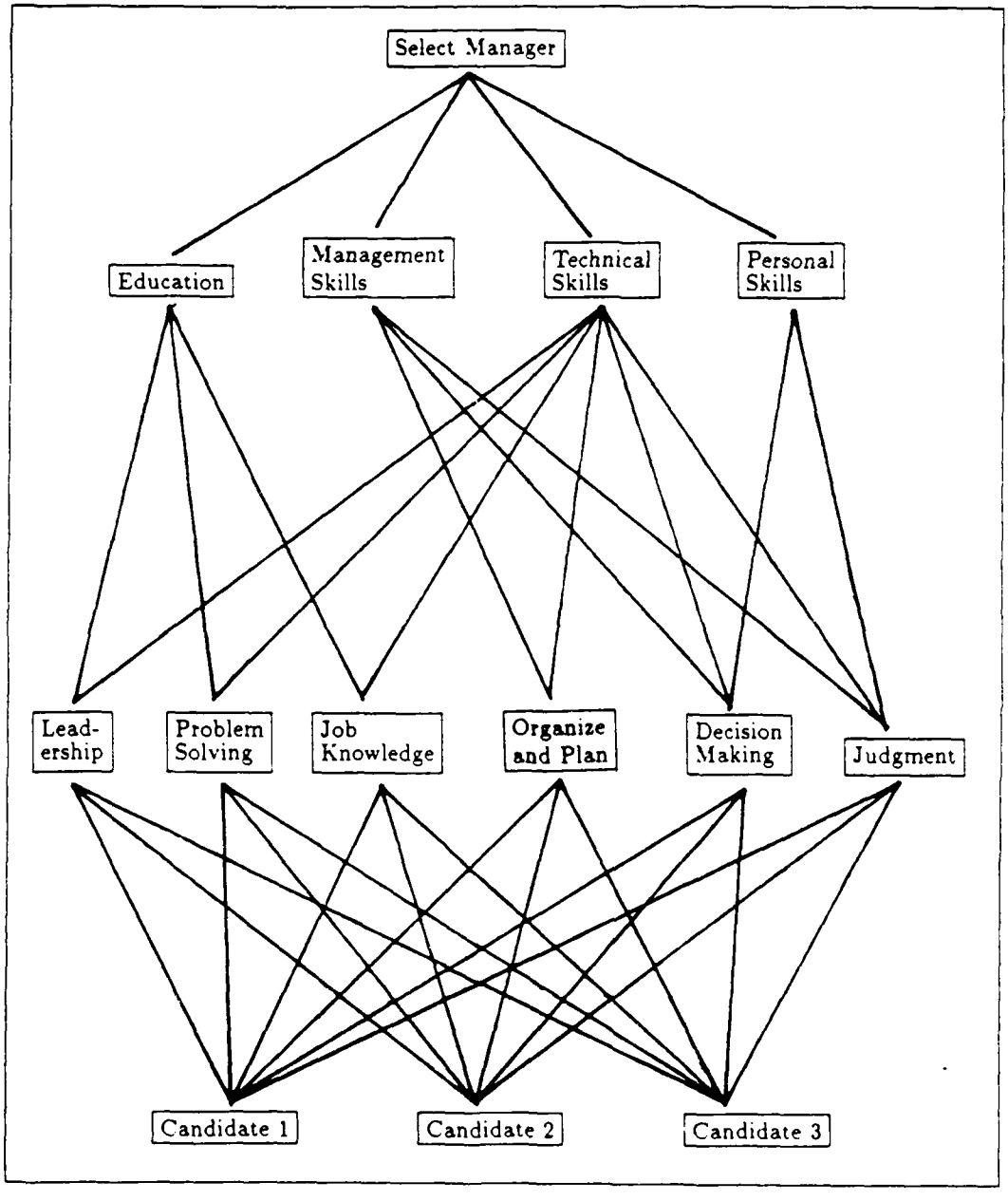


Figure 5: Hierarchy for Choosing a Management Candidate (23:40)

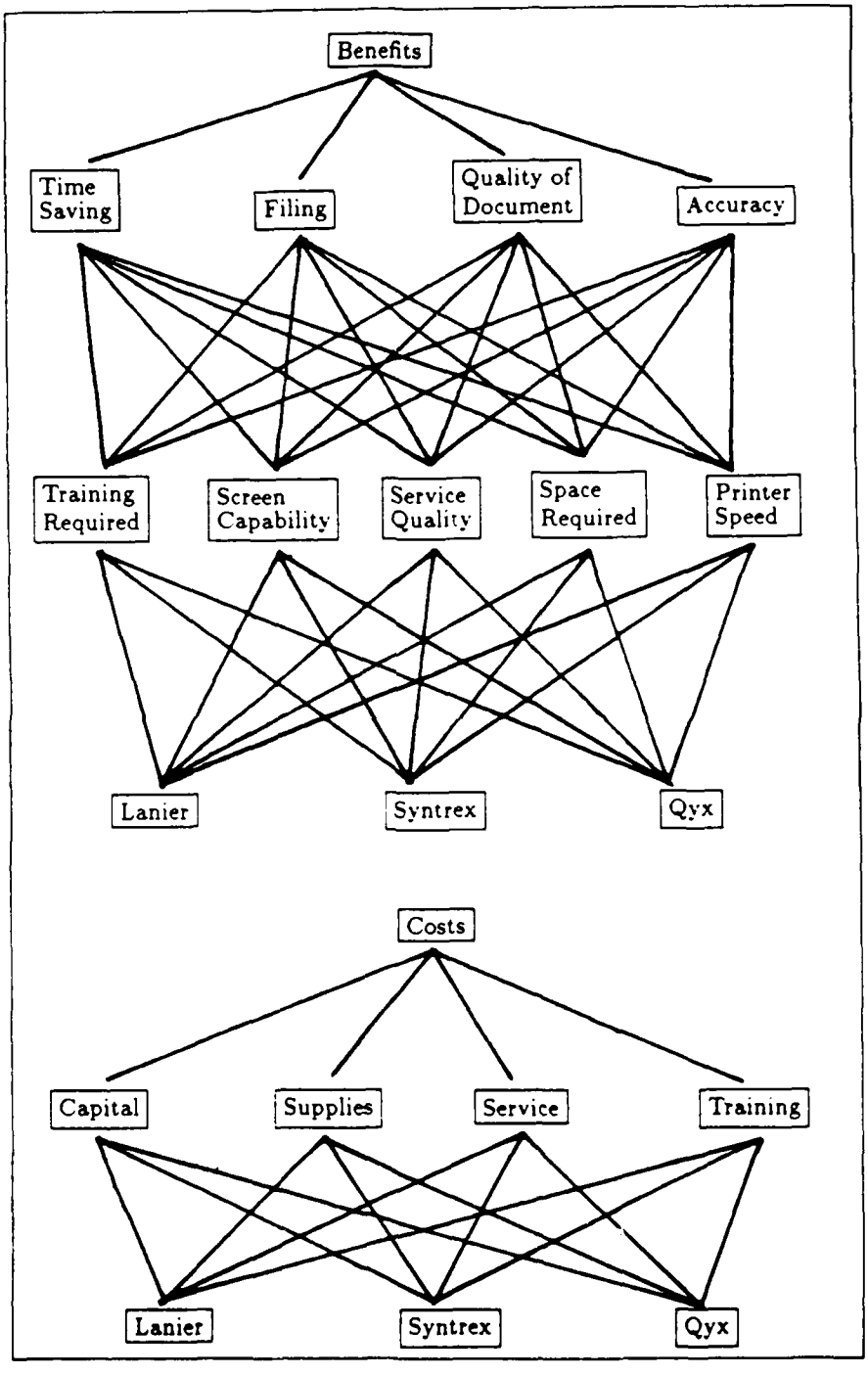


Figure 6: Hierarchies for Choosing Word Processing Equipment (23:38)

More Examples Saaty points out that, "No inviolable rule exists for constructing hierarchies," but does go on to say that a few patterns for decision hierarchies have developed through the years (23:29,32). The following examples show some of the areas that the AHP has been used in the past.

Figure 5 is a hierarchy to select a manager for a position in a company. Level 1 is the goal of the hierarchy with Level 2 being the criteria on which the candidates will be evaluated. Level 3 contains abilities that the company is looking for in a manager. Level 4 contains the alternatives, in this case, the candidates for the job. Notice that not every element in Level 3 is related to every element in Level 2 (23:40). Saaty points out that the hierarchy need not be complete (23:36). An element in one level of the hierarchy does not have to relate to every element in the next highest level (23:36).

The next example is one for choosing word processing equipment. For this example, two hierarchies are used with the first hierarchy concerned with benefits and the second hierarchy concerned with costs. Each hierarchy is evaluated and then a benefit/cost ratio is calculated to determine the relative ranking of machines. Figure 6 contains both hierarchies used for this example.

Summary

This chapter discussed some of the housing problems that are being dealt with as of this writing. Though most of the literature addresses the issue of housing the poor, some of the concepts are applicable to military family housing problems. The issue of long waiting lines could be given more attention to make sure that those who are in most need are given a higher priority. The issue of relocating during renovation has some merit since the military uses renovation as an option to purchasing or leasing housing assets (5).

Military personnel have the same needs as their civilian counterparts and these needs should be taken into account when building new units. The Analytic Hierarchy

Process has proven to be a valid decision tool in many areas. The ease and flexibility of the AHP make it a viable tool to use in deciding where to build military housing.

III. The Hierarchy, Methodology, and Extensions

Overview

This chapter consists of three sections with the first being a description of the methodology used in building the hierarchy. The second section is a description of the hierarchy itself, and the last section gives some examples that could be used by the DHA but will not be numerically evaluated.

Methodology

In general, there is a three step process for building a hierarchy. The first step is to generate a focus or a goal of the system (24:16). The second step is to develop a set of alternatives and the third step is to determine the relevant criteria that are needed to relate the goal with the alternatives (24:16). However, as Saaty points out, there is no set way for determining the relevant criteria, but he does say that all the relevant criteria should be included to fully describe the process (23:29,35). The main focus of the study was to build a hierarchy that included the criteria that relate the choice of where to build housing units with actual locations in a specific area.

The methodology used in constructing the hierarchy for this study basically consisted of the following steps:

1. Interviewing the Army, Navy, and Air Force housing departments to determine military needs in housing.
2. Determinating human needs in housing.
3. Constructing hierarchy relying on the expertise of the Defense Housing Agency for guidance.

The first two steps were used to get information on the needs of the military person seeking housing, and the relevant criteria to be included in the hierarchy. The third step was completed using the expertise of the DHA to ensure that the hierarchy modeled the decision accurately.

Interviewing Through several interviews with the Army, Navy, and Air Force housing offices in Washington D.C., the housing needs of the military personnel were determined. The main thrust of the interviews was to determine the differences and similarities that exist between the services in determining the housing deficit at an installation. However, the interviews showed two things. The first was that each service has its own way for the determination of the housing deficit. These differences were discussed in Chapter I. The second item that was revealed was a desire by all services to improve the housing situation for every military person, regardless of rank. Richard Smith, Army Housing Systems Analyst, said that one of the Army's goals was to minimize personnel housing problems when being relocated (25). Smith said that providing excellent housing was good for retention and morale (25). By providing for the physical aspects of housing such as safe neighborhoods and good schools for the children of the serviceman and servicewoman, the psychological aspects can be indirectly satisfied (4,25).

Human Needs Through the housing literature, it was determined what the needs are in providing housing. Besides providing for protection from the elements of nature, housing provides psychological aspects of safety and satisfaction (16:1). Since it is hard to directly provide for the psychological aspects, certain physical criteria were sought that provide for acceptable housing by military standards and to also provide, indirectly, for the psychological aspects that housing should provide. The criteria were chosen as the intersection of criteria that the literature discussed.

There are five main criteria: Cost, Proximity, Access, Neighborhood, and Schools. Cost was chosen for obvious reasons. The DHA would like to provide

the best housing for the cost (5). This is not to say that the DHA wants to provide the most inexpensive housing, but does want to provide the most inexpensive housing that provides the best of all the other criteria. Proximity to the installation was chosen because a housing project should be as close to the work environment as possible. Access to local shopping, entertainment, and schools provides convenience and satisfaction of being close to everyday needs and activities. Neighborhood was included to provide a family type atmosphere that offers safety and pleasant surroundings. Schools was included to make those families with school age children satisfied that their children will be attending some of the best schools in the area.

By providing for these five criteria, a location can be selected that meets the needs of the military and gives the personnel a nice and enjoyable place to live. The third phase of the study was to construct a hierarchy that was logically oriented and provided the decision maker information that is of some use.

Construction of Hierarchy A rough hierarchy was first built based on the information obtained from the interviews and literature. The hierarchy was then sent to the Defense Housing Agency to be evaluated. The main focus at the DHA was to make sure that the criteria were logically ordered in the hierarchy and that all the relevant criteria were included. Figure 7 is the hierarchy that the DHA believes best represents the decision to be made.

The Hierarchy

Figure 7 is the hierarchy that was developed for this study. There are four levels to the hierarchy with Level 1 being the focus–to decide where to build military housing assets. Level 2 contains the criteria of most importance in deciding where to build. Level 3 contains subcriteria of Level 2 to further discriminate how the locations differ on the main criteria. Finally, Level 4 contains candidate locations to be evaluated on each criteria in Level 3.

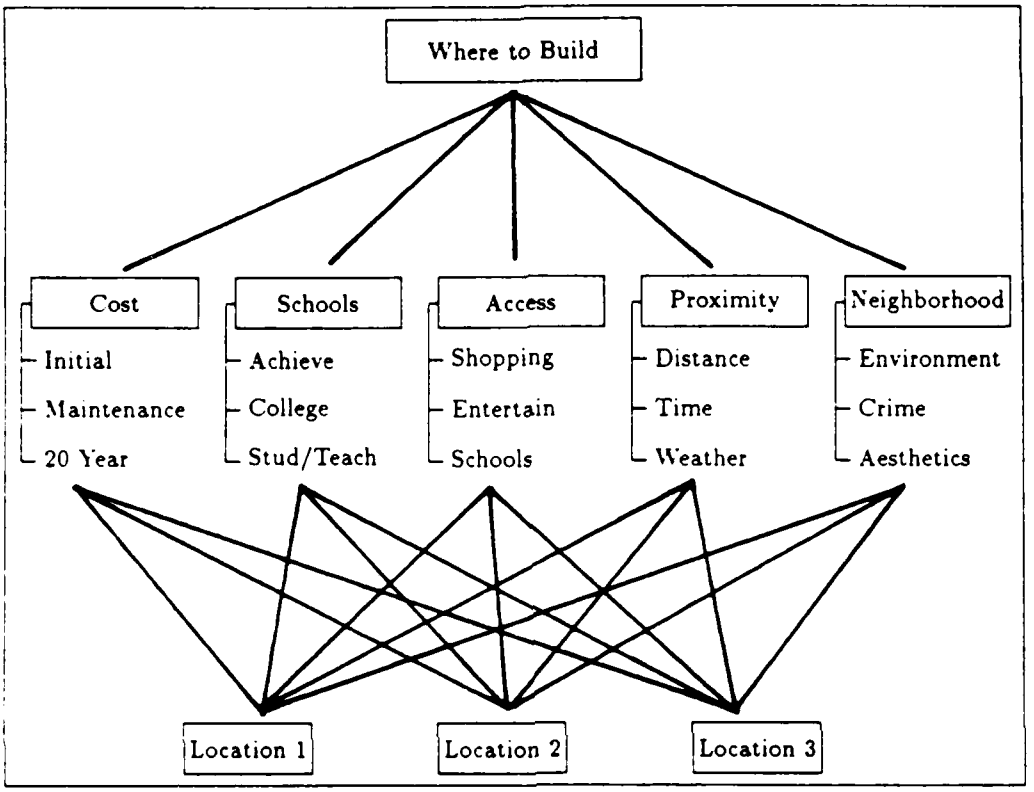


Figure 7: Hierarchy for Evaluating Candidate Locations

There are five main criteria used in this hierarchy: Cost, Schools, Access, Proximity, and Neighborhood. The relative importance of each criteria to the overall goal will have a great impact on the location selected. Therefore, the criteria to be used and the candidate locations should be explained in detail before any numerical analysis is performed in Chapter IV. The following subsections describe the criteria and alternatives in some detail.

Cost Cost is used to evaluate each candidate location on the projected cost of building in that area. Cost is further broken down into Initial Cost, Maintenance Cost, and a 20 Year Present Worth of the cost to build in that area.

Initial Cost is the cost for total construction of housing in a specific area. Maintenance Cost is the projected yearly cost to keep the housing in acceptable

condition. The 20 Year Present Worth includes yearly costs such as electricity, water, sewage, etc.

Schools Schools is used to evaluate each candidate location's school system. A given school system is evaluated on how it performs on Achievement Scores (SAT), Student/Teacher Ratio, and the Percentage of Students going to College from each school system.

Access Access is used to evaluate each candidate location's access to Local Shopping, Entertainment, and Schools.

Proximity Proximity is used to evaluate each candidate location's proximity to the installation. Because the local geography has an impact on the time of travel, Proximity is broken down into Distance from Installation, Time to Installation, and the Impact of Bad Weather on Travel to the installation.

Neighborhood Neighborhood is used to evaluate the candidate location's local neighborhood based on the Overall Environment, Security, and Aesthetics. The neighborhood should provide a safe and aesthetically pleasing environment.

Candidate Locations Level 4 contains the candidate locations to be evaluated. Figure 7 contains generic locations, but a rigorous study of the outlying area should be conducted when determining candidate locations. Only those locations that offer a feasible alternative should be considered. Saaty points out that there should be no more than 9 items in any level of the hierarchy because of the human inability to make comparisons on more than 9 items (24:24). If there are more than 9 locations to be evaluated, they should be clustered on a similar criteria and then evaluated on the clustered locations (24:241). Once a cluster has been evaluated as the best cluster, the locations within the cluster should be re-evaluated to see which location is the best based on the criteria.

Research Questions Before this hierarchy can be put into practice and numerically evaluated, the two research questions must be considered. To reiterate the questions:

1. What are the relevant criteria in selecting the location to build military housing?
2. Once built, is the hierarchy logical in its representation and does it model the decision to be made?

Both questions have been addressed to the point that a hierarchy has been developed that, according to the Defense Housing Agency, contains all the relevant criteria, is logical in its representation, and models the decision to be made.

Extensions of the AHP to Some Housing Problems

One of the problems, as pointed out in Chapter I, is the fact that there are currently three methods used for defining the housing deficit, one for each service. Assuming that they are all sufficient for defining the deficit, which one is the best that could be used by all the services. Figure 8 is sample hierarchy that could be used to evaluated each method on several criteria and then rank order the methods based on the relative importance of the criteria.

The relevant criteria in this hierarchy are: Cost, Time, Accuracy, Believability, and Flexibility. Cost would be the cost to complete a study for defining a deficit at an installation. Time would be the man-hours needed to complete a study and Accuracy would measure the estimated accuracy of the method. The method must be measured on the estimated believability by Congress since Congress has the final word on the budget. Finally, Flexibility must be measured to estimate the given methods ability to be used by each service.

Another area that the AHP could be used is in the determination of whether to build to own, lease to own, lease, or renovate. This would be determined prior to

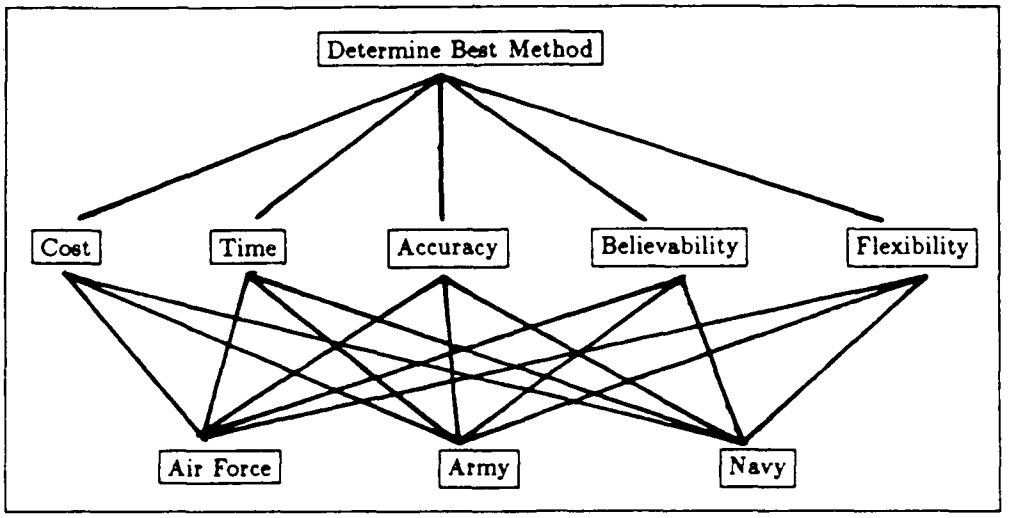


Figure 8: Hierarchy to Choose Method for Determining Deficit

the decision of where to build and after the determination of the deficit. Figure 9 gives a hierarchy that could possibly be used in the own versus lease decision.

Level 2 consists of risk factors in providing housing. The risk factors are: Inflation, Competition from the local community for the housing, and the Regulatory Standards that govern construction. Level 3 is a prediction of how Level 2 will react in the near future. Level 4 contains the objectives of the DHA and is related to Level 3 by determining how the objectives would be affected by the different scenarios. Level 5 contains the actions that are available and are related to Level 4 by determining the relative ability of each to achieve the objectives.

The AHP is a flexible process and the use of it by the Defense Housing Agency could prove to be very beneficial as a decision tool.

Summary

This chapter has provided the hierarchy that was developed to help in the decision of where to build military family housing at a given installation. Figure 7 is the hierarchy with generic locations as the alternatives. Chapter IV will take

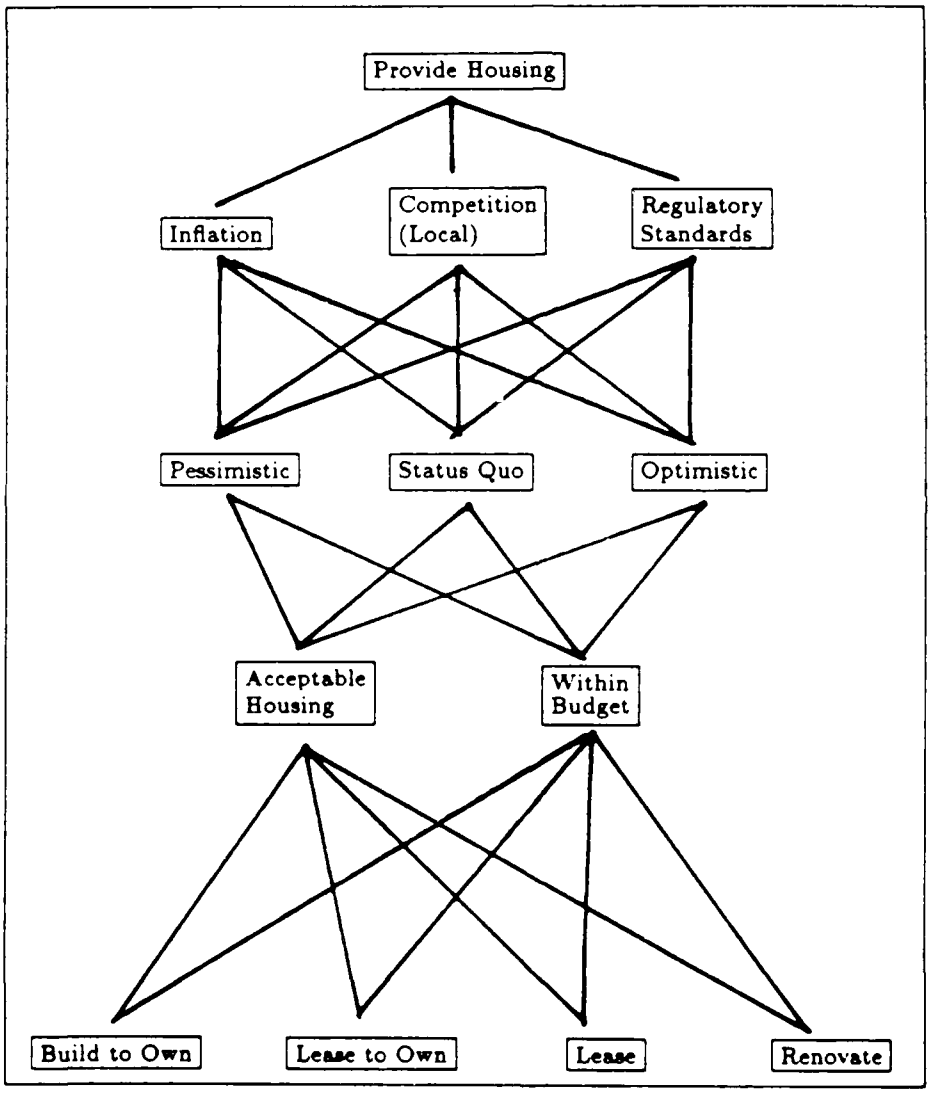


Figure 9: Hierarchy to Decide How to Provide Housing

this hierarchy and apply it at Wright- Patterson AFB, Ohio with specific locations to show how the process works. This chapter also described the methodology that was used as the hierarchy was developed. Through interviews and literature, the relevant criteria were defined. Also, the expertise of the DHA was used to make sure the hierarchy was logical and modeled the decision to be made. Finally, two extensions were provided that the DHA could use in other areas.

IV. Results

Overview

This chapter will discuss the results of evaluating the hierarchy that was built in Chapter III. A three step process was used to evaluate the hierarchy. First, a set of alternatives were generated so that a believable application of the hierarchy could be conducted. Second, pairwise comparisons were sought from those most knowledgeable on a certain criterion. Lastly, the comparisons were synthesized to get the overall ranking of the Candidate Locations.

Generating Candidate Locations

To evaluate the hierarchy, a set of alternatives (i.e. Candidate Locations) had to be generated. In generating the Candidate Locations, there was a major assumption that was made that allowed the study to be conducted at Wright-Patterson AFB, Ohio. The assumption was that Page Manor, a major military housing project, was to be relocated because it had become an unacceptable area to house military personnel. Once the assumption was made that Page Manor was to be relocated, the process of generating Candidate Locations was fairly straightforward. Three criteria were chosen to help generate the locations.

1. Location has enough acreage to support construction.
2. Location is within 30 miles of installation.
3. Location is zoned properly for construction.

Page Manor is a 1471 unit complex spanning approximately 220 acres (22). By interviewing an established developer in the area, it was evident that there were only 4 locations in the area that could support the construction and that were already zoned for housing construction (20). Also, these locations are all within 30 miles of

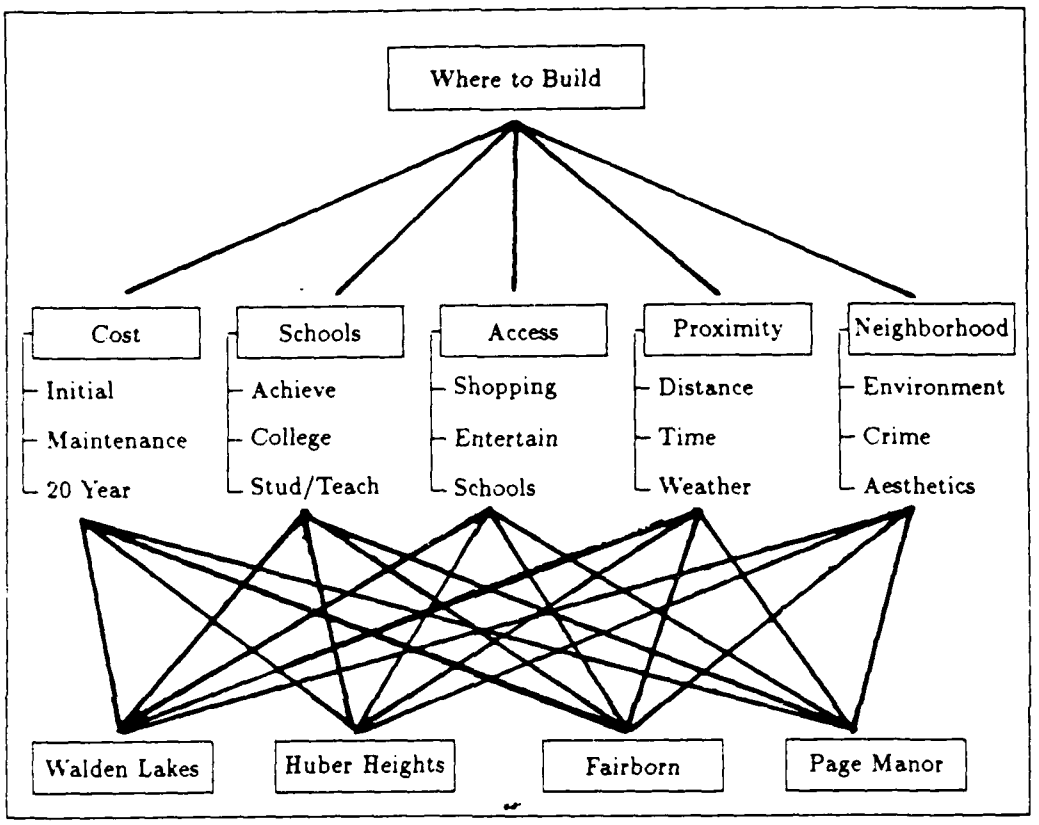


Figure 10: Hierarchy for Evaluating Candidate Locations

the installation. Appendix A is a set of maps of the Dayton, Ohio area that point out the specific locations in relation to the installation. The 4 locations are Walden Lakes, Huber Heights, Fairborn, and the present location of Page Manor.

Figure 10 is the hierarchy built in Chapter III with the Candidate Locations placed in Level 4. The next step is to perform pairwise comparisons on the criteria.

Pairwise Comparisons

To perform the pairwise comparisons, several agencies were asked to participate. The DHA was asked to make comparisons on the higher levels of the hierarchy relating Level 2 with Level 1, and relating Level 3 with Level 2. The housing office

at the Air Force Logistics Command (AFLC) was also asked to make the same comparisons as the DHA. These comparisons were then combined using the geometric mean. The actual steps will be discussed in the next section. The housing office at Wright–Patterson AFB made the comparisons on how the locations, in Level 4, related to the subcriteria associated with Access, Proximity, and Neighborhood. A local High School Senior Guidance Counselor gave the comparisons on how the locations related to the subcriteria associated with Schools. The DHA also made the comparisons on how the locations related to the subcriteria associated with Cost. Overall, there were 4 groups that participated in making the comparisons.

Relating Level 2 with Level 1 Figure 11 has 2 matrices that show how the DHA and the AFLC housing offices perceive the relative importance of the criteria in Level 2 in relation to choosing a location to build housing. The first matrix shows the judgments by the DHA, performed by Colonel Crownover, Director, Defense Housing. The Consistency Ratio (C.R.) of .037 says that the judgments are fairly consistent. The weights generated by the first matrix show that the DHA believes that Cost is the most important factor followed by Proximity, Schools, Neighborhood, and Access, respectively. The weights, or relative importance, of the criteria are calculated when the entire hierarchy is synthesized.

The second matrix in Figure 11 was generated by Major Stilson, Assistant Housing Manager, AFLC. The relative weights show that the AFLC and DHA differ somewhat on their judgments with Cost being the most important factor followed by Proximity, Schools, Access, and Neighborhood, respectively. Not only are the weights different, but the AFLC feels that Access is more important than Neighborhood.

To account for the differences in the DHA and AFLC's judgments, their judgments were combined to form new pairwise comparison matrices. To combine the judgments of the DHA and the AFLC, the geometric mean of the judgments were taken to form new matrices. Figure 12 shows the two matrices from Figure 11 be-

	DHA					AFLC				
Where to Build	Cost	Prox	Schl	N'hd	Ac	Cost	Prox	Schl	N'hd	Ac
Cost	1	4	6	7	8	1	3	6	9	8
Proximity	1/4	1	3	4	5	1/3	1	2	3	6
Schools	1/6	1/3	1	2	3	1/6	1/2	1	4	4
N'hood	1/7	1/4	1/2	1	2	1/9	1/3	1/4	1	1/3
Access	1/8	1/5	1/3	1/2	1	1/8	1/6	1/4	3	1
Weights	.516	.225	.104	.066	.044	.568	.203	.127	.039	.063
			C.R.	=	.037			C.R.	=	.062

Figure 11. Matrices Relating Level 2 with Level 1 (5,27)

Where to Build	Cost	Prox	Schl	N'hd	Ac
Cost	$\sqrt{1 \cdot 1}$	$\sqrt{4 \cdot 3}$	$\sqrt{6 \cdot 6}$	$\sqrt{7 \cdot 9}$	$\sqrt{8 \cdot 8}$
Proximity	$\sqrt{1/4 \cdot 1/3}$	$\sqrt{1 \cdot 1}$	$\sqrt{3 \cdot 2}$	$\sqrt{4 \cdot 3}$	$\sqrt{5 \cdot 6}$
Schools	$\sqrt{1/6 \cdot 1/6}$	$\sqrt{1/3 \cdot 1/2}$	$\sqrt{1 \cdot 1}$	$\sqrt{2 \cdot 4}$	$\sqrt{3 \cdot 4}$
N'hood	$\sqrt{1/7 \cdot 1/9}$	$\sqrt{1/4 \cdot 1/3}$	$\sqrt{1/2 \cdot 1/4}$	$\sqrt{1 \cdot 1}$	$\sqrt{2 \cdot 1/3}$
Access	$\sqrt{1/8 \cdot 1/8}$	$\sqrt{1/5 \cdot 1/6}$	$\sqrt{1/3 \cdot 1/3}$	$\sqrt{1/2 \cdot 3}$	$\sqrt{1 \cdot 1}$
	⇓	⇓	⇓	⇓	⇓
Where to Build	Cost	Prox	Schl	N'hd	Ac
Cost	1	3.5	6.0	7.9	8.0
Proximity	1/3.5	1	2.4	4.5	5.5
Schools	1/6.0	1/2.4	1	2.8	3.5
N'hood	1/7.9	1/4.5	1/2.8	1	1/1.2
Access	1/8.0	1/5.5	1/3.5	1.2	1
Weights	.555	.227	.120	.049	.049
			C.R.=.032		

Figure 12: Geometric Mean of the DHA and AFLC Matrices

ing combined into a new matrix with the associated weights and Consistency Ratio. This matrix is the combination of only two matrices, but the process can combine as many matrices that is appropriate to the study. The geometric mean is calculated by multiplying each judgment together and taking the n^{th} root (23:227). If 4 matrices are combined, then the 4^{th} root is taken. Figure 12 shows the process for 2 matrices, so the square root is used to calculate the geometric mean.

A representative question asked in relating Level 2 to Level 1 was, "Proximity to the installation is how much more important than having a nice neighborhood?" The answer that the DHA gave was moderate–strongly which is a 4 on the 1-9 scale. Therefore, a 4 was placed in the 2nd row, 4th column. The reciprocal, 1/4, was

placed in the 4th row, 2nd column. The AFLC said that Proximity is strongly more important which is a 5 on the 1–9 scale. So, a 5 was placed in the 2nd row 4th column and the reciprocal, 1/5, was placed in the 4th row, 2nd column. The geometric mean of these judgments are $\sqrt{4 \cdot 5} = 4.47$ with the reciprocal $\sqrt{1/4 \cdot 1/5} = 1/4.47 = 0.22$. These numbers are then placed in the appropriate element of the matrix.

Relating Level 3 with Level 2 The process at this level is the same as in Level 2 except there are 5 matrices (1 for each criteria) needed instead of just 1. Figure 13 is a set of matrices that show how the DHA and the AFLC perceive the relative importance of Level 3 with each of the criteria in Level 2. Note that all the matrices have an C.R. of less than 0.1. Figure 14 contains the combined DHA and AFLC matrices using the geometric mean.

A representative question at this level for Proximity was, "The time one must travel to work is how much more important than the distance?" In this case the DHA said there was a near equality, which means a 2 was placed in the 1st row, 2nd column. The AFLC said that distance was strongly more important than time so a 1/5 was placed in the 1st row, 2nd column. The geometric mean of these two judgments is $\sqrt{2 \cdot 1/5} = 0.63$. Another representative question asked at this level for Neighborhood was, "Security is how much more important to a neighborhood than its aesthetics?" The DHA and AFLC agreed on this question, saying that Security is moderate–strongly more important than Aesthetics.

Relating Level 4 with Level 3 This section required 15 matrices to be compared, one for each of the subcriteria in Level 3. Figures 15–19 show the comparison matrices, weights and C.R. of the matrices. In performing the pairwise comparisons at this level, there was only one agency asked to do the comparisons for each matrix. Some of the matrices were somewhat inconsistent, but only the revised matrices are shown in the figures.

	DHA			AFLC		
Cost	Main	Init	20	Main	Init	20
Maintenance	1	1/7	1/5	1	1/5	2
Initial	7	1	3	5	1	8
20 Year	5	1/3	1	1/2	1/8	1
Weights	.072	.649	.279	.162	.751	.087
	C.R.	=	.056	C.R	=	.005
Schools	Ach	Col	S/T	Ach	Col	S/T
Achievment	1	3	7	1	3	7
College	1/3	1	5	1/3	1	3
Stud/Teach	1/7	1/5	1	1/7	1/3	1
Weights	.649	.279	.072	.669	.243	.088
	C.R.	=	.056	C.R.	=	.006
Access	Shop	Entr	Schl	Shop	Entr	Schl
Shopping	1	6	1/4	1	4	1/4
Entertainment	1/6	1	1/9	1/4	1	1/7
Schools	4	9	1	4	7	1
Weights	.243	.056	.701	.229	.075	.696
	C.R.	=	.093	C.R	=	.066
Proximity	Dist	Time	Weth	Dist	Time	Weth
Distance	1	1/2	4	1	5	7
Time	2	1	5	1/5	1	3
Weather	1/4	1/5	1	1/7	1/3	1
Weights	.333	.570	.097	.731	.188	.081
	C.R.	=	.021	C.R.	=	.056
Neighborhood	Envi	Secu	Aest	Envi	Secu	Aest
Environment	1	2	5	1	3	7
Security	1/2	1	4	1/3	1	4
Aesthetics	1/5	1/4	1	1/7	1/4	1
Weights	.570	.333	.097	.659	.263	.079
	C.R.	=	.056	C.R.	=	.028

Figure 13: Matrices Relating Level 3 with Level 2 (5,27)

Cost Figure 15 contains the comparisons of the Candidate Locations with the subcriteria under Cost. A representative question asked in this section was, "The initial cost of construction in Fairborn is how much more important than the initial cost of construction in Walden Lakes?"

Before making the comparisons on Cost, actual figures had to evaluated to show the difference in building in one area versus another area. The cost to build and maintain housing was broken down into the following:

1. Initial - Cost of total construction.
2. Maintenance - Cost of repairs to keep units in acceptable condition.

Cost	Main	Init	20
Maintenance	1	1/5.9	1/1.6
Initial	5.9	1	4.9
20 Year	1.6	1/4.9	1
Weights	.112	.725	.163
	C.R.	=	.008
Schools	Ach	Col	S/T
Achievment	1	3	7
College	1/3	1	3.9
Stud/Teach	1/7	1/3.9	1
Weights	.660	.261	.079
	C.R.	=	.025
Access	Shop	Entr	Schl
Shopping	1	4.9	1/4
Entertainment	1/4.9	1	1/7.9
Schools	4	7.9	1
Weights	.236	.065	.698
	C.R.	=	.080
Proximity	Dist	Time	Weth
Distance	1	1.6	5.3
Time	1/1.6	1	3.9
Weather	1/5.3	1/3.9	1
Weights	.544	.359	.097
	C.R.	=	.003
Neighborhood	Envi	Secu	Aest
Environment	1	2.4	5.9
Security	1/2.4	1	4
Aesthetics	1/5.9	1/4	1
Weights	.612	.300	.088
	C.R.	=	.023

Figure 14: Combined DHA and AFLC Matrices from Level 3

3. 20 Year P.W. - Cost of operating expenses (gas, water, electricity, sewage, etc.) for next 20 years brought back to a present worth.

In trying to estimate the cost of these items, it was discovered that there was no difference in costs, repairs, or operating expenses to build in Walden Lakes versus Fairborn versus Huber Heights or Page Manor (3). The only cost differences were going to be in the initial land value to acquire a given property (3). Table 2 contains the cost of purchasing 220 acres in each area (20). There would be no cost to acquire Page Manor since it is already owned by the Government.

Once the cost differences were established, the DHA made the comparisons on

Table 2. Land Acquisition Costs (20)

Location	Cost Per Acre	Cost of 220 Acres
Walden Lakes	30,000	$6,600,000
Huber Heights	10,000	$2,200,000
Fairborn	12,000	$2,640,000

Table 3. Information on School Systems (1,12,17,26)

Location	School System	Achievment Scores (SAT)	% Students Going To College	Student/Teacher Ratio
Walden Lakes	Beavercreek	982	79	21/1
Huber Heights	Wayne	1001	66	22/1
Fairborn	Fairborn	1000	35	14/1
Page Manor	Stebbins	926	70	16/1

the cost figures. Notice the two matrices in Figure 15 that contain all 1's in the elements. This is saying that the locations do not differ on these costs. However, the locations do differ on land costs as spelled out in Table 2. But, the land costs are small compared to the overall project, which caused the numbers in the Initial Cost matrix to be small. The impact of these matrices will be discussed later.

Schools Table 3 shows the information on the school systems that are related to the various locations. This information was gathered from the schools themselves. Also, the Senior Guidance Counselor at Beavercreek High School made the comparisons. He was asked to make the comparisons because he showed a genuine interest in the study. A representative question asked in this section was, "Fairborn's Student/Teacher ratio is how much better than Huber Heights Student/Teacher ratio?"

Access, Proximity, and Neighborhood These sections were evaluated at the Base Housing Office by Cheryl Walters, expert on off-base housing. All these comparisons were much more subjective than Cost and Schools because there was not as much information to help make the comparison except on Time and Distance.

Maintenance Cost	W	H	F	P	20 Year Cost	W	H	F	P
Walden Lakes	1	1	1	1	Walden Lakes	1	1	1	1
Huber Heights	1	1	1	1	Huber Heights	1	1	1	1
Fairborn	1	1	1	1	Fairborn	1	1	1	1
Page Manor	1	1	1	1	Page Manor	1	1	1	1
Weights	.250	.250	.250	.250	Weights	.250	.250	.250	.250
	C.R.	=	.000			C.R.	=	.000	

Initial Cost	W	H	F	P
Walden Lakes	1	1/2	1/2	1/3
Huber Heights	2	1	1	1/2
Fairborn	2	1	1	1/2
Page Manor	3	2	2	1
Weights	.122	.227	.227	.424
	C.R.	=	.004	

Figure 15: Matrices Relating Candidate Locations with Sub-Criteria under Cost (5)

She performed a total of 9 pairwise comparison matrices.

Synthesis

This section discusses the synthesis of the hierarchy and sensitivity analysis. As explained in Chapter II, synthesizing a hierarchy combines all the pairwise comparison matrices and gives a ranking of the alternatives. Expert Choice, a computer model, was used to do all the calculations on synthesis and sensitivity analysis. The comparisons made in the previous 7 figures were used as input to the model. Once all the data was input into the model, the hierarchy could be synthesized.

The synthesis of the hierarchy was performed in three passes. The first pass was the synthesis of the hierarchy based on the original judgments. The second and third passes were done to show the sensitivity of the rankings based on certain criteria and to show some potential problems with the AHP. Also, each pass contains three different runs of the hierarchy. Since the DHA and the AFLC both gave judgments, one run was made for each of their judgments separately and one run was made for the combination of their judgments. This made a total of nine runs of the hierarchy.

Achievment(SAT)	W	H	F	P
Walden Lakes	1	1/3	1/3	5
Huber Heights	3	1	1	6
Fairborn	3	1	1	6
Page Manor	1/5	1/6	1/6	1
Weights	.168	.390	.390	.053
	C.R.	=	.040	

College	W	H	F	P
Walden Lakes	1	6	3	7
Huber Heights	1/6	1	1/5	3
Fairborn	1/3	5	1	5
Page Manor	1/7	1/3	1/5	1
Weights	.562	.096	.289	.053
	C.R.	=	.083	

Student/Teacher	W	H	F	P
Walden Lakes	1	3	1/5	1/5
Huber Heights	1/3	1	1/6	1/6
Fairborn	5	6	1	1/3
Page Manor	5	6	3	1
Weights	.101	.054	.308	.537
	C.R.	=	.097	

Figure 16: Matrices Relating Candidate Locations with Sub-Criteria under Schools (26)

Shopping	W	H	F	P
Walden Lakes	1	2	2	2
Huber Heights	1/2	1	4	4
Fairborn	1/2	1/4	1	1
Page Manor	1/2	1/4	1	1
Weights	.381	.368	.126	.126
	C.R.	=	.092	

Entertainment	W	H	F	P
Walden Lakes	1	4	4	2
Huber Heights	1/4	1	1	1
Fairborn	1/4	1	1	1/3
Page Manor	1/2	1	3	1
Weights	.495	.153	.114	.238
	C.R.	=	.044	

Schools	W	H	F	P
Walden Lakes	1	2	1/3	1/3
Huber Heights	1/2	1	1/4	1/2
Fairborn	3	4	1	2
Page Manor	3	2	1/2	1
Weights	.148	.106	461	285
	C.R	=	044	

Figure 17: Matrices Relating Candidate Locations with Sub-Criteria under Access (29)

Distance	W	H	F	P	Time	W	H	F	P
Walden Lakes	1	1/2	1/3	1/4	Walden Lakes	1	3	1/2	1/3
Huber Heights	2	1	1/2	1/2	Huber Heights	1/3	1	1/3	1/3
Fairborn	3	2	1	1	Fairborn	2	3	1	1
Page Manor	4	2	1	1	Page Manor	3	3	1	1
Weights	.100	.185	.345	.370	Weights	.187	.097	.335	.381
	C.R.	=	.004			C.R.	=	.044	

Weather	W	H	F	P
Walden Lakes	1	4	1/3	1/2
Huber Heights	1/4	1	1/4	1/4
Fairborn	3	4	1	2
Page Manor	2	4	1/2	1
Weights	.187	.074	.454	.285
	C.R.	=	.053	

Figure 18: Matrices Relating Candidate Locations with Sub–Criteria under Proximity (29)

Environment	W	H	F	P	Security	W	H	F	P
Walden Lakes	1	5	6	9	Walden Lakes	1	3	3	5
Huber Heights	1/5	1	3	6	Huber Heights	1/3	1	2	4
Fairborn	1/6	1/3	1	3	Fairborn	1/3	1/2	1	4
Page Manor	1/9	1/6	1/3	1	Page Manor	1/5	1/4	1/4	1
Weights	.644	.215	.097	.044	Weights	.509	.249	.177	.066
	C.R.	=	.069			C.R.	=	.059	

Aesthetics	W	H	F	P
Walden Lakes	1	2	3	8
Huber Heights	1/2	1	2	6
Fairborn	1/3	1/2	1	4
Page Manor	1/8	1/6	1/4	1
Weights	.491	.291	.168	.050
	C.R.	=	.011	

Figure 19: Matrices Relating Candidate Locations with Sub–Criteria under Neighborhood (29)

Table 4: Relative Ranking for Pass 1

Location	DHA	AFLC	Combination
Walden Lakes	.206	.191	.191
Huber Heights	.212	.219	.216
Fairborn	.272	.271	.276
Page Manor	.309	.320	.317

Pass 1 The first pass at synthesizing used the initial judgments performed by the DHA and AFLC. This was done to see if the relative ranking of the alternatives would be different for the DHA and AFLC and to see how combining their judgments would change the ranking. Using all the pairwise comparison matrices in the previous figures, the hierarchy was synthesized. The results for the DHA, AFLC, and combined judgments were that Page Manor always had the highest ranking followed by Fairborn, Huber Heights, and Walden Lakes respectively. Table 4 contains the relative ranking of the alternatives for the first pass.

Scenario The sensitivity charts and cost scenario are discussed next to show why the second and third passes were performed. If a decision were to be made based on Pass 1, Page Manor would be the most favorable choice. This is not to say that Page Manor is a bad place to build, but by looking at some of the sensitivity charts and making some assumptions about how important initial costs really are, the relative ranking of the alternatives could possibly change.

Sensitivity Charts The sensitivity charts are located in the appendices. Appendix B contains the sensitivity charts for the main criteria and the subcriteria for Pass 1. Appendix B explains how the sensitivity charts work in detail. The main focus of the charts is to show how the relative ranking of the alternatives would change if the importance of a specific criteria were to change. Because of the similarity in the sensitivity charts for each run, only the charts for the combined DHA and AFLC judgments for each pass are given. Appendix C contains the charts for Pass 2 and Appendix D contains the charts for Pass 3. The next paragraph

will discuss the sensitivity charts for the main criteria for Pass 1 which are the first five charts in Appendix B. Understanding the charts will help understand what will happen in Passes 2 and 3.

Beginning with the sensitivity chart for Cost, Figure 23 in Appendix B, it can be seen that Fairborn and Page Manor dominate Huber Heights and Walden Lakes for all the relative weights that Cost could have. Also, if the relative importance of Cost were to change from its present value to approximately 0.35, Fairborn would become the most favorable location to build. Looking at the sensitivity chart for Schools it can be seen that Fairborn dominates Huber Heights, and Huber Heights dominates Walden Lakes for all values. If the relative importance of Schools were to increase to approximately 0.26, then Fairborn again would become the most attractive location to build. The next sensitivity chart for Access again shows that Page Manor and Fairborn dominate Walden and Huber Heights for all values. Fairborn would also become the most favorable location if the relative importance of Access were to increase to approximately 0.31. Once again, the sensitivity chart for Proximity shows that Fairborn and Page Manor dominate Walden Lakes and Huber Heights for all values. However, Fairborn is also dominated by Page Manor and will not become the most attractive place to build for any value for the relative importance of Access. The last chart in Appendix B is the sensitivity chart for Neighborhood. This chart shows that there are no dominated locations for this criteria. This chart also shows that Walden Lakes will become the most favorable location to build if the relative importance of Neighborhood were to increase to approximately 0.22.

Costs It has already been stated that the cost of construction, utilities, maintenance, etc. for any given area is going to be the same. The only differences in costs are in the land acquisition costs, which range from $2.2 to 6.6 million. The land costs range from 2.1 to 6.4% of the total construction, which is approximately $103 million ($70,000 an unit) for building 1471 units (5.20). Also, one consideration is that, although the land at Page Manor is currently owned, it

will cost approximately $3.5 million to tear down the existing buildings (3).

The following table gives the costs to get each location in the same position for construction. These costs are only for the land value of Walden Lakes, Fairborn, and Huber Heights, and for the destruction of the current Page Manor housing.

Table 5: Costs to Acquire Land and Tear Down Page Manor

Location	Cost Per Acre	Cost of 220 Acres	Difference	% Total Construction
Walden Lakes	30,000	$6,600,000	$4,400,000	4.3
Huber Heights	10,000	$2,200,000	$0	0.0
Fairborn	12,000	$2,640,000	$440,000	0.4
Page Manor	Destruction	$3,500,000	$1,300,000	1.3

Notice the percentage of total construction costs for the different locations. By discussing this matter with the DHA, it was assumed that these costs differences could be considered negligible. By making this assumption, there are two options in dealing with the Cost criteria. The first option, Pass 2, is to leave the Cost criteria in the hierarchy and change the Initial Cost matrix. The second option, Pass 3, is to completely take the Cost criteria, and all its subcriteria, out of the hierarchy and re–evaluate the hierarchy.

Pass 2 This option would be to leave the Cost criteria in the hierarchy but to change the subcriteria matrix for Initial Cost. The Initial Cost matrix would be changed to a matrix containing only 1's in all the elements. As can be seen in the previous figures, the subcriteria under Cost consist of matrices filled with 1's for all the judgments except Initial Cost. This matrix was based on land acquisition costs since construction costs are the same. However, since the land acquisition costs are relatively small, and the added cost to tear down Page Manor has been pointed out, it is assumed that all these costs are negligible and 1's are placed in the Initial Cost matrix.

So, without actually performing Pass 2, how can the relative ranking of the locations be predicted when the Initial Cost judgments are all changed to 1's? The discussion on the sensitivity charts pointed out that the relative ranking of the locations will change if the importance of Cost is decreased. However, the importance of Cost is not going to change and, nor is the importance of the subcriteria Initial Cost is not going to change. The charts for the subcriteria can be found after the main criteria charts in Appendix B. Although the importance of Initial Cost is not going to change, the sensitivity chart for this subcriteria gives the information needed to make the prediction.

Notice the sensitivity chart for Initial Cost. Fairborn and Huber Heights are insensitive to any change in the relative importance of Initial Cost. The reason for their insensitivity is because, for Pass 1, these were the only two locations that were considered equal in the Initial Cost judgments. Now, assuming that all the locations will be considered equal, Page Manor and Walden Lakes will also be insensitive in the Initial Cost chart. This means that the lines for Page Manor and Walden Lakes will be parallel to and lie between the lines for Fairborn and Huber Heights. This will make Fairborn the most attractive place to build followed by Page Manor, Walden Lakes, and Huber Heights, respectively.

After synthesizing the hierarchy with the Initial Cost judgments changed, it can be seen in the next table that the previous prediction was correct.

The sensitivity chart for Initial Cost for Pass 2 shows that all the locations are insensitive to the importance of the subcriteria.

Since all costs are assumed to be the same between locations, Cost will not be a discriminating criteria in evaluating the hierarchy. Notice the sensitivity charts for the main criteria Cost and the subcriteria under Cost in Appendix C for Pass 2. The sensitivity charts for Cost show that the ordering of the locations will not change no matter how much importance is placed on the Cost criteria because all the lines are parallel. In one sense, the Cost criteria is transmitting no information

Table 6: Relative Ranking of Alternatives for Pass 2

Location	DHA	AFLC	Combination
Walden Lakes	.253	.244	.242
Huber Heights	.221	.229	.225
Fairborn	.280	.281	.285
Page Manor	.246	.246	.247

to the decision maker and becomes the least important criteria (30:190). The burden of the ranking falls on the other criteria. Pass 3 looks at deleting the Cost criteria from the hierarchy altogether since it contributes nothing to the hierarchy if all the costs are assumed to be the same.

Pass 3 This option is to completely take out the cost criteria and re–evaluate the hierarchy. To accomplish this option, the pairwise comparison matrix relating Level 2 with Level 1 has to be performed with Cost deleted. Figure 21 contains the matrices relating the two levels, however, only the DHA could be contacted to make the comparisons. The AFLC could not be contacted, so the matrix in Figure 21 is the estimated pairwise comparison matrix for the AFLC keeping their original order of the other criteria. The other matrices in Level's 3 and 4 need not be re–evaluated.

As was done in Pass 2, there is a way to predict what will happen in Pass 3. However, this pass is different than Pass 2 because the judgments relating Level 2 with Level 1 had to be re–evaluated but, a rough estimate can be made.

Looking in Appendix B at the sensitivity chart for the main criteria, Cost, a prediction of the relative ranking of the alternatives can be made if the Cost criteria were removed from the hierarchy. Totally removing a criteria from a hierarchy means that the hierarchy will have a relative importance of 0.000. By moving the dashed line to the left as far as it can go will be the estimate of the ranking of the

	DHA				AFLC			
Where to Build	Prox	Schl	N'hd	Ac	Prox	Schl	N'hd	Ac
Proximity	1	6	4	7	1	4	7	5
Schools	1/6	1	2	3	1/4	1	4	2
N'hood	1/4	1/2	1	2	1/7	1/4	1	1/2
Access	1/7	1/3	1/2	1	1/5	1/2	2	1
Weights	.637	.175	.121	.067	.203	.127	.039	.063
		C.R.	=	.052		C.R.	=	.024

Where to Build	Prox	Schl	N'hd	Ac
Proximity	1	4.9	5.3	5.9
Schools	1/4.9	1	2.8	2.4
N'hood	1/5.3	1/2.8	1	1
Access	1/5.9	1/2.4	1	1
Weights	.637	.175	.121	.067
		C.R.	=	.033

Figure 20. Pairwise Comparison Matrices with Cost Deleted (5)

Table 7. Relative Ranking of the Alternatives for Pass 3

Location	DHA	AFLC	Combination
Walden Lakes	.234	.194	.212
Huber Heights	.168	.192	.181
Fairborn	.325	.339	.334
Page Manor	.272	.273	.274

alternatives. The chart says that Fairborn would become the most attractive place to build followed by Page Manor, Walden Lakes, and Huber Heights, respectively

Once the synthesis was performed it was found that the prediction was correct. The following table gives the relative ranking of the alternatives with the Cost criteria deleted.

Decision Given the above discussion, where should the housing be built? The final decision rests in the decision maker's hands. If he or she feels that the initial land acquisition costs are relevant, then the AHP ranks Page Manor as the most attractive location to build. However, if land acquisition costs are considered negligible, both

Pass 2 and Pass 3 rank Fairborn as the most attractive location to build.

The decision to assume that the land acquisition costs were negligible was due to the fact of the large construction costs. This assumption will not be proper in all situations, especially for smaller projects with less units to be built or for projects where land costs are extremely large per acre. Also, the assumption that construction costs are going to be the same is not always valid. The assumption in this study was that the same type of housing would be built in each location, however, this is not always the case. One type of housing should be built in one location while another type of housing should be built in another location to "blend in with the surrounding area" [3]. This will cause different construction costs and must be accounted for in the judgments.

Problems

There were several problems that arose during this study, and most of these problems had to do with the AHP itself.

One problem that arose in conducting this study was getting agencies to participate. However, in the case of the guidance counselor at Beavercreek High School, who showed a genuine interest in the study, the AFLC, and the DHA, most participants had to be convinced that they should help in some way. For instance, when some of the local developers were first approached about obtaining information for a study at AFIT, most balked or said they would return the call. None of the developers contacted returned the call. To get the support of a local developer, another developer, was contacted about a study that was supported by the Defense Housing Agency and the assumption was that Page Manor was to be relocated. When the study was described in this manner, the developer willingly discussed at length the various possibilities in the local area for possible construction because he felt that he could possibly make some money on this type of project.

Some of the problems in this study were with the AHP process itself. One

problem is in making the pairwise comparisons. The process should be understood by the person making the comparisons. A problem arose in this area when one of the participants was very apprehensive at first about making the comparisons, but after some practice the person was very competent in making the judgments. On the other hand, the idea of consistency arose several times with another participant and had to be reminded several times until the process was complete. Another example is understanding the 1-9 scale. At one point the verbal scale of the 1-9 scale was used and then translated into the number scale.

The last problem of the study, not related to the AHP, was probably the biggest as far as time constraints are concerned. One of the pairwise comparison matrices was input into Expert Choice backwards. The subcriteria for Distance was input wrong which had a major impact on the relative ranking of the alternatives. Pass 1 did not change much because Page Manor was still the most attractive place to build. However, Pass 2 and Pass 3 changed quite a bit with Walden Lakes being the most attractive place to build with the incorrect matrix, and with Fairborn being the most attractive place to build with the correct matrix. The reason that there was a difference was because with the distance matrix backwards, it made the proximity of Walden Lakes to the installation much better than Fairborn even though Walden Lakes is twice as far as Fairborn is from Wright- Patterson.

Although the problems in evaluating this hierarchy were not insurmountable, it is felt that they did detract the participants from making better judgments. Future studies should be aware of the possible problems in dealing with several agencies and combining all the necessary data to complete study. Also, double checks on the input data should be made to make sure that the data relates the true relationships of the criteria and alternatives.

Summary

This chapter applied the hierarchy built in Chapter III to evaluating the relocation of Page Manor, a large military housing development at Wright-Patterson AFB, Ohio. When the hierarchy was first evaluated, the AHP ranked the present location of the housing as the most attractive. However, this ranking was due to fact that there would be no land acquisition costs at this location. By assuming that the land acquisition costs were negligible, and the process re-evaluated, the AHP ranked another location, Fairborn, as the most attractive location to build.

It should be pointed out that this application of the hierarchy is unique to Wright-Patterson AFB. Future applications of this hierarchy might reveal the same relationships for the criteria, but most likely there will be something in the next application that will make it unique to that installation.

Although some problems did arise in the application of the hierarchy, they were not major stumbling blocks to the study. Future studies should be aware of the possible problems that can occur using the Analytic Hierarchy Process.

V. *Conclusions and Recommendations*

Conclusions

The main conclusion of this study is that the AHP would be a good decision aid at the installation level housing offices. The hierarchy developed in this study would allow candidate locations to be evaluated on several criteria to ensure that the housing locations selected are in the best interest of the installation and the personnel. The AHP forces the decision maker to evaluate the relative importance of all the criteria before making a final decision.

If the DHA plans on using the Analytic Hierarchy Process, they need to fully educate those installations where it is going to be used. A superficial understanding of the process will most likely lead to a poorly applied hierarchy. Without the proper education, many technicians may take the first synthesis of the hierarchy as the best solution without looking at how sensitive the alternatives are to slight changes in the relative importance of the criteria. This study showed that the hierarchy applied at Wright-Patterson AFB was very sensitive to the subcriteria Initial Cost, and without addressing this sensitivity, the decision of where to build housing might have been different.

Recommendations

If this hierarchy is to be used at the installation level housing offices, an intense study should be conducted as to its feasibility. This study should be done to find out if a large number of people in the housing arena feel comfortable with the hierarchy. Saaty points out that, assuming that the AHP is a valid approach, and the hierarchy is accepted as logical in its representation, then the hierarchy should be able to model the decision.

Future Areas of Research

This section discusses some possible areas of research discovered in this study that the DHA migh be interested in pursuing. Some of the areas of research are:

1. Determine whether current methods of defining the deficit are correct.
2. Determine the best method that is currently being used by the services.
3. Determine best criteria for determining deficit.

The following sub-sections will discuss each of the above areas. Although each of the above research topics are related, it would be up to the DHA as to which topic to pursue first.

Current Methods This study would be to determine whether the current methods are properly calculating the deficit. Although this sounds relatively straightforward, there is not much literature on this subject and there are three methods to be evaluated. The problem in this type of study is to find a way to statistically evaluate the methods. Also, what are the methods going to be judged against. If the actual deficits were known then there would be nothing to measure. However, there are many installation housing managers that feel that the actual deficit is sometimes much larger than the estimates reported by the current methods. They know that the housing is unacceptable just by daily association with the problems that come across their desk (5).

This study could be accomplished by working directly with the housing managers. They could point to the problems that they have in determining the deficit and then it could be determined where the current methods fall short of making the determination.

Determine the Best Method that is Currently in Use Currently there are three methods of determining the deficit--one for each service. This study could determine

which of these methods is currently determining the deficit the best. The study described before this one would have to be done to accomplish this study. Also, the above study would have to show that the current methods are all sound ways of determining the deficit. Then, based on certain criteria of what constitutes a sound method of determining a deficit, the three current methods could be evaluated. Figure 8 at the end of Chapter III could be a starting point of this study. The use of the AHP seems to be suited for this type of study. The key to accomplishing this study would be to find the correct criteria to use. However, if the three methods were previously found to be unsuitable for determining the deficit, this study would have little merit.

Determine Best Criteria for Determining the Deficit The initial scope of this thesis was to determine a better method for determining the deficit. Determining the best criteria would have been a sub-section of that study. Because of the broad scope of the initial study, a more workable thesis had to be done. Chapter I pointed out the 6 criteria for whether a house, apartment, or mobile home is considered unacceptable. But there are extenuating circumstances where these criteria can not always be applied. One circumstance is when a nice home is within the 30 mile radius but because of the geography (bridges, railroad tracks, etc.) the person can not drive into work in a reasonable time.

Concluding Remarks

The use of the Analytic Hierarchy Process is becoming an accepted decision tool in many civilian companies because of its ease of use and flexibility. The use of the AHP and the hierarchy developed in this study has shown an application that the DHA may want to apply at the installation level housing offices. It is hoped that this study will help the DHA in their future studies.

Appendix A. *Maps of Local Area*

The following maps show how the Candidate Locations are situated with Wright-Patterson, AFB. Figure 21 is a map of Walden Lakes and Figure 22 is a map of Huber Heights and Fairborn. A third map of Page Manor was not provided because it appears in each map because of its proximity to the installation.

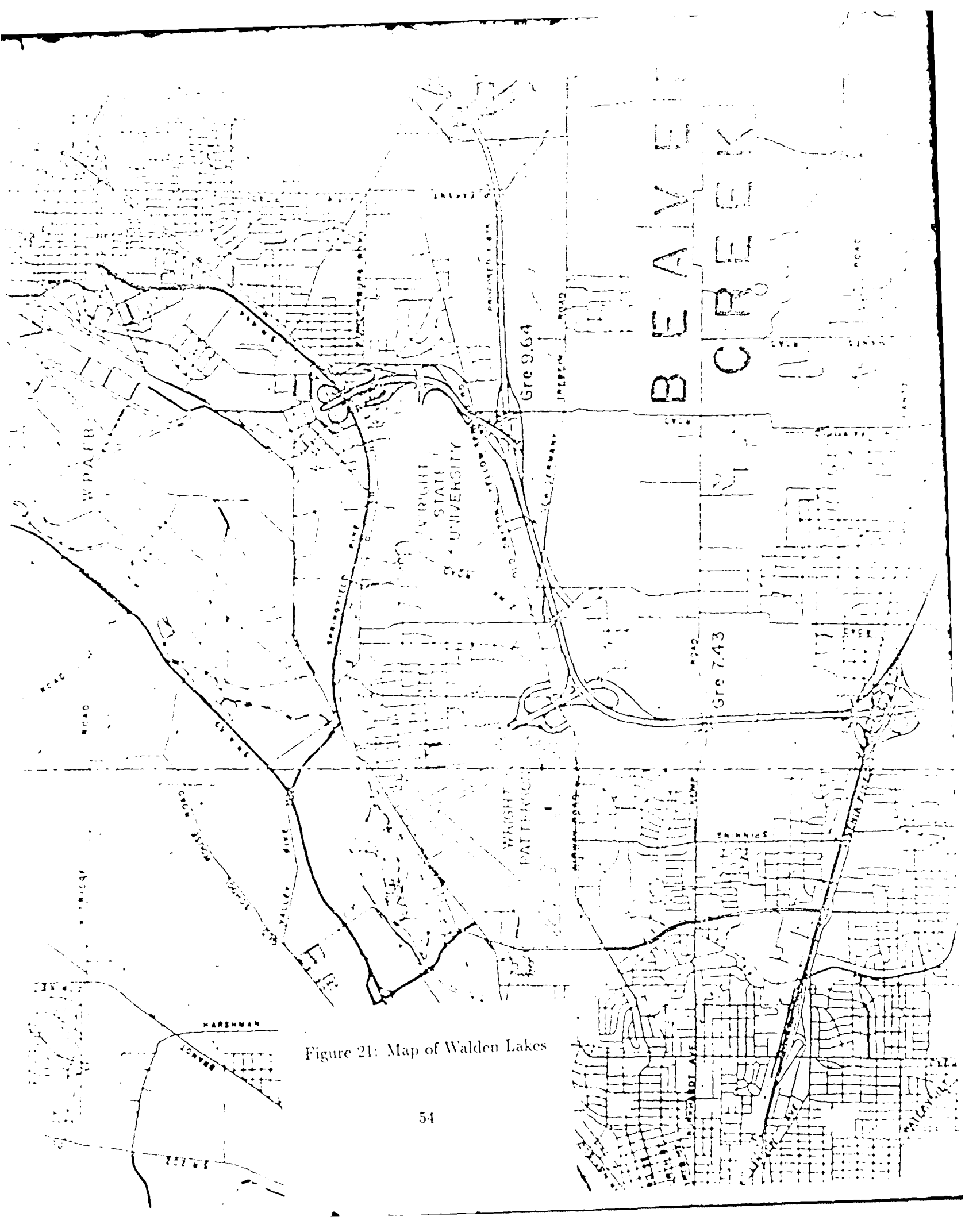
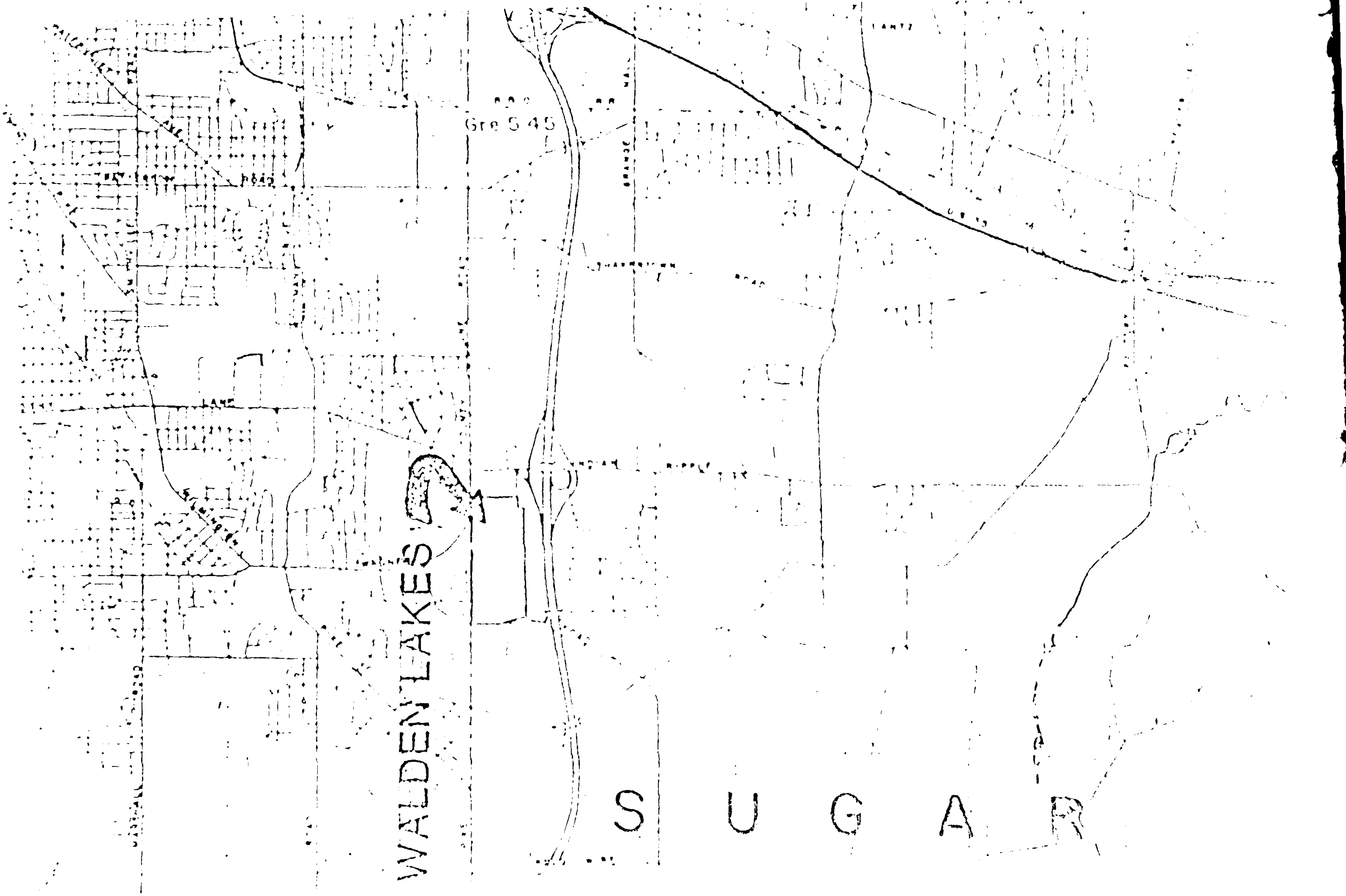
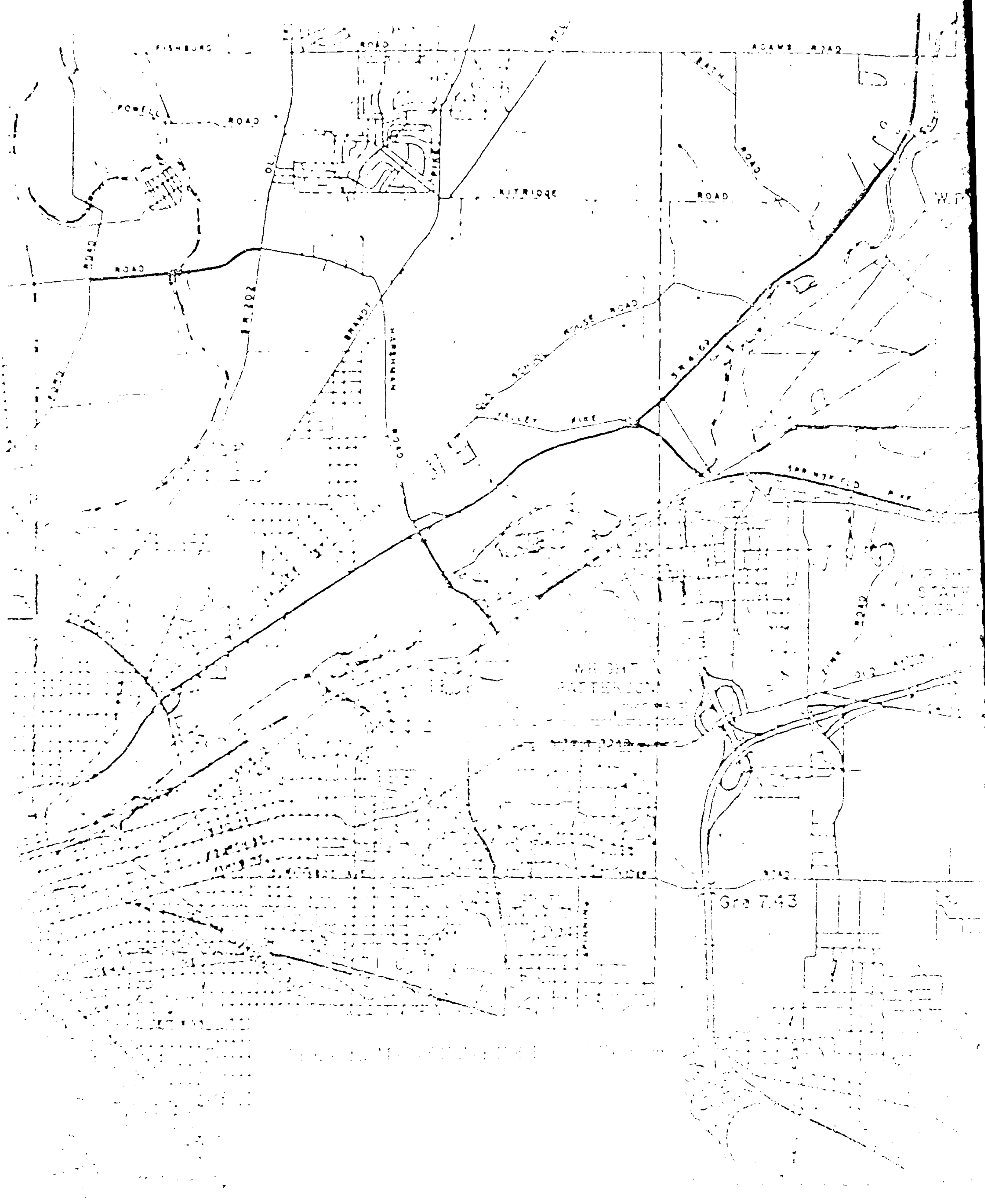
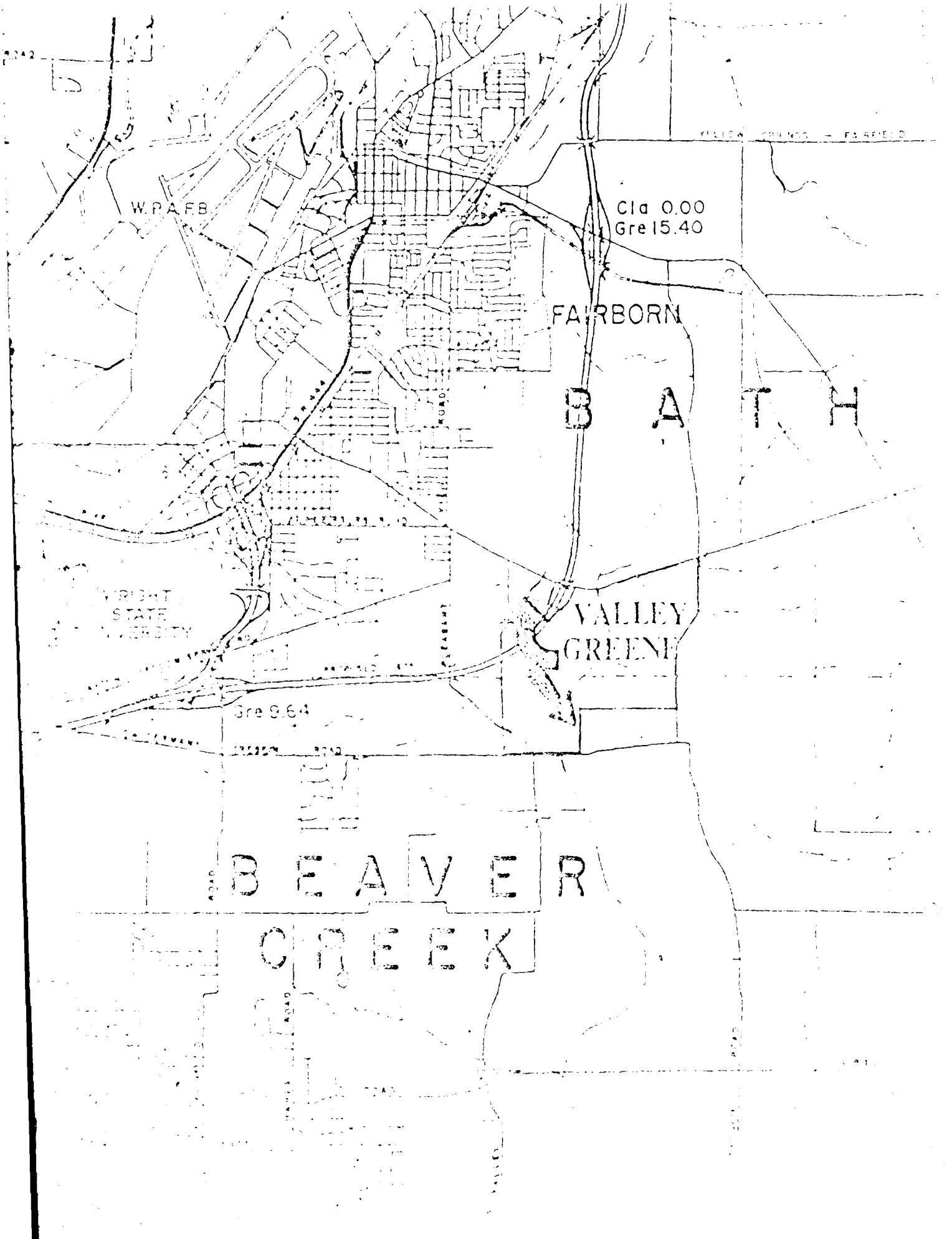


Figure 21: Map of Walden Lakes


Gre S 45
WALDEN LAKES
SUGAR


FISHBURG
ROAD
ADAMS ROAD
POWELL
ROAD
KITRIDGE
ROAD
BATH
ROAD
PIKE
S.R. 202
BRANDT
VALLEY PIKE
SPRINGFIELD PIKE
WRIGHT
PATTERSON
ROAD
Gre 7.43


W.P.A.F.B.
Cla 0.00
Gre 15.40
FAIRBORN
B A T H
VALLEY
GREENE
Gre 9.64
B E A V E R
C R E E K

Appendix B. *Sensitivity Charts for Pass 1*

The following charts are the sensitivity charts for the first pass of the hierarchy.

Explanation of Charts

Each chart is the sensitivity of a specific criteria and shows how the relative ranking of the alternatives would change as the relative importance of the criteria changed. The vertical dashed line is the current importance of the criteria. Assuming that the line moves to the right means that the relative importance of that criteria is increasing. Assuming that the line moves to the left means that the relative importance of the criteria is decreasing. Changing the relative importance of a criteria might change the ranking of the alternatives. These charts show what the ranking would be if the importance of the criteria were to change to a specific value. Remember that changing the importance of one criteria would mean that the other criteria would change in the opposite direction.

Another way to look at these charts is see what the relative ranking of the alternatives would be if the relative importance of the main criteria were changed to 1.00 or 0.00. A relative importance of 1.00 would mean that the alternatives would be ranked based totally on this main criteria. A relative importance of 0.00 would mean that the alternatives would be ranked as if this criteria were completely deleted from the hierarchy. The subcriteria can be looked at in a similar way. A relative importance of 1.00 for a subcriteria means that the other subcriteria under that one main criteria are deleted. A relative importance of 0.00 for a subcriteria means that that it is deleted from the hierarchy below that one main criteria.

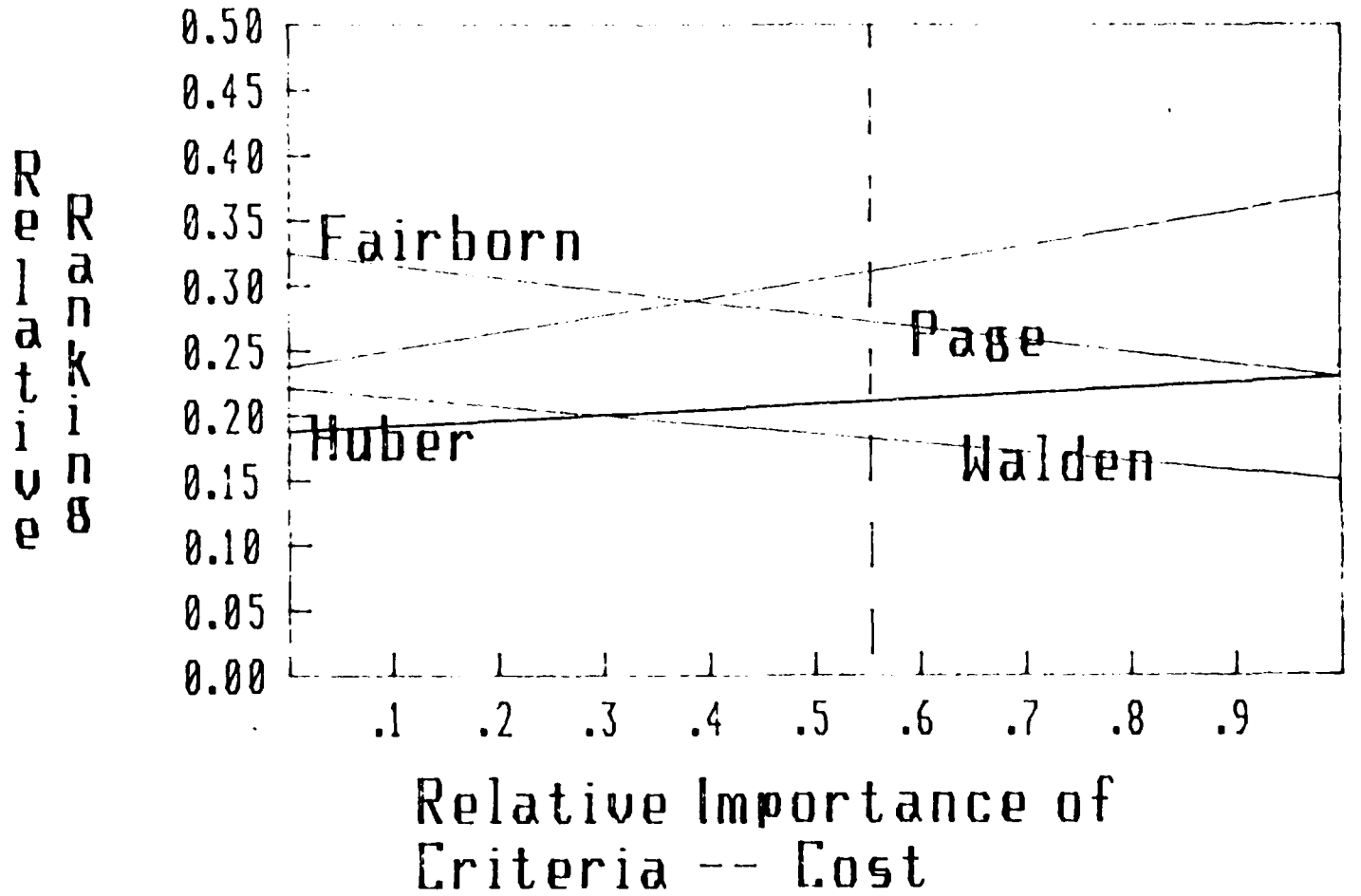


Figure 23: Sensitivity Chart for Main Criteria Cost in Pass 1

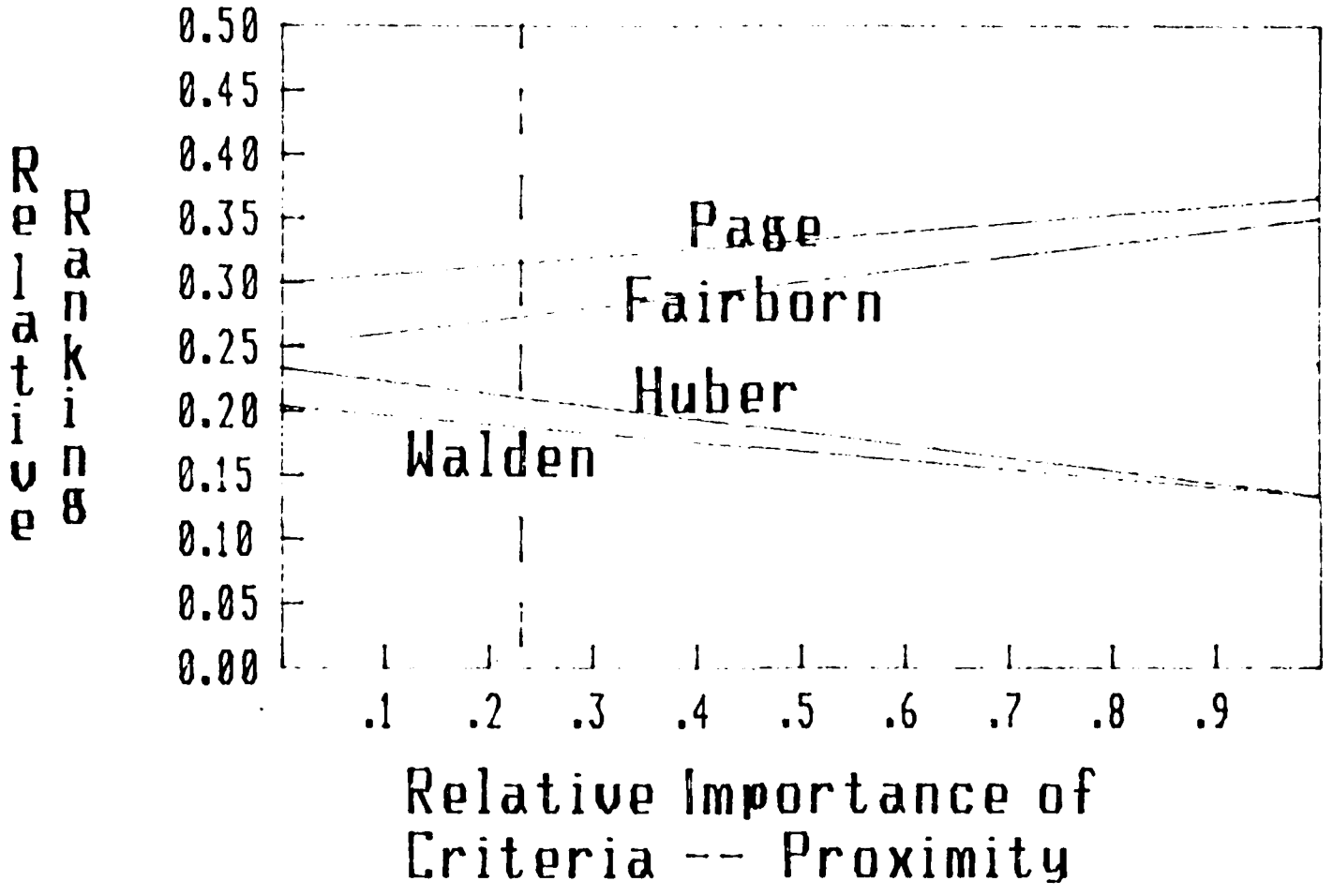


Figure 24: Sensitivity Chart for Main Criteria Proximity in Pass 1

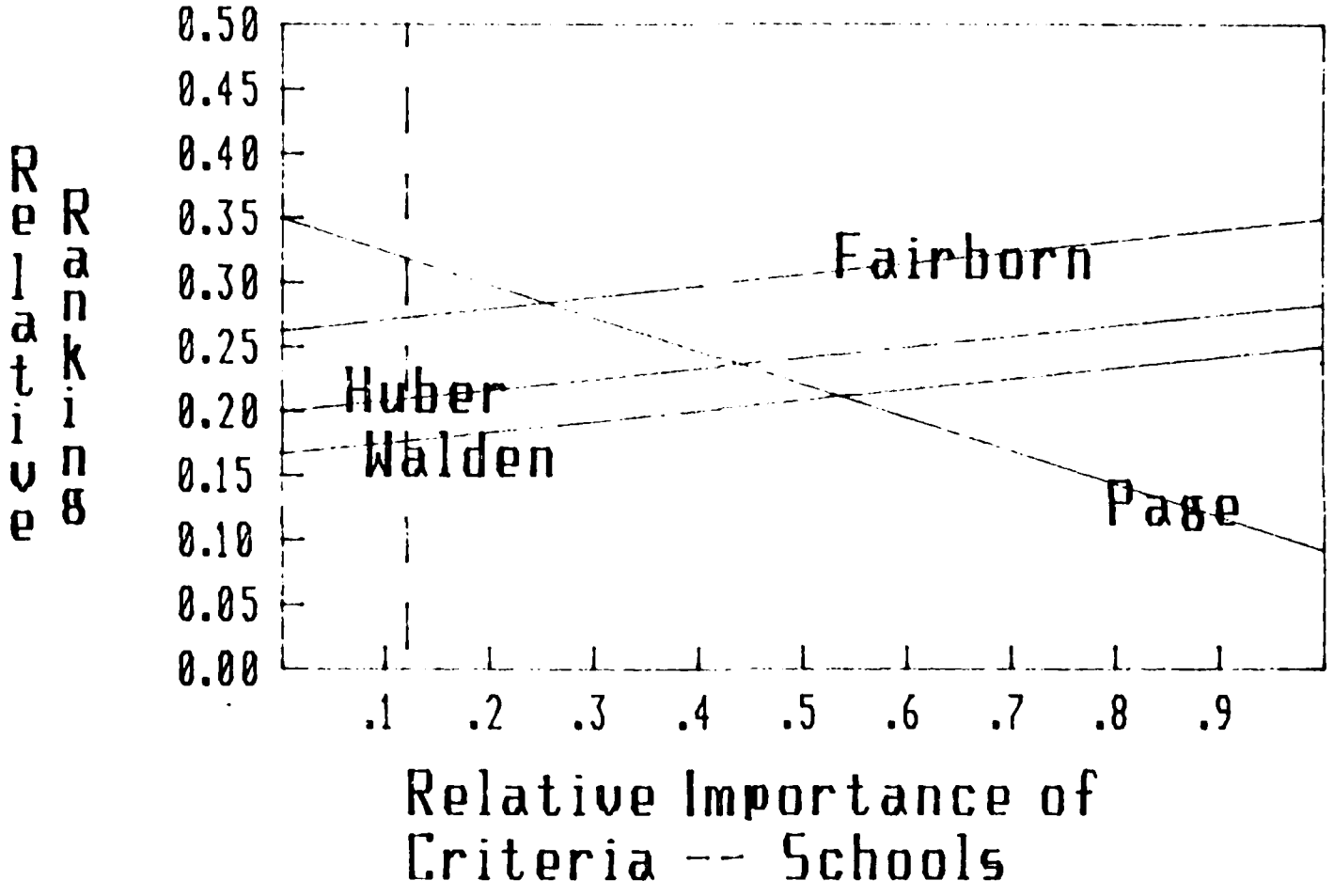


Figure 25: Sensitivity Chart for Main Criteria Schools in Pass 1

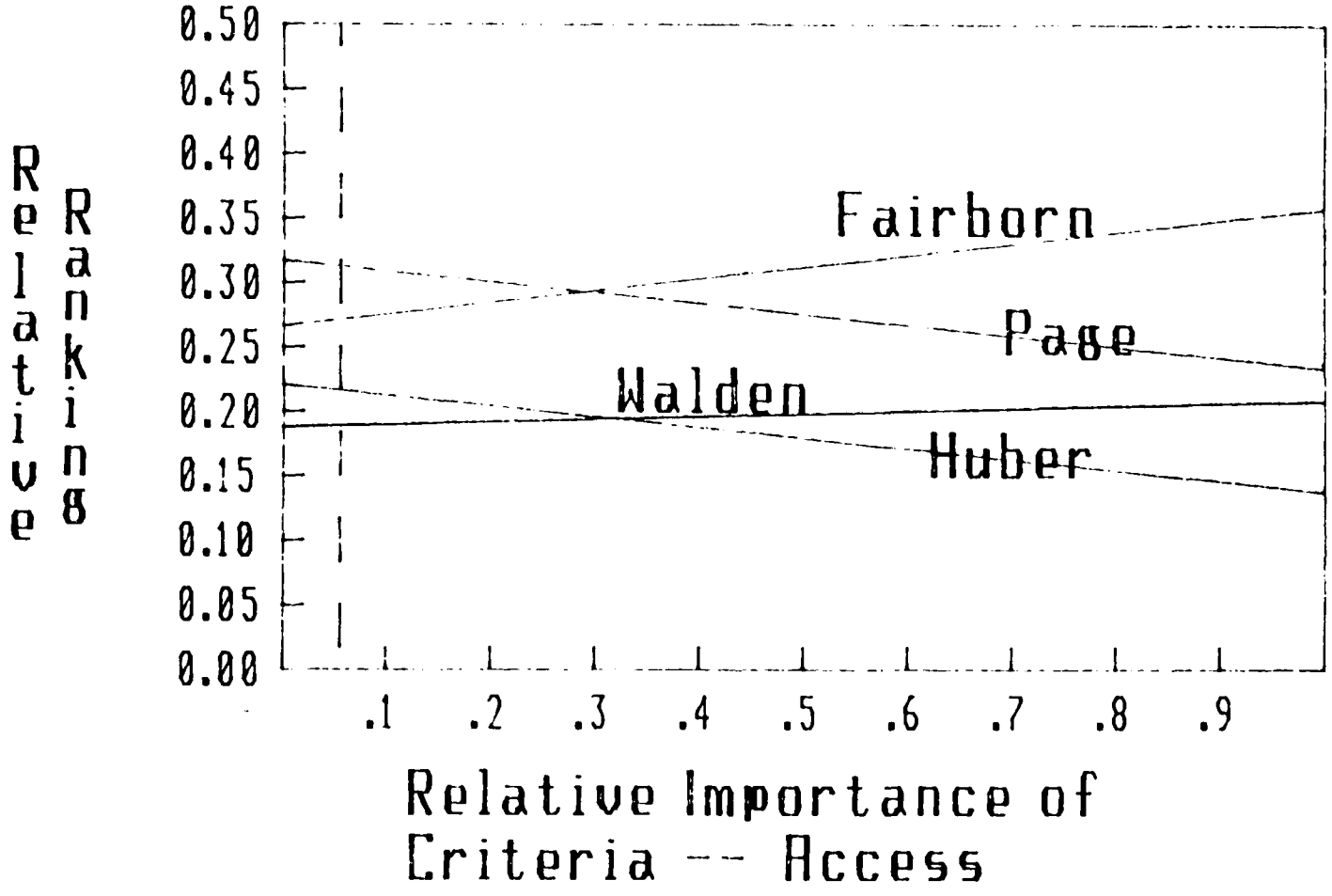


Figure 26: Sensitivity Chart for Main Criteria Access in Pass 1

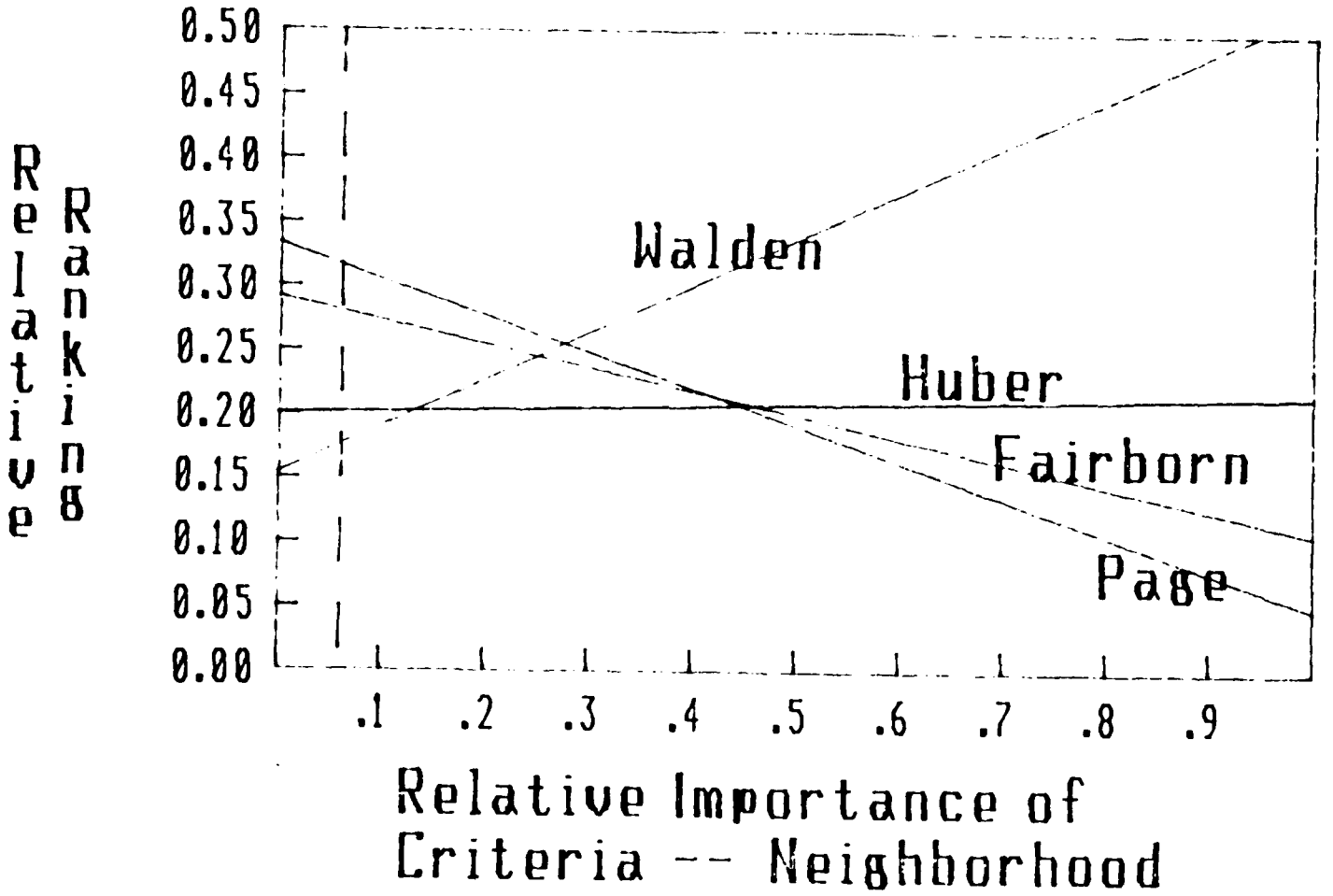


Figure 27: Sensitivity Chart for Main Criteria Neighborhood in Pass 1

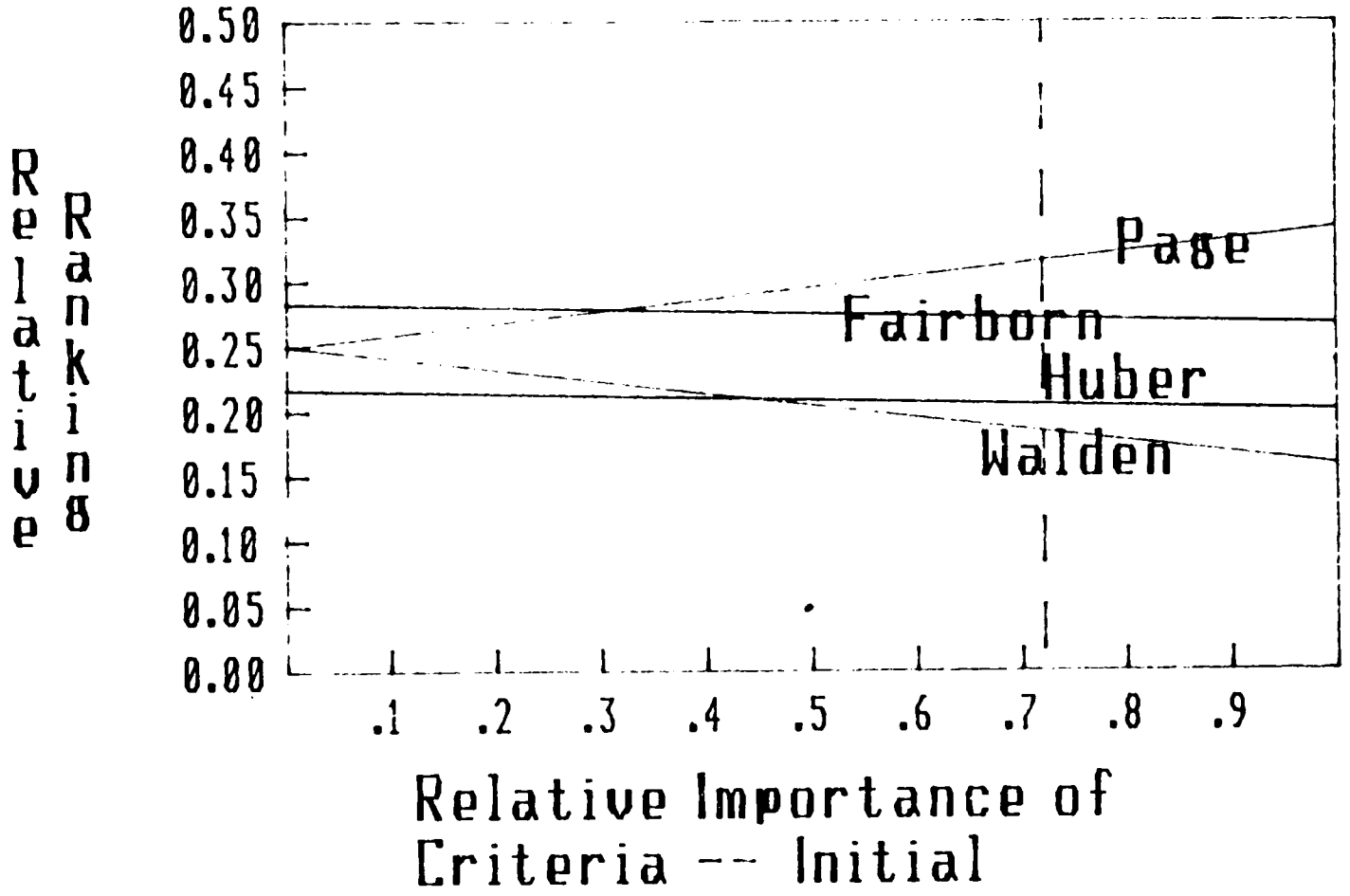


Figure 28: Sensitivity Chart for Subcriteria Initial Cost in Pass 1

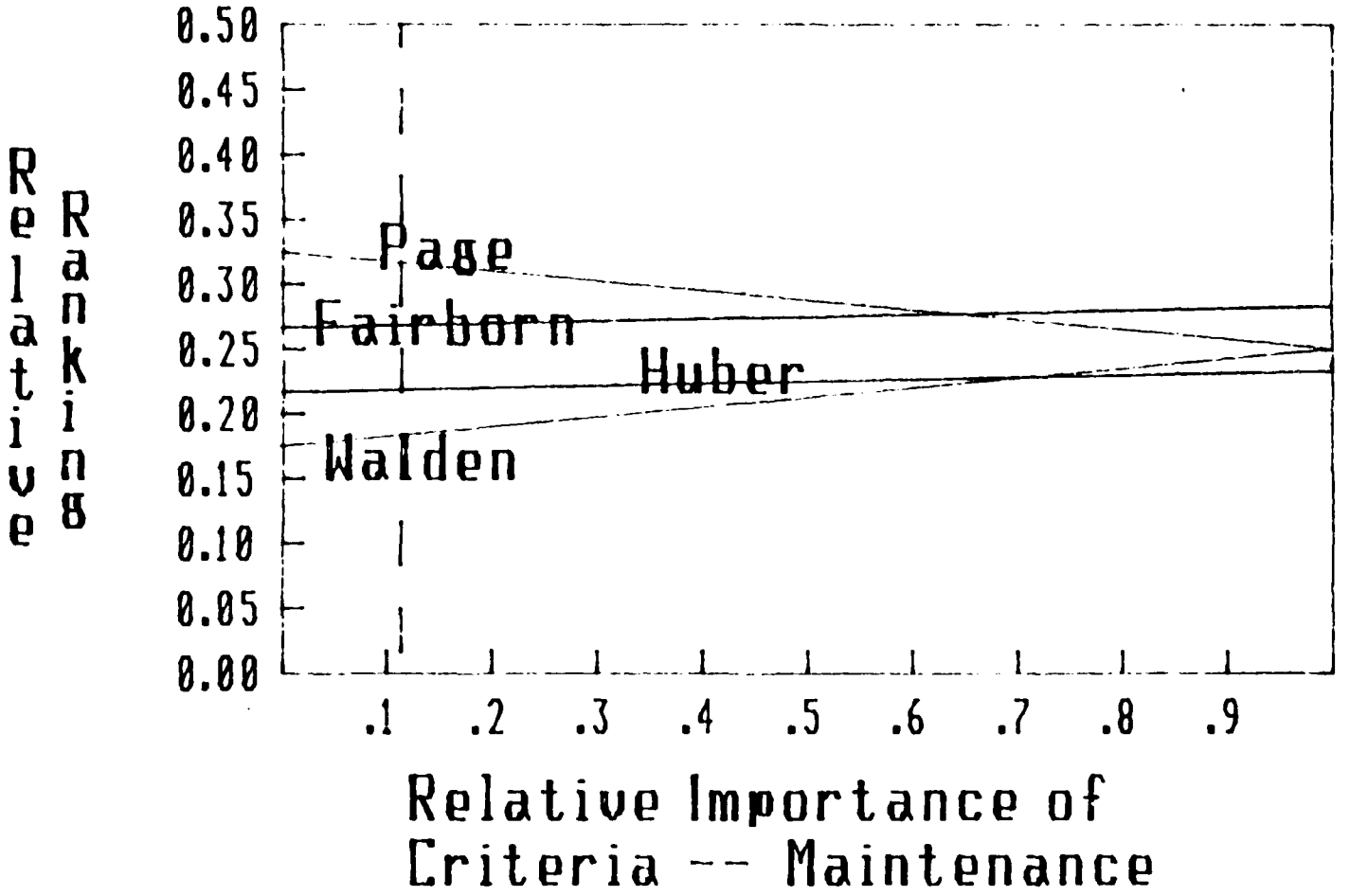


Figure 29: Sensitivity Chart for Subcriteria Maintenance Cost in Pass 1

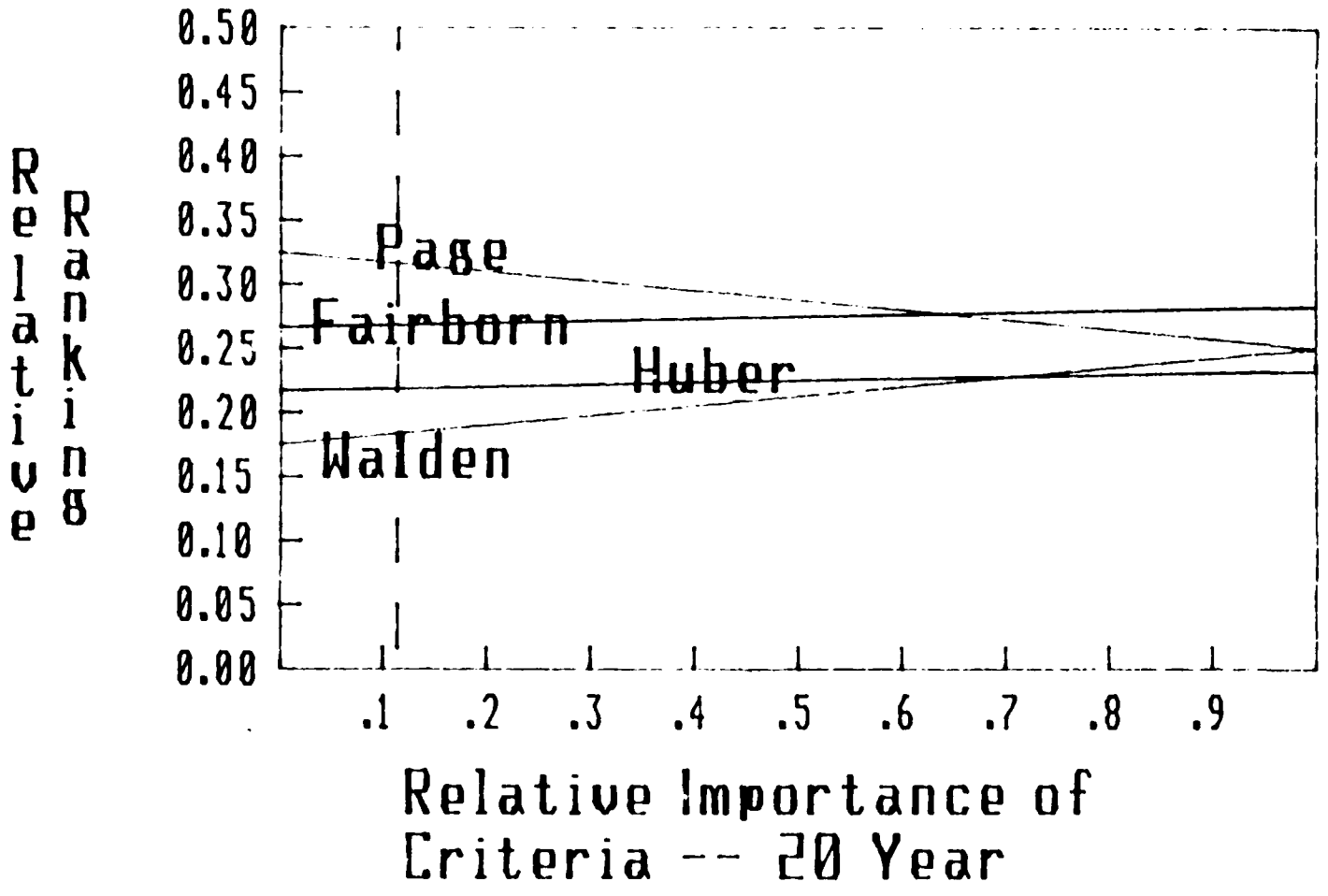


Figure 30: Sensitivity Chart for Subcriteria 20 Year Cost in Pass 1

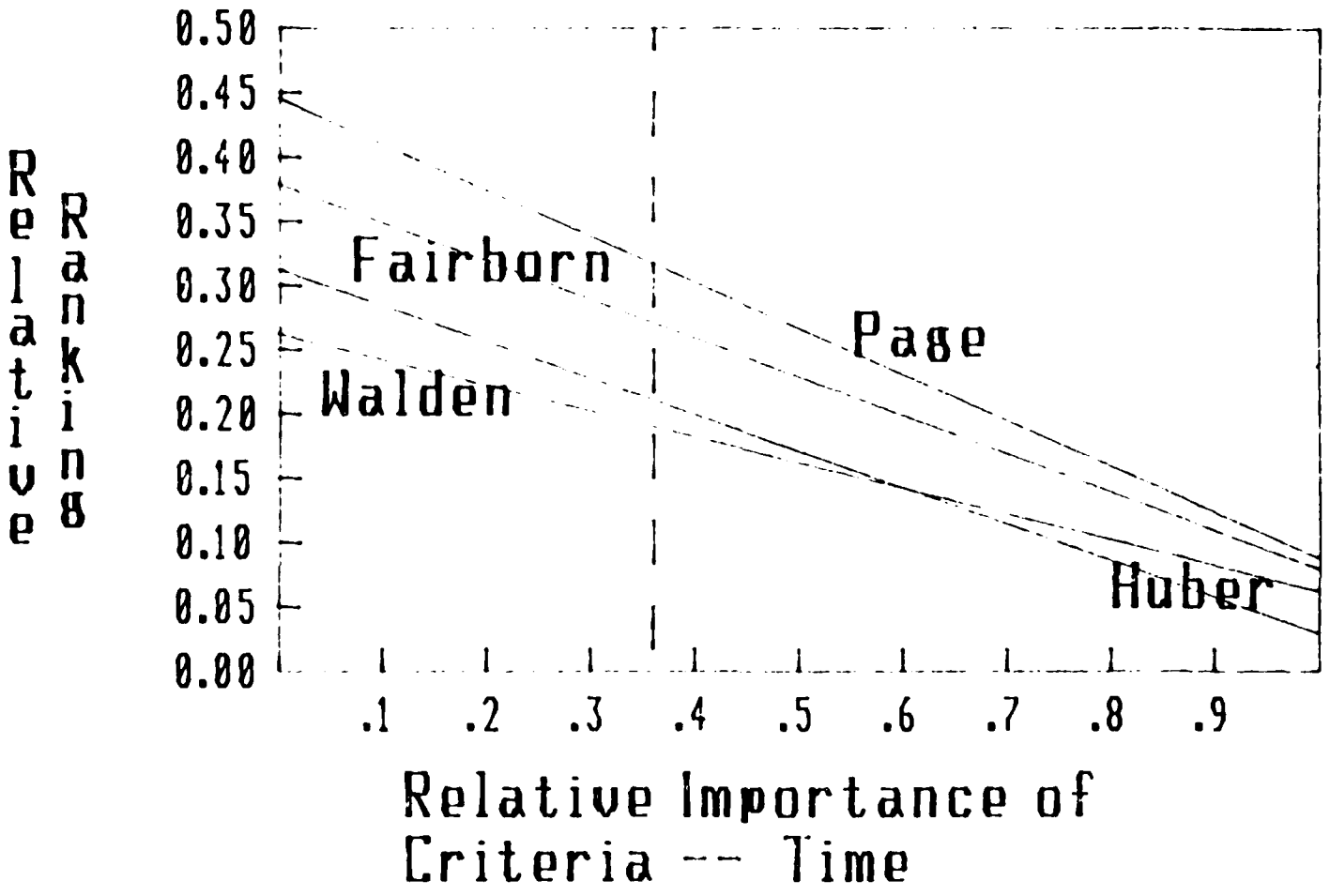


Figure 31: Sensitivity Chart for Subcriteria Time in Pass 1

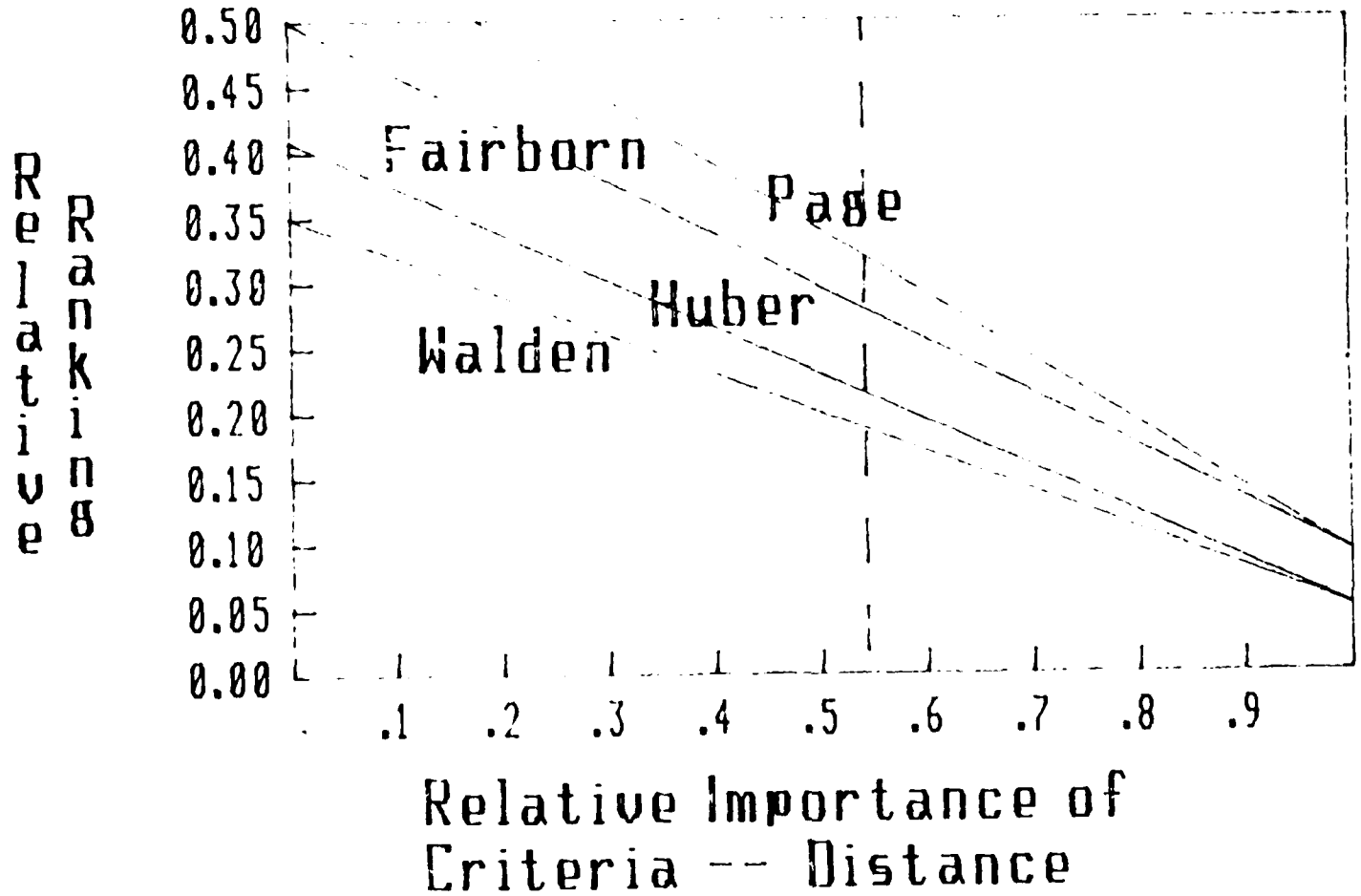


Figure 32: Sensitivity Chart for Subcriteria Distance in Pass 1

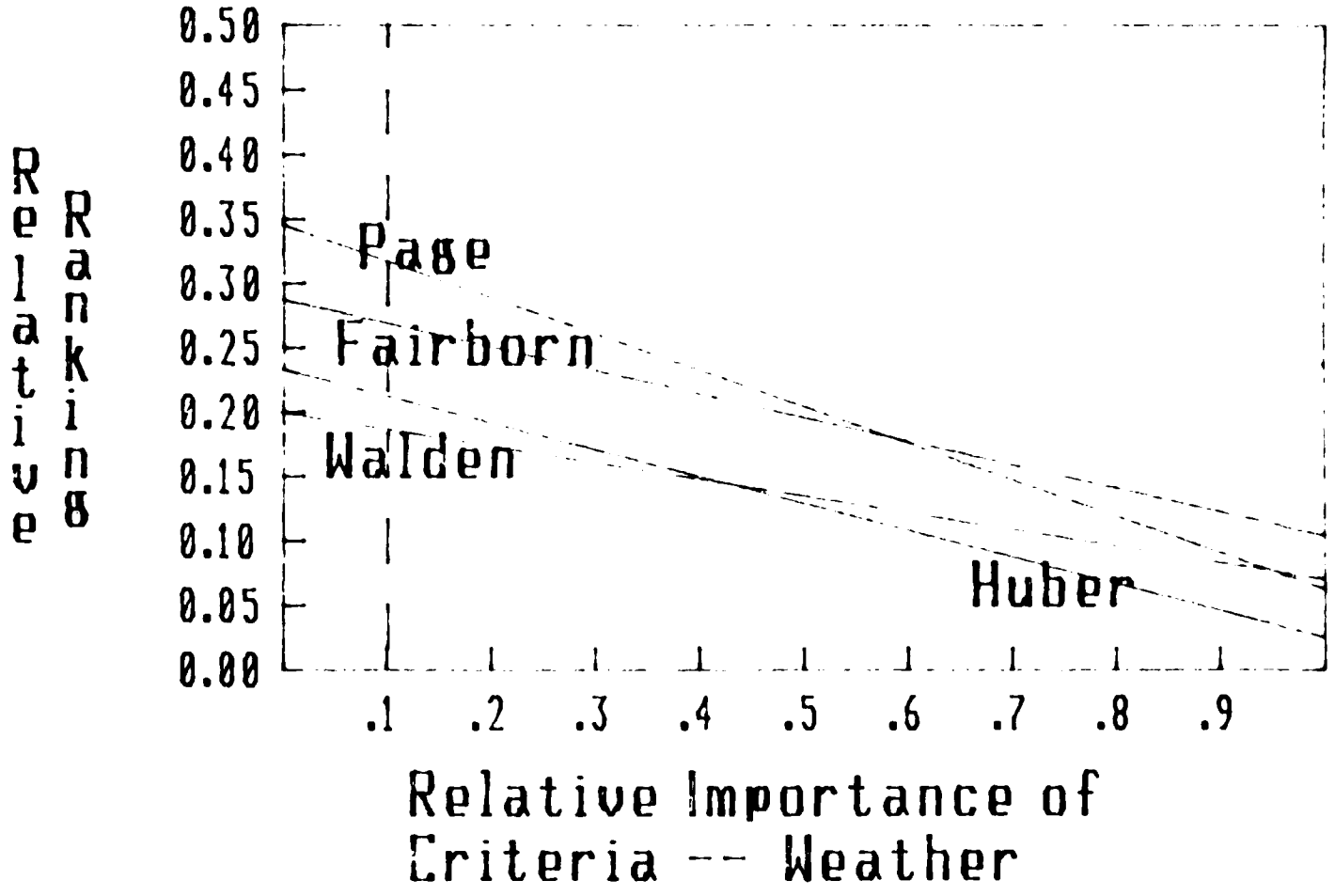


Figure 33: Sensitivity Chart for Subcriteria Weather in Pass 1

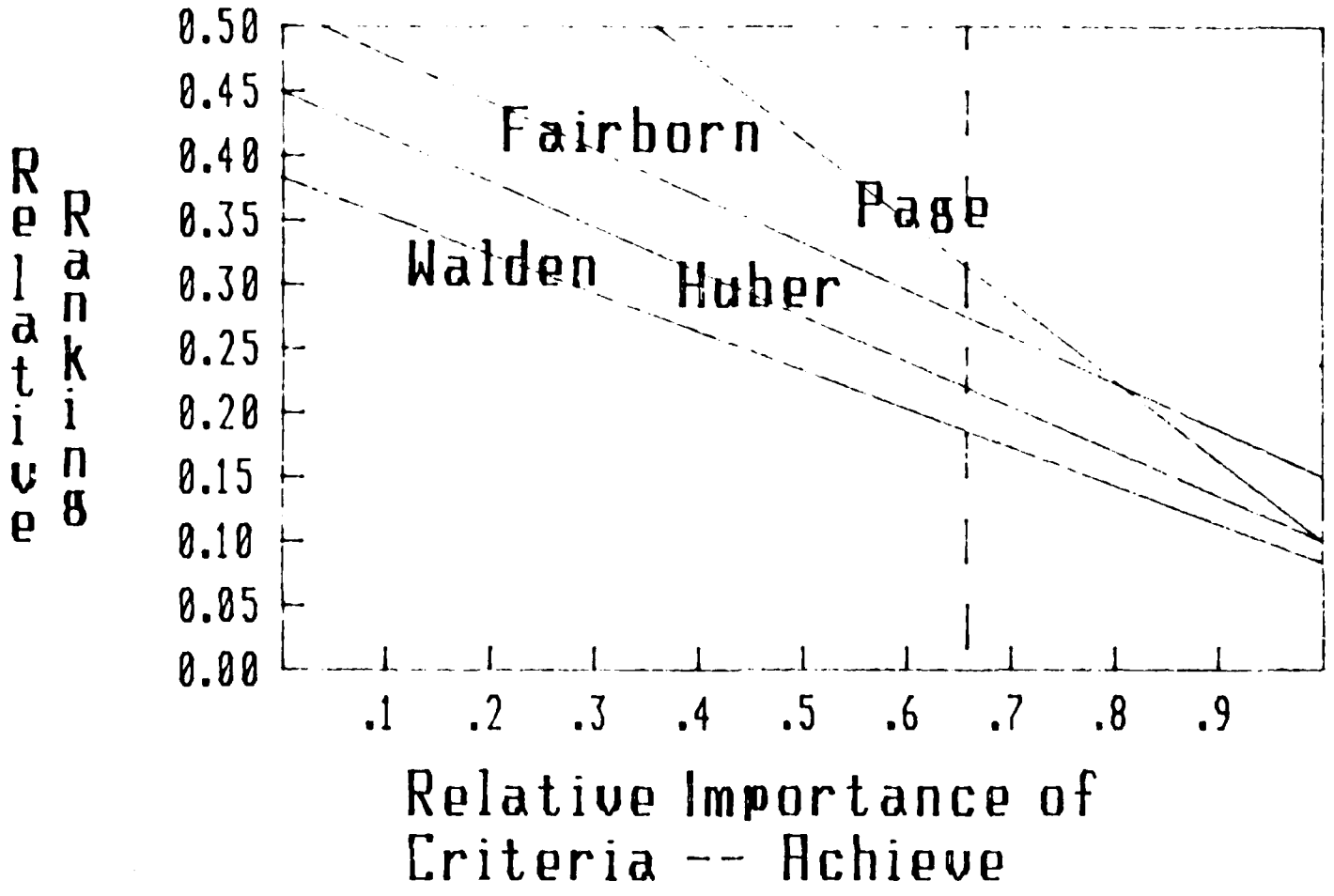


Figure 34: Sensitivity Chart for Subcriteria Achievement Scores(SAT) in Pass 1

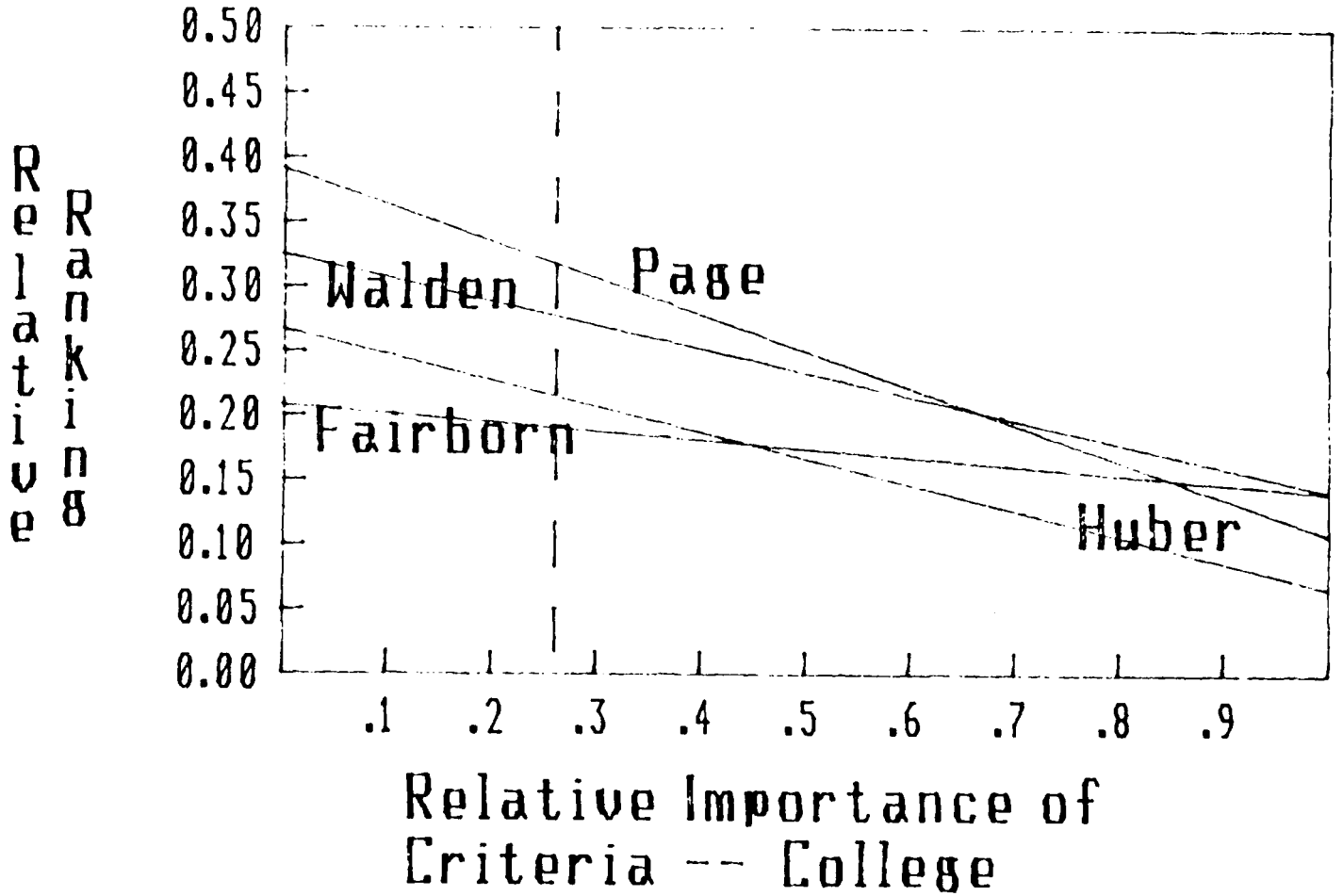


Figure 35: Sensitivity Chart for Subcriteria Percentage of Students Going to College in Pass 1

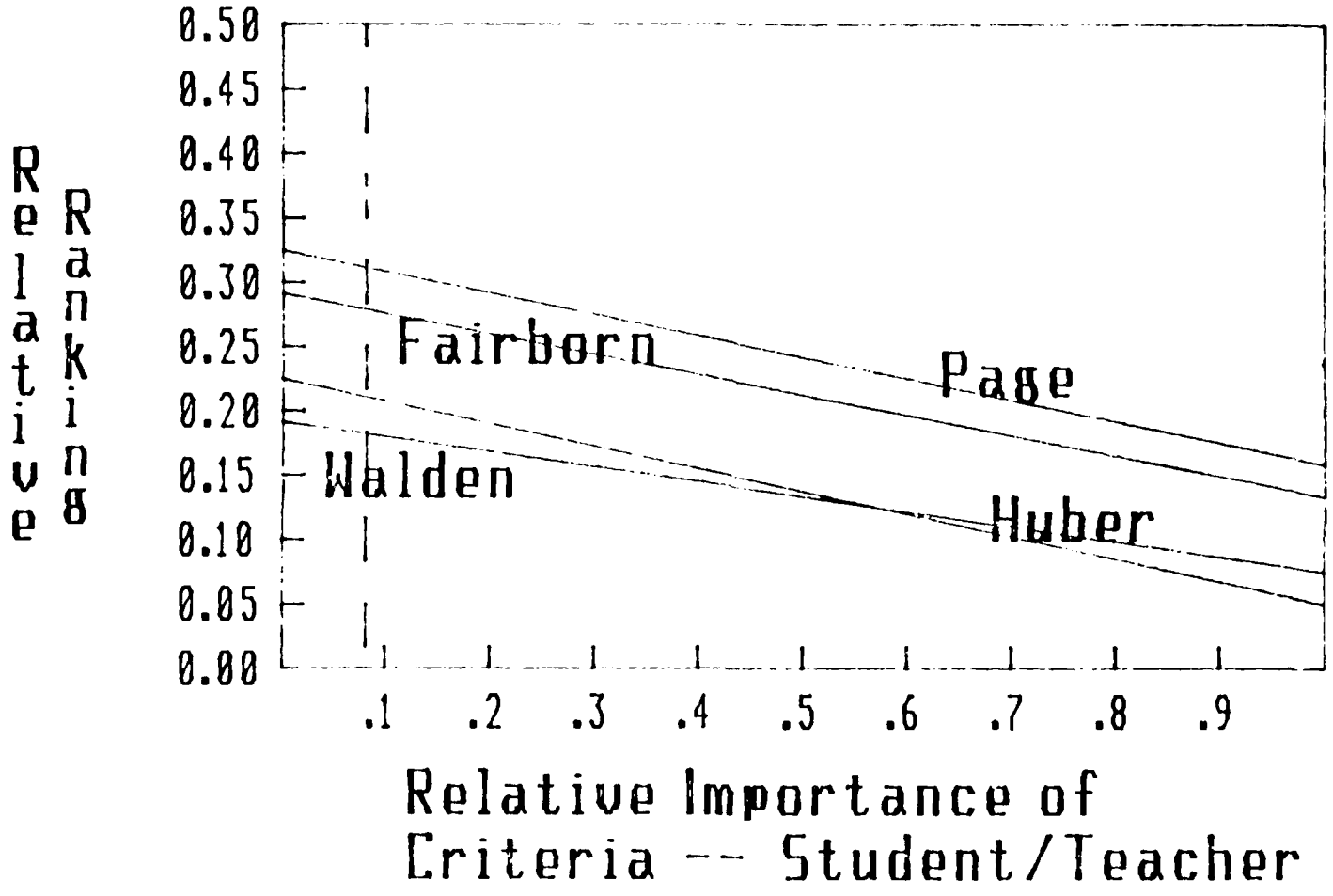


Figure 36: Sensitivity Chart for Subcriteria Student/Teacher Ratio in Pass 1

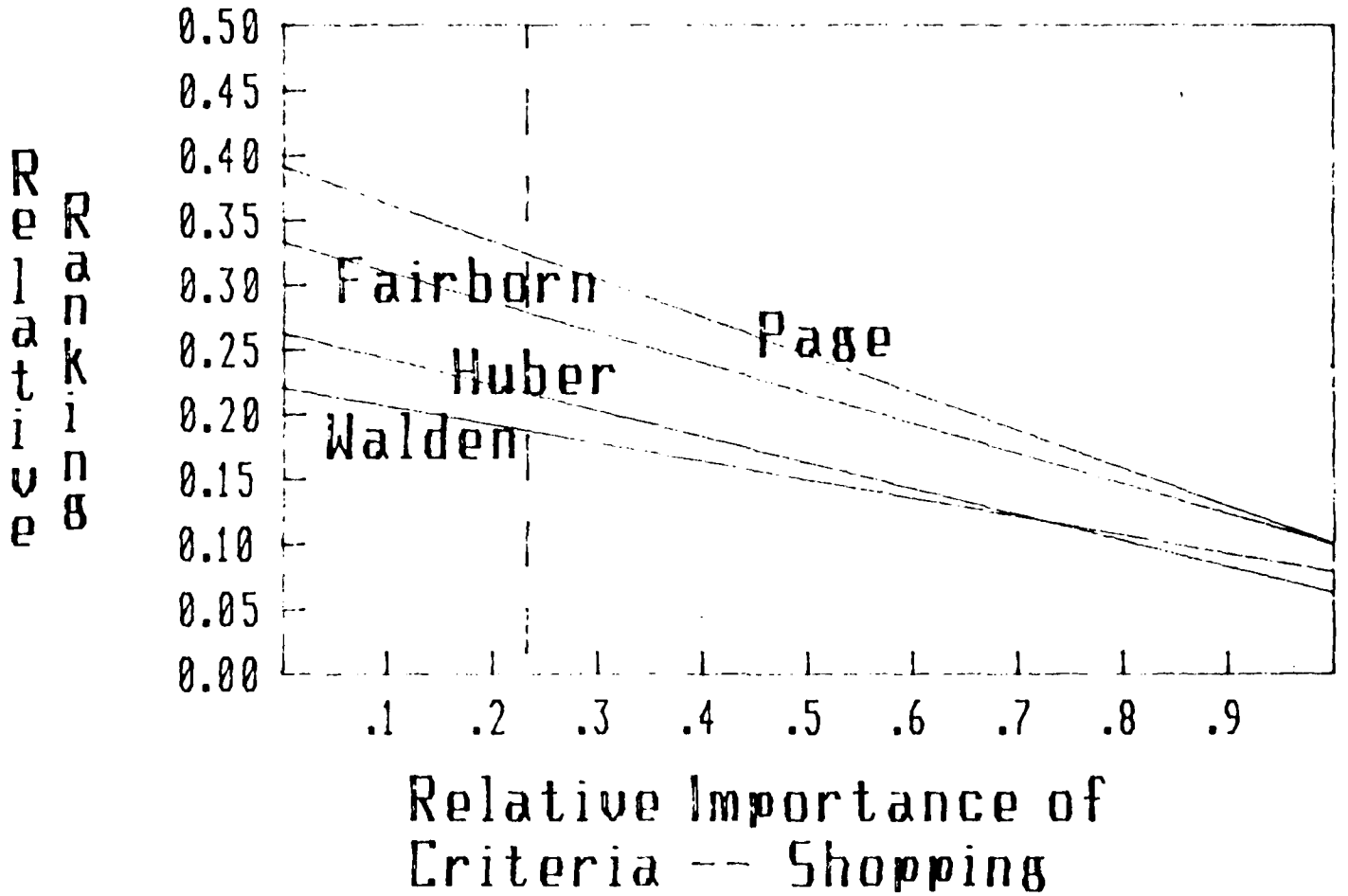


Figure 37: Sensitivity Chart for Subcriteria Shopping in Pass 1

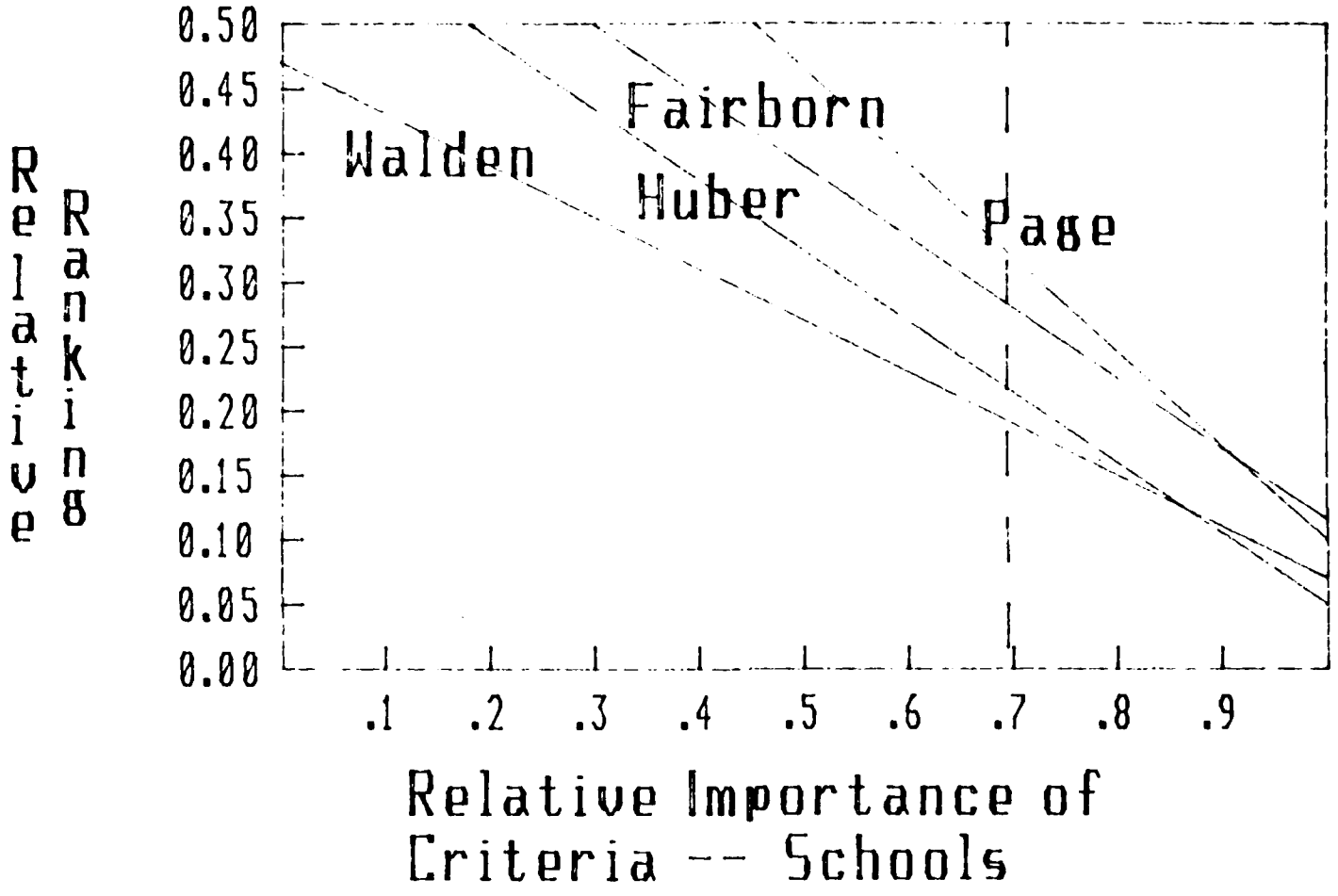


Figure 38: Sensitivity Chart for Subcriteria Schools in Pass 1

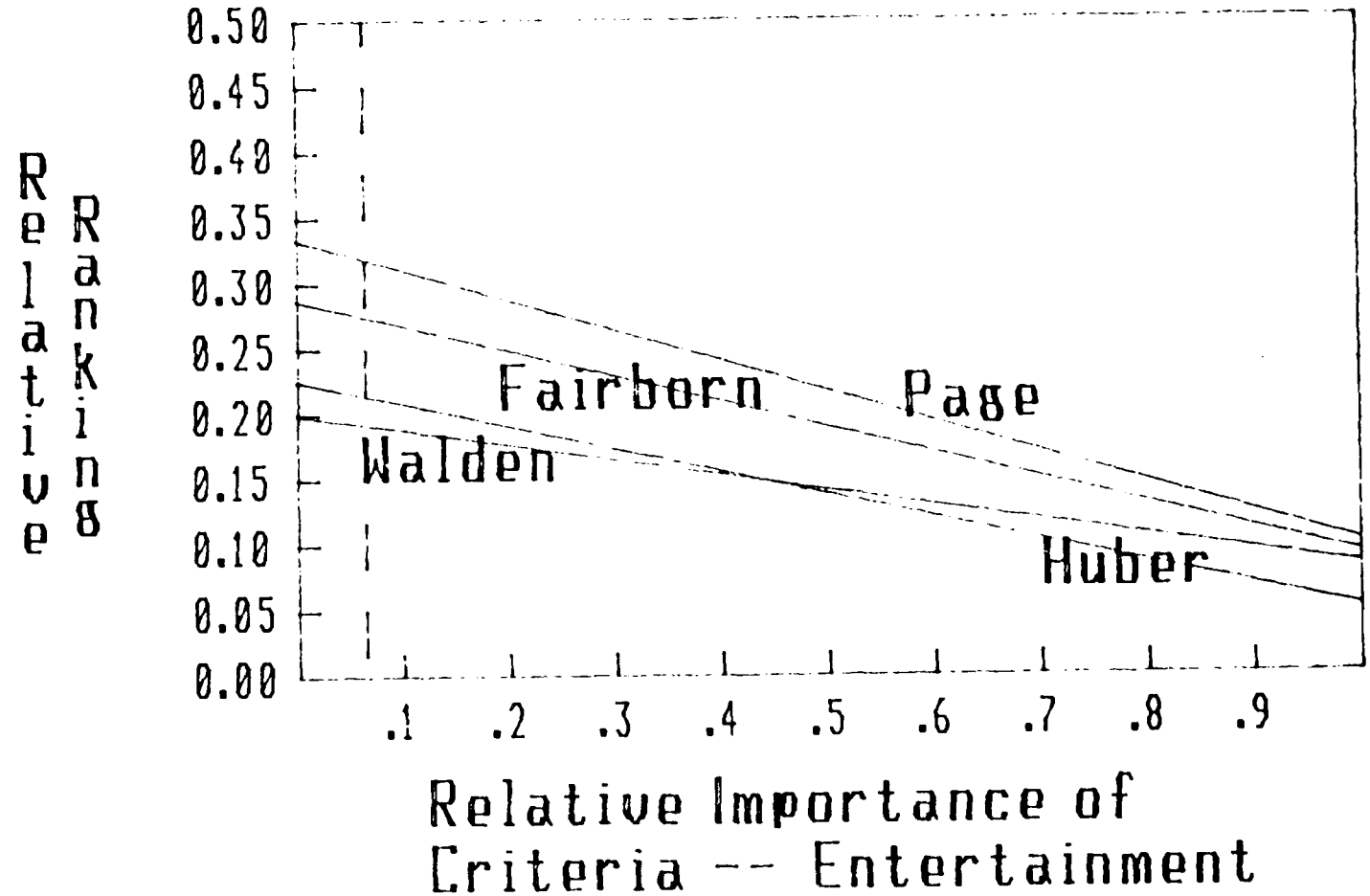


Figure 39: Sensitivity Chart for Subcriteria Entertainment in Pass 1

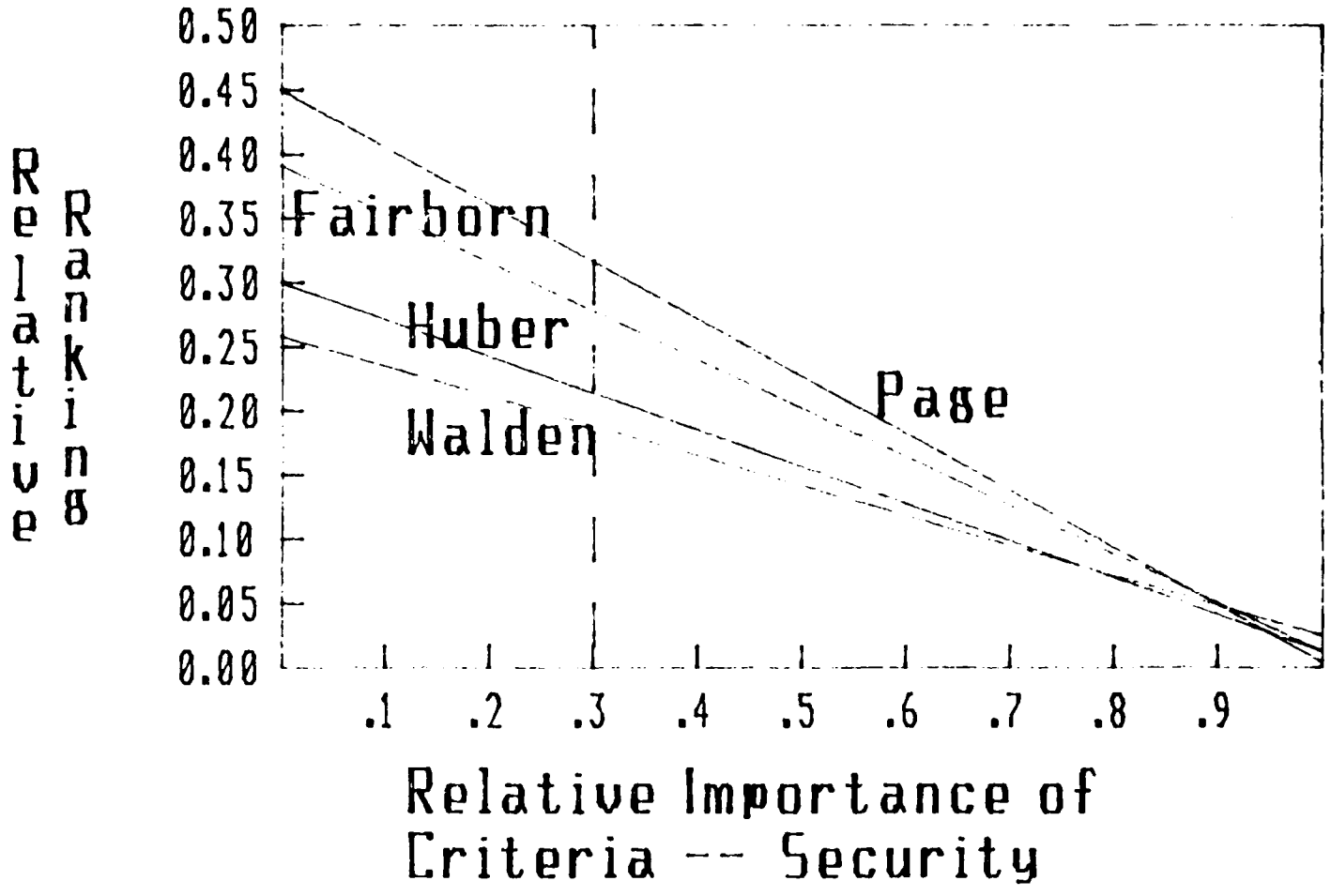


Figure 40: Sensitivity Chart for Subcriteria Security in Pass 1

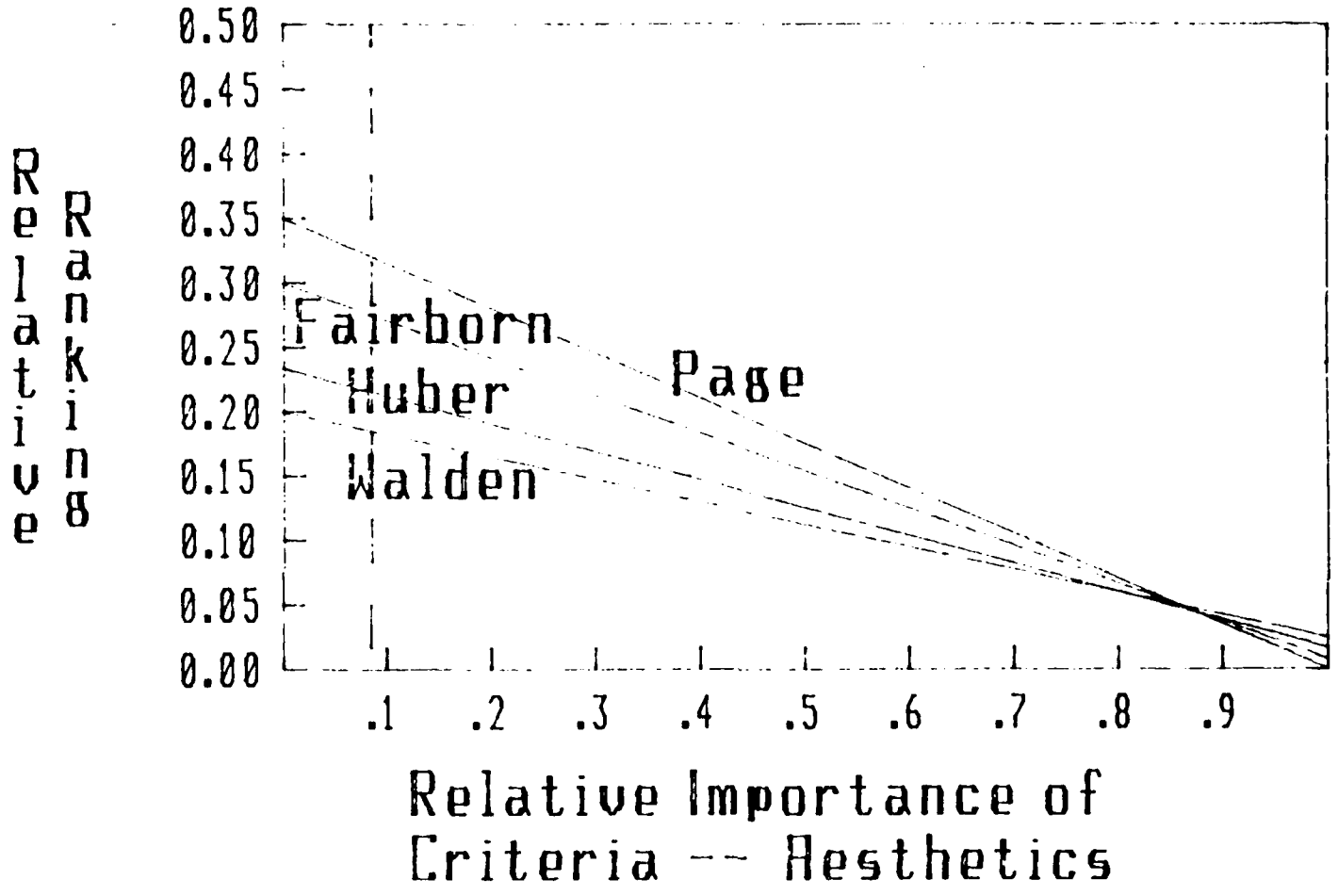


Figure 41: Sensitivity Chart for Subcriteria Aesthetics in Pass 1

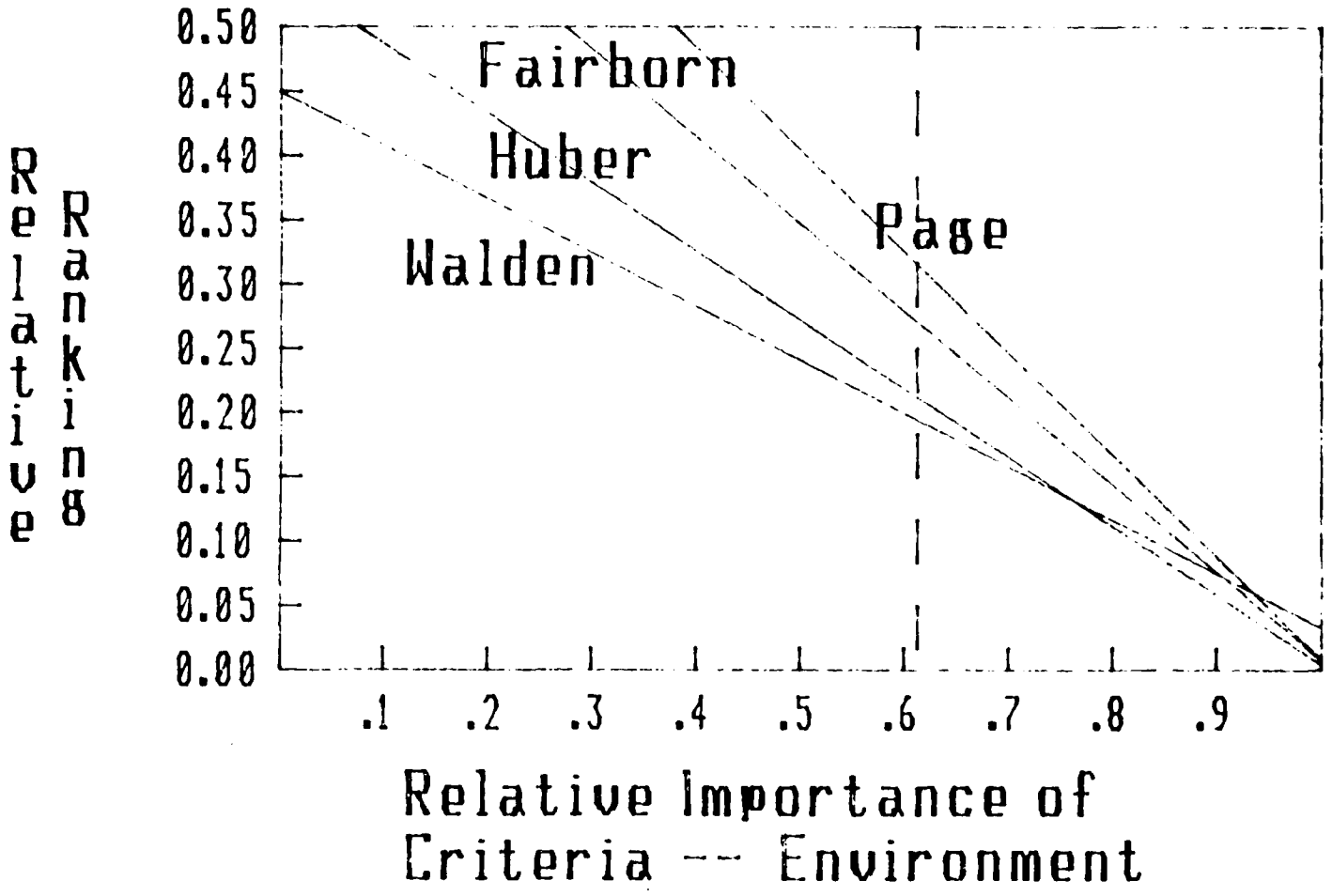


Figure 42: Sensitivity Chart for Subcriteria Environment in Pass 1

Appendix C. *Sensitivity Charts for Pass 2*

The following charts are the sensitivity charts for the second pass of the hierarchy.

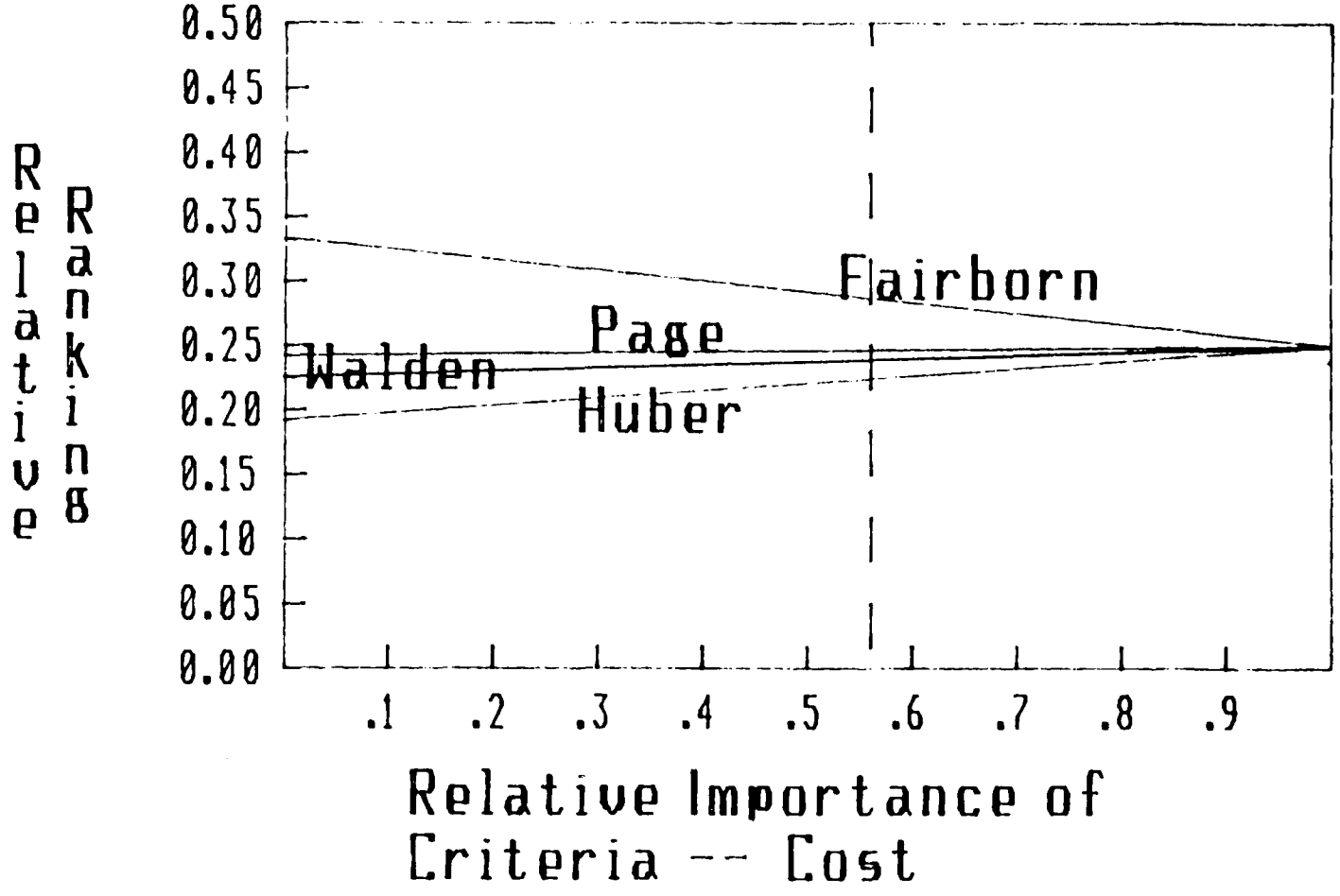


Figure 43: Sensitivity Chart for Main Criteria Cost in Pass 2

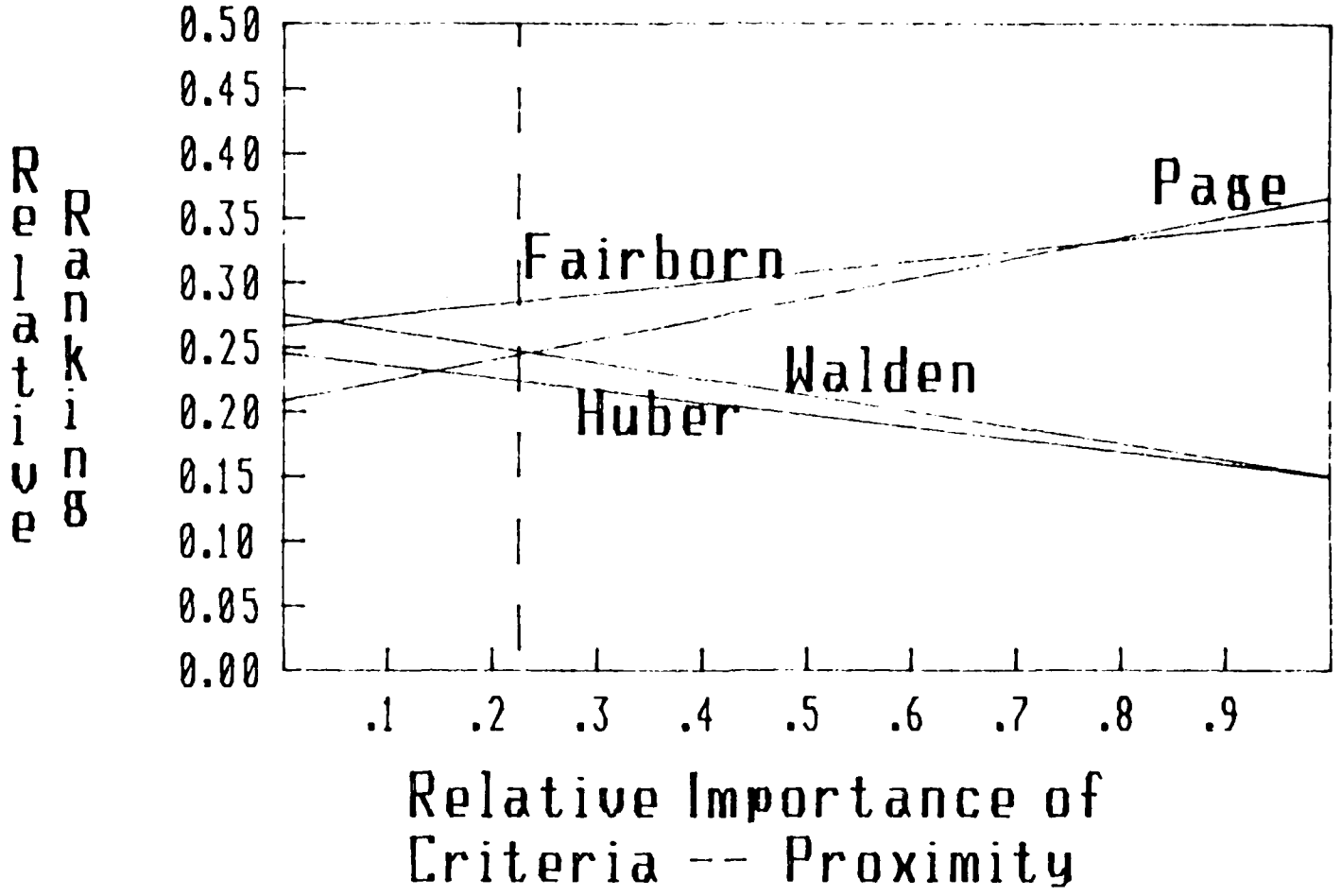


Figure 44: Sensitivity Chart for Main Criteria Proximity in Pass 2

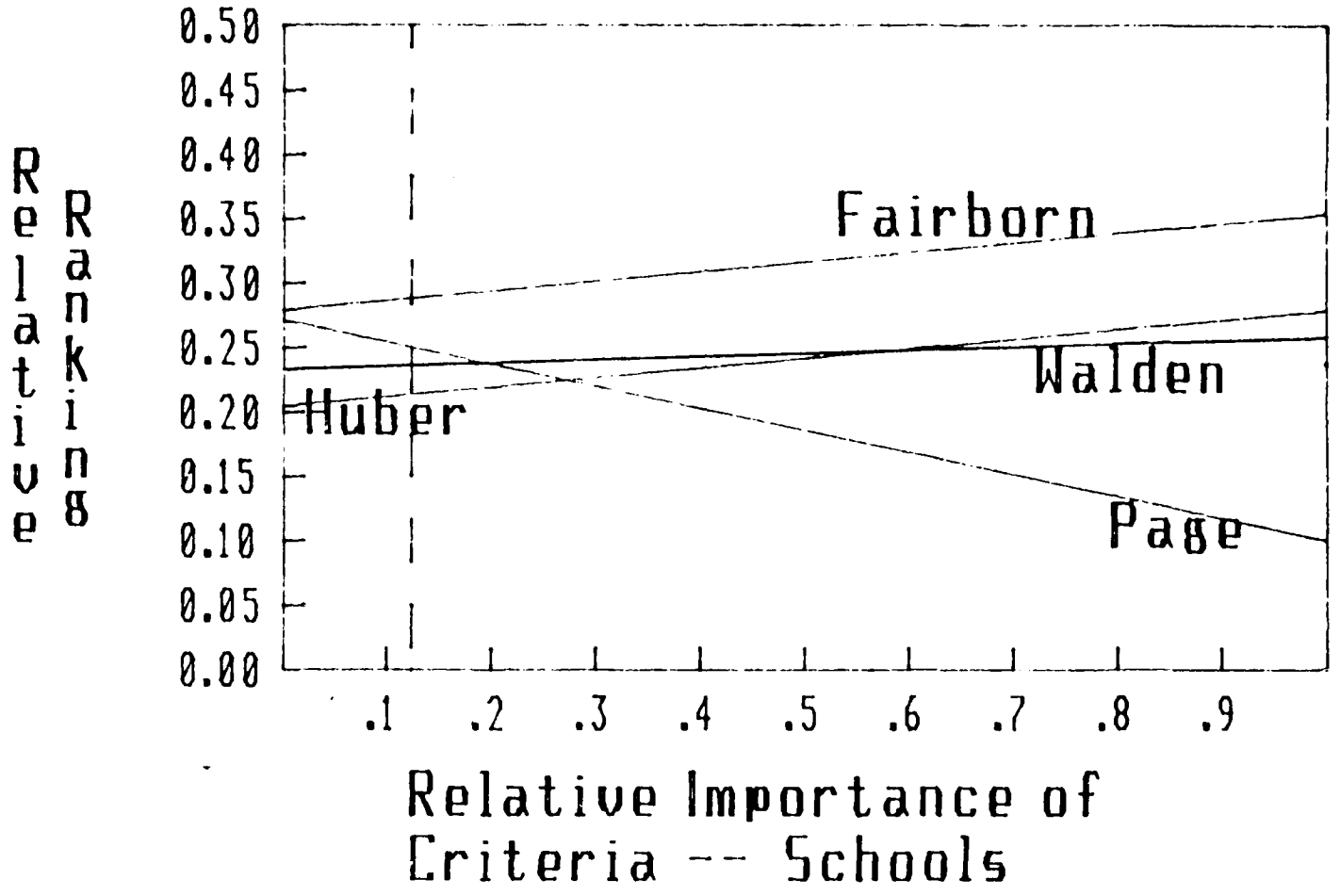


Figure 45: Sensitivity Chart for Main Criteria Schools in Pass 2

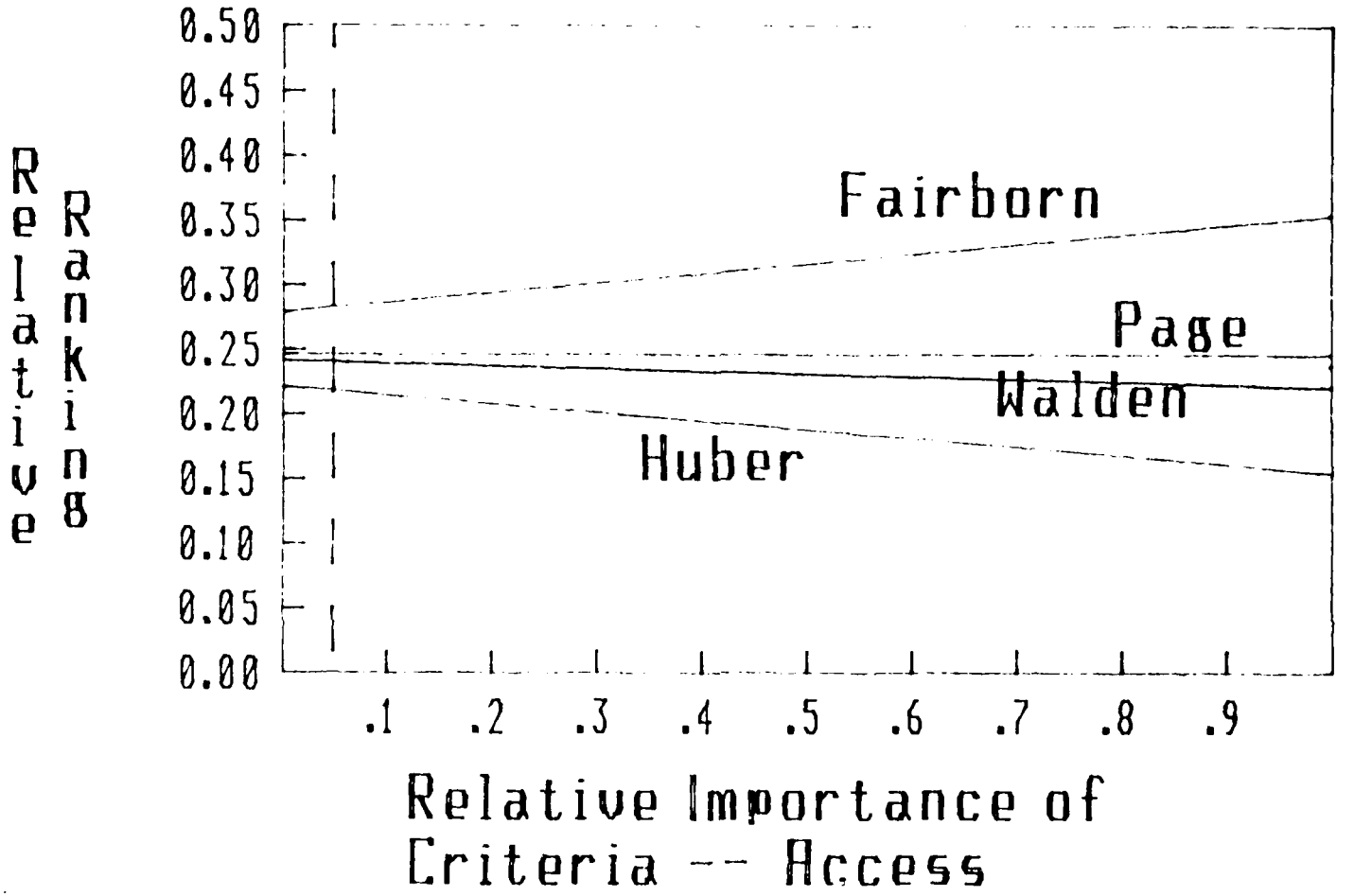
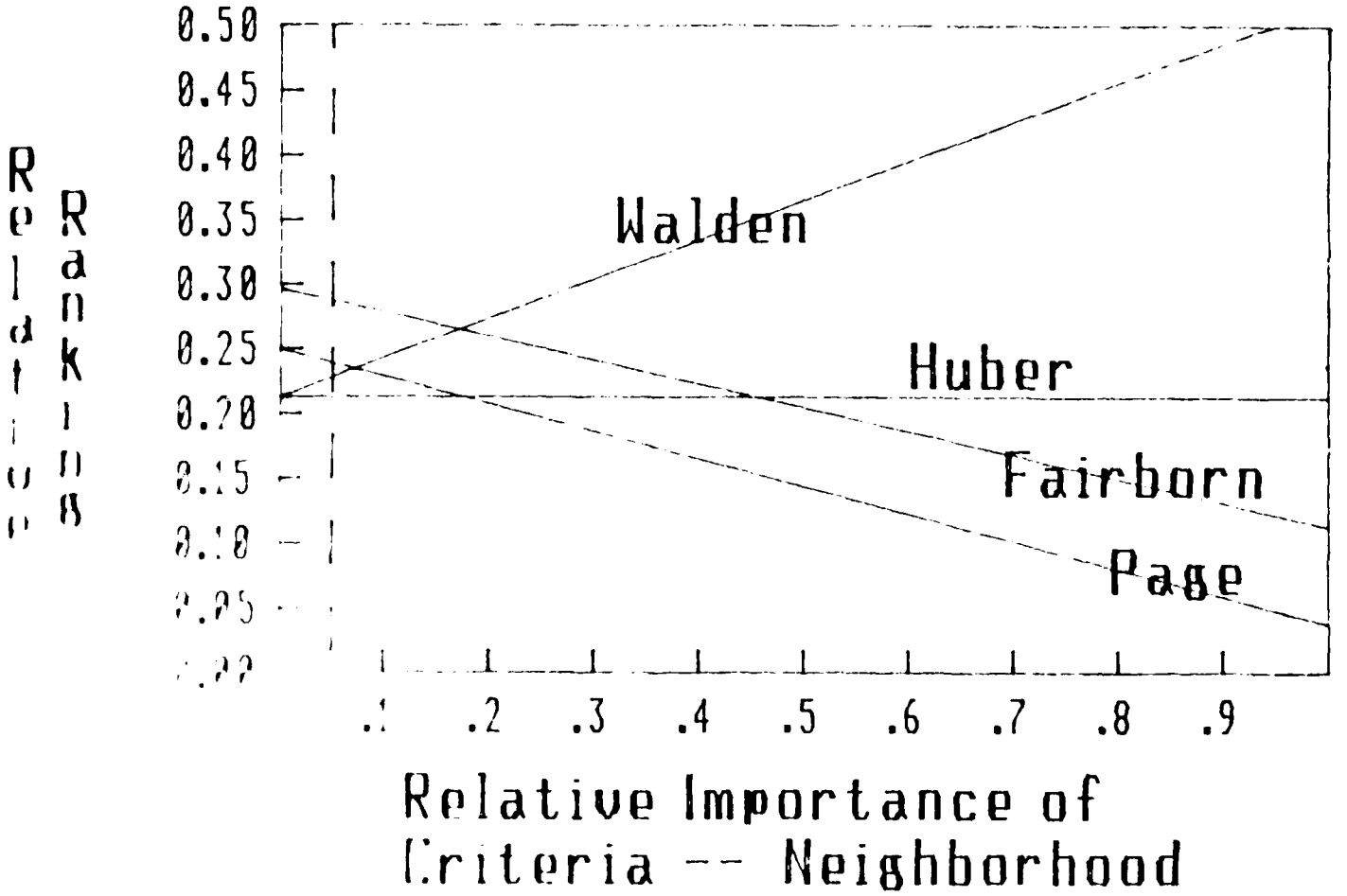


Figure 46: Sensitivity Chart for Main Criteria Access in Pass 2



Sensitivity Chart for Main Criteria Neighborhood in Pass 2

AD-A189 780 AN APPLICATION OF THE ANALYTIC HIERARCHY PROCESS TO EVALUATE CANDIDATE LO..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. G A LUETHKE 2/2

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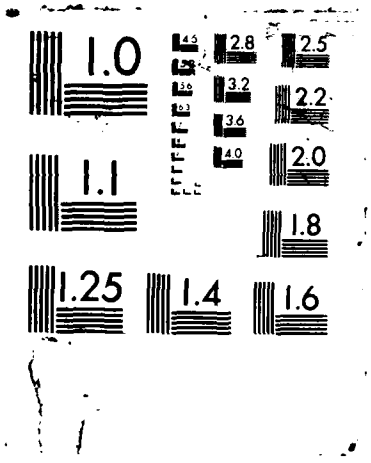
1.0
1.1
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1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

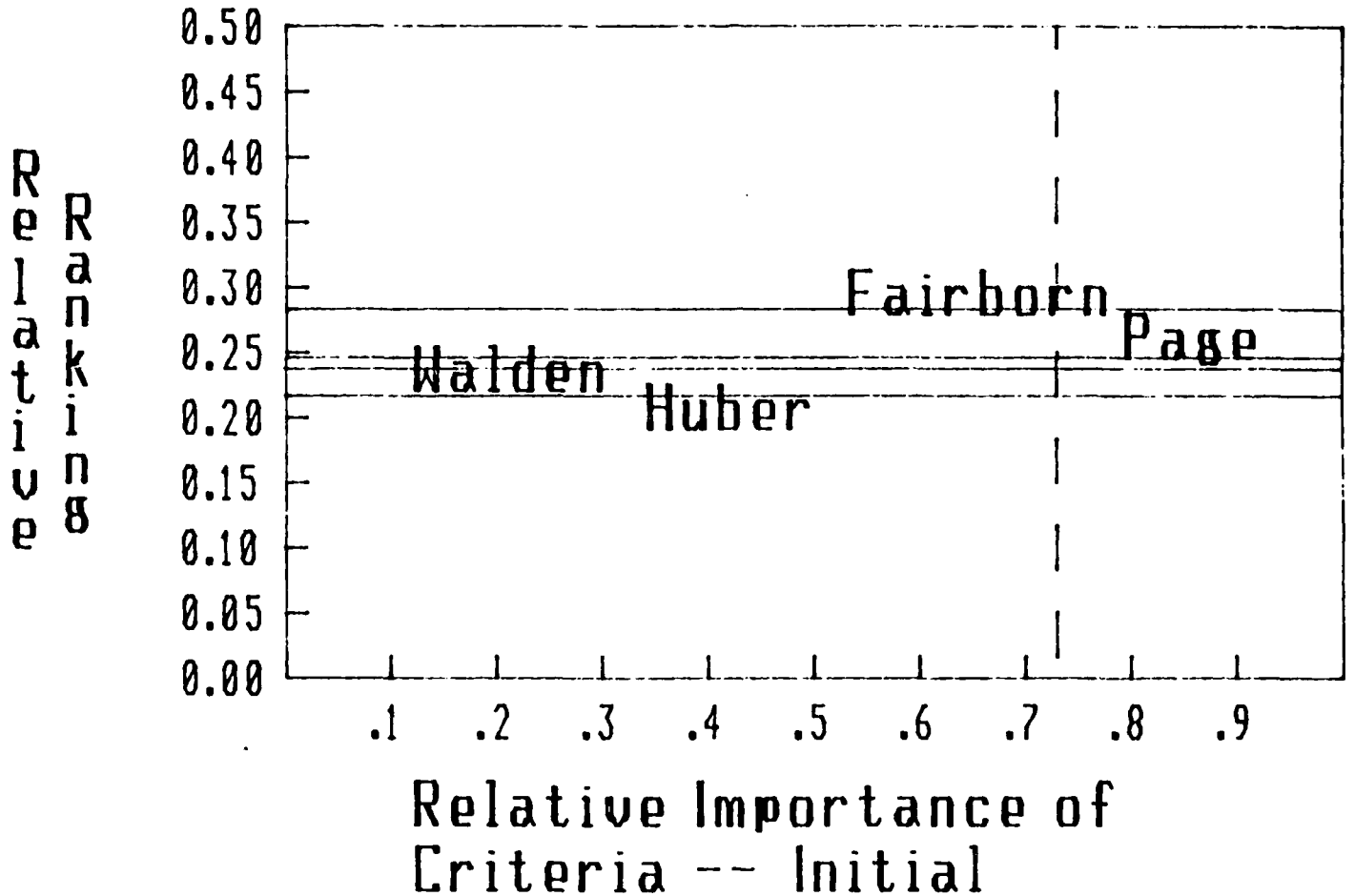

Figure 48: Sensitivity Chart for Subcriteria Initial Cost in Pass 2

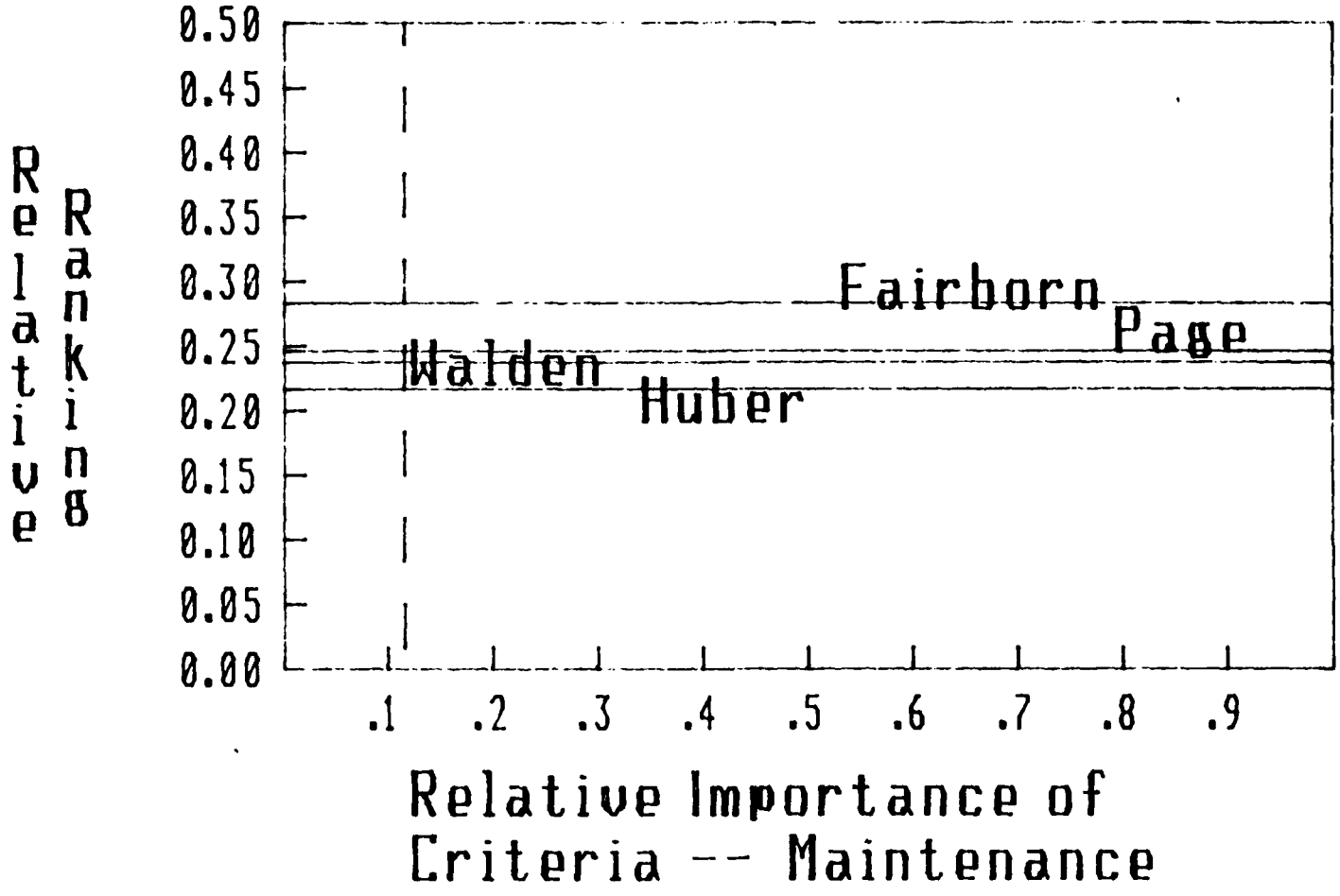

Figure 49: Sensitivity Chart for Subcriteria Maintenance Cost in Pass 2

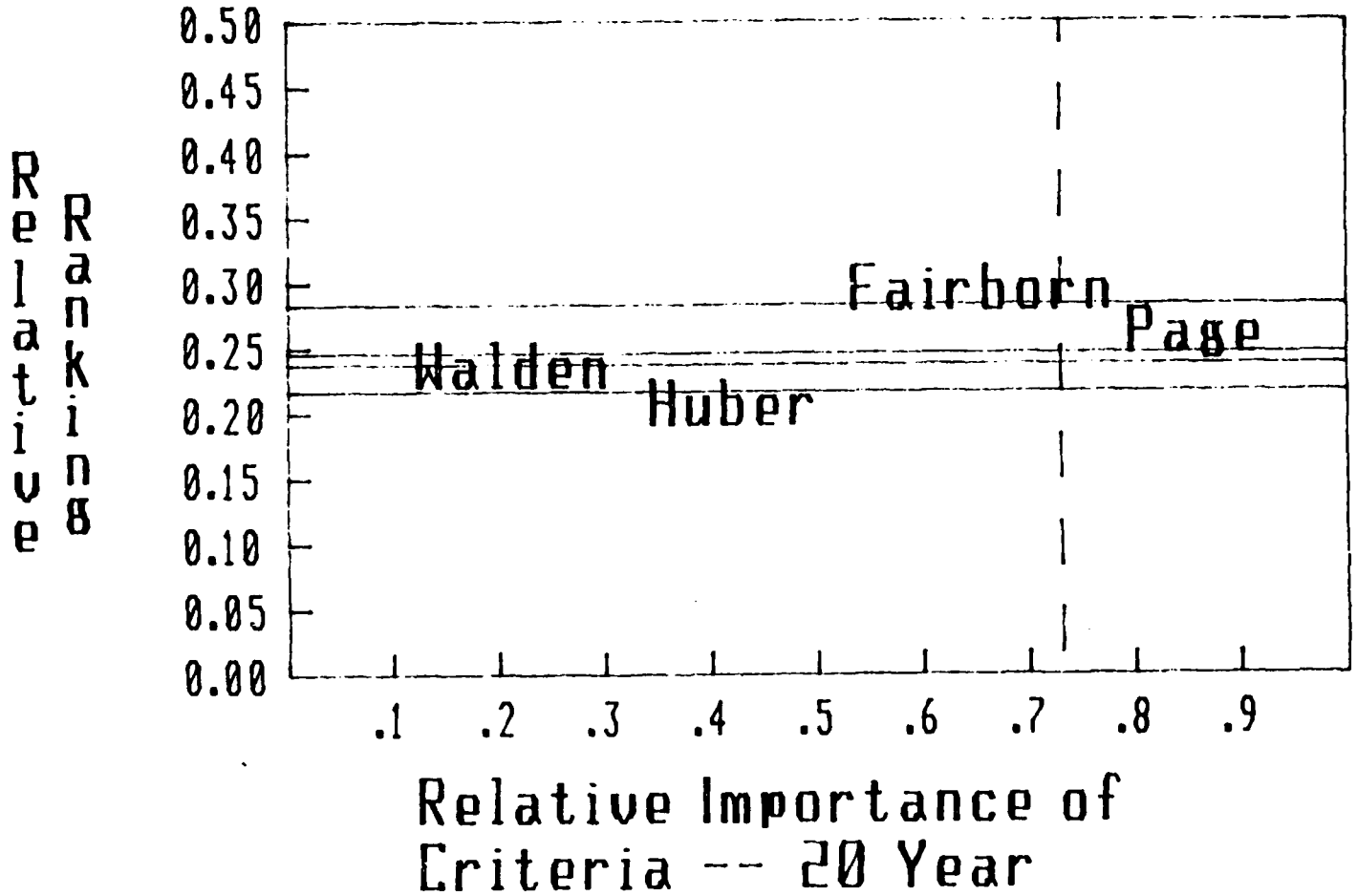

Figure 50: Sensitivity Chart for Subcriteria 20 Year Cost in Pass 2

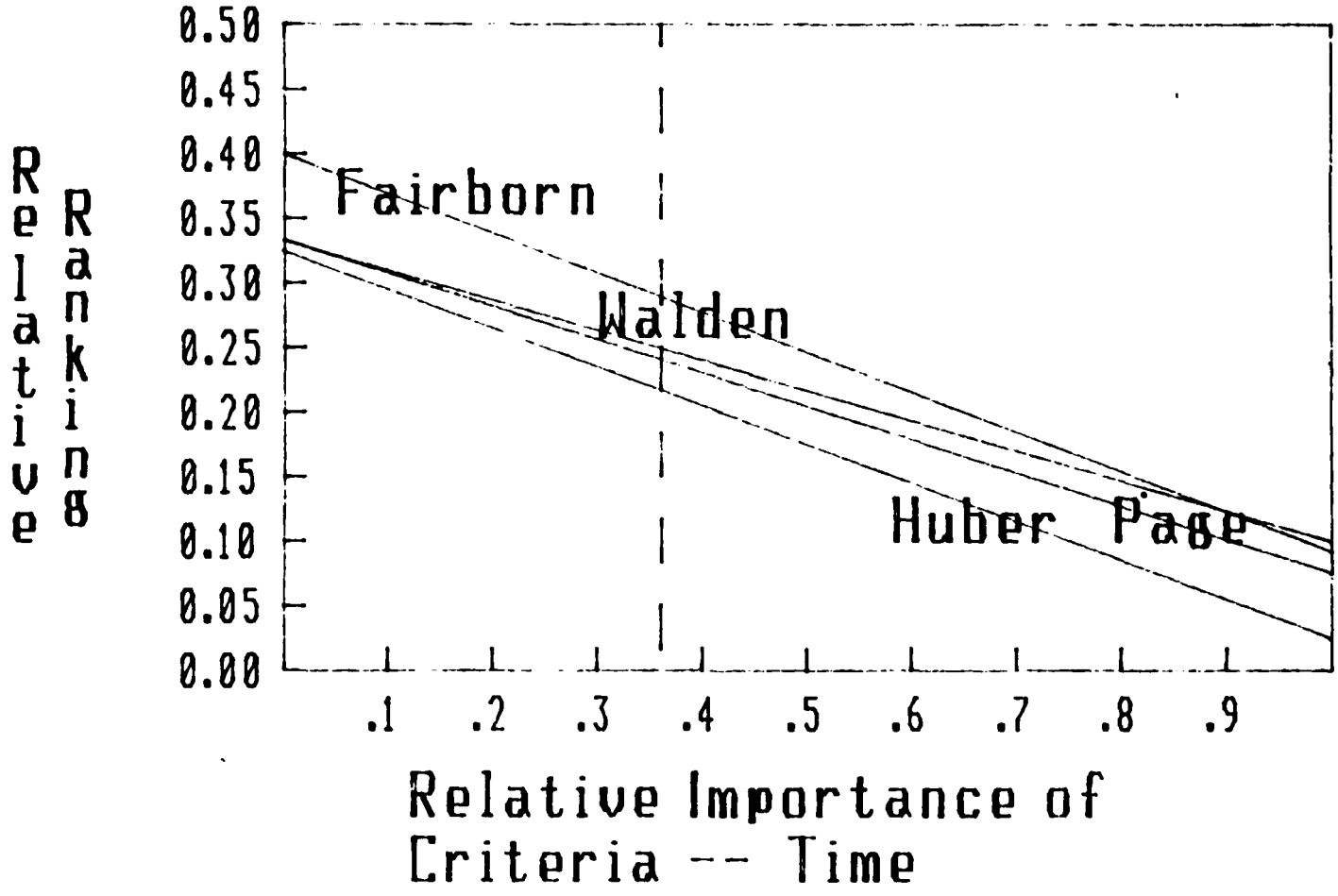

Figure 51: Sensitivity Chart for Subcriteria Time in Pass 2

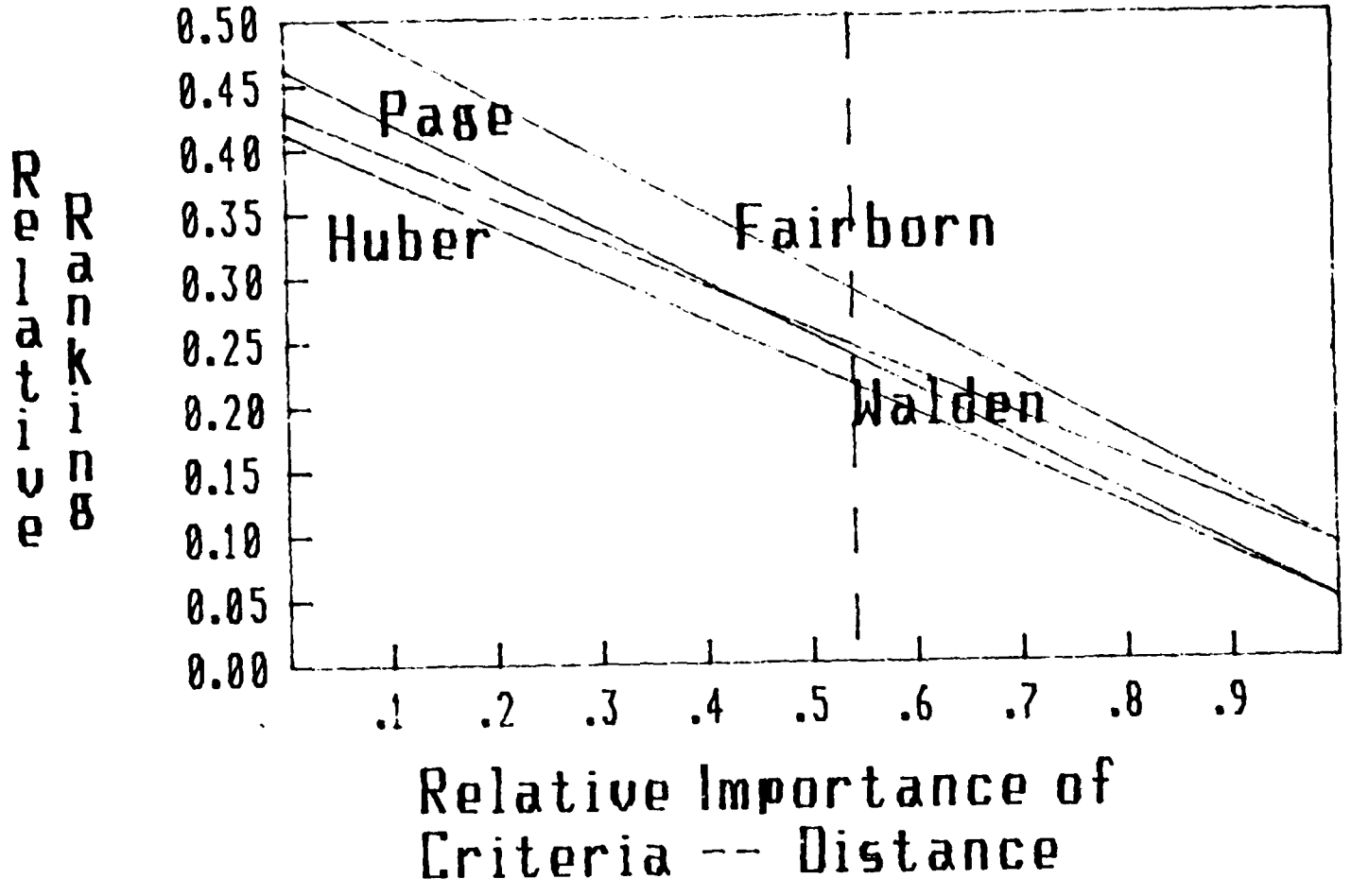

Figure 52: Sensitivity Chart for Subcriteria Distance in Pass 2

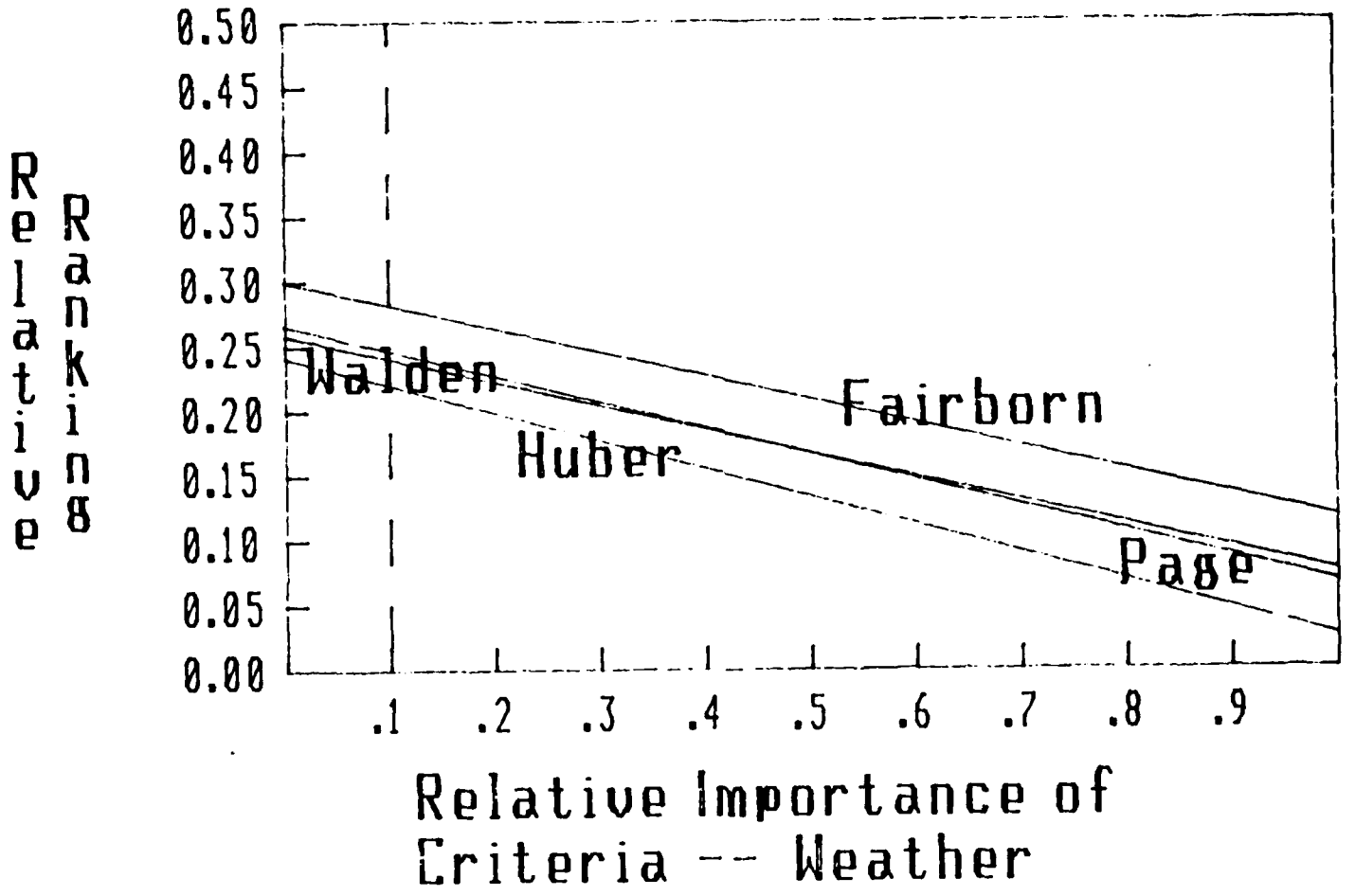

Figure 53: Sensitivity Chart for Subcriteria Weather in Pass 2

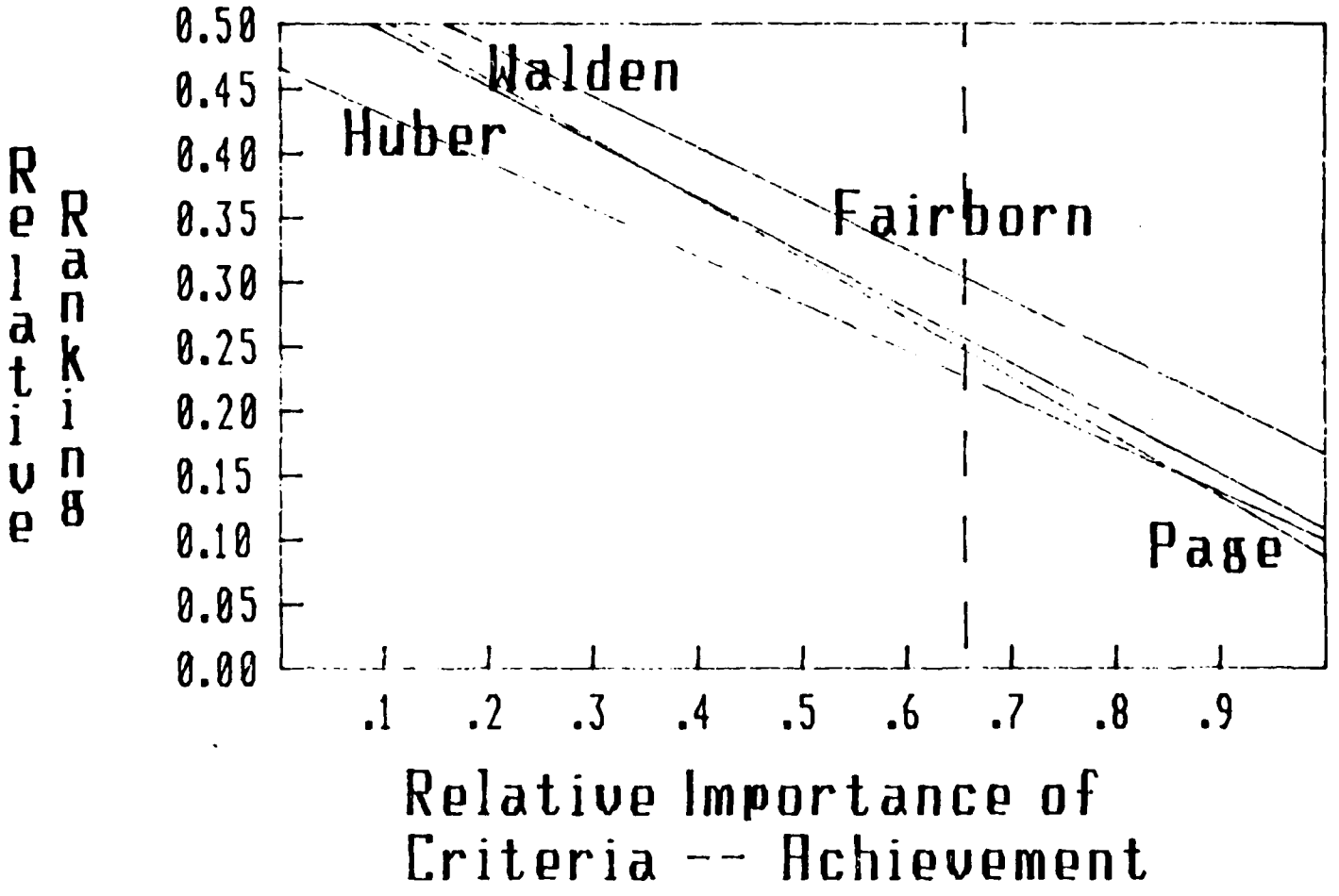

Figure 54: Sensitivity Chart for Subcriteria Achievement Scores(SAT) in Pass 2

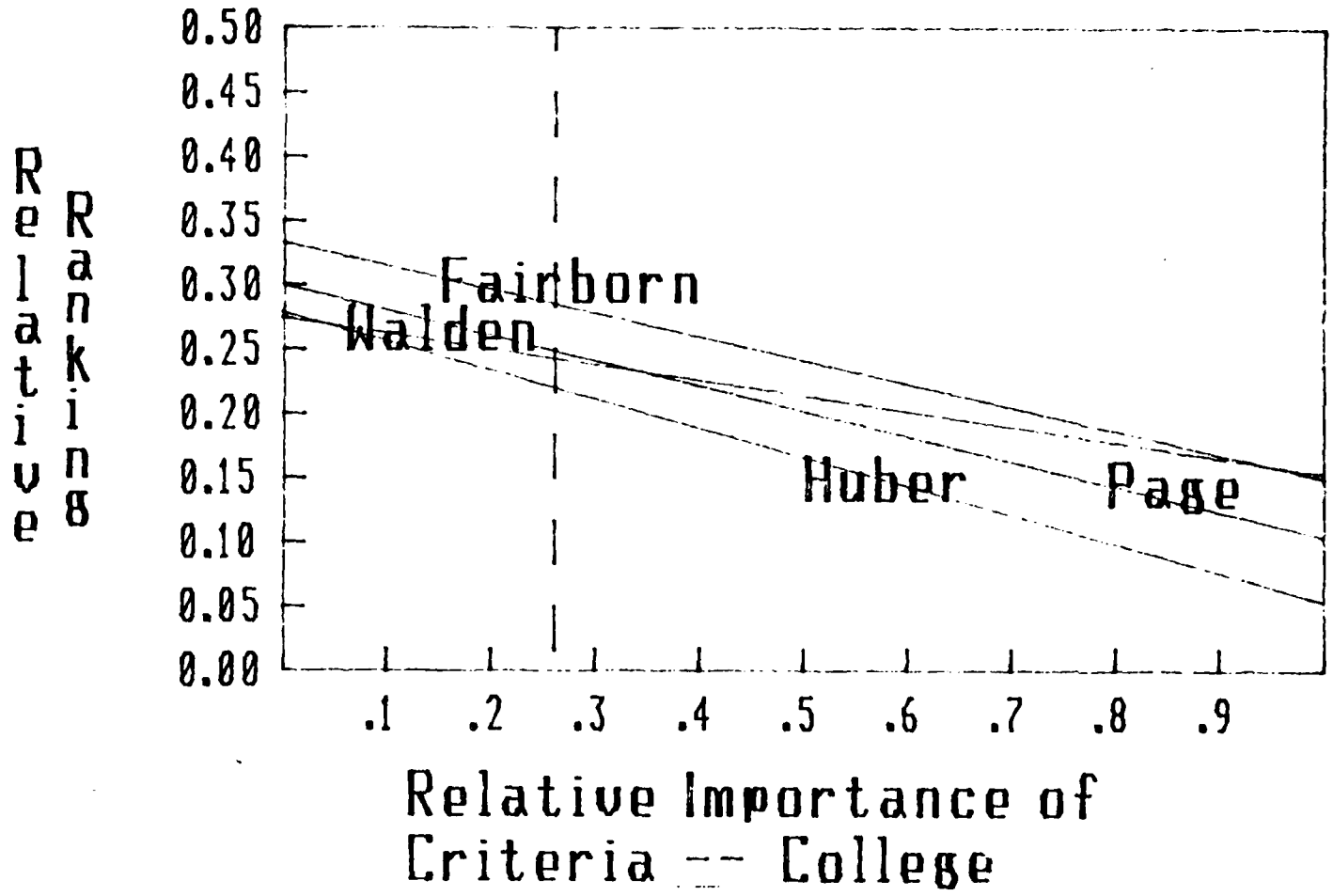

Figure 55: Sensitivity Chart for Subcriteria Percentage of Students Going to College in Pass 2

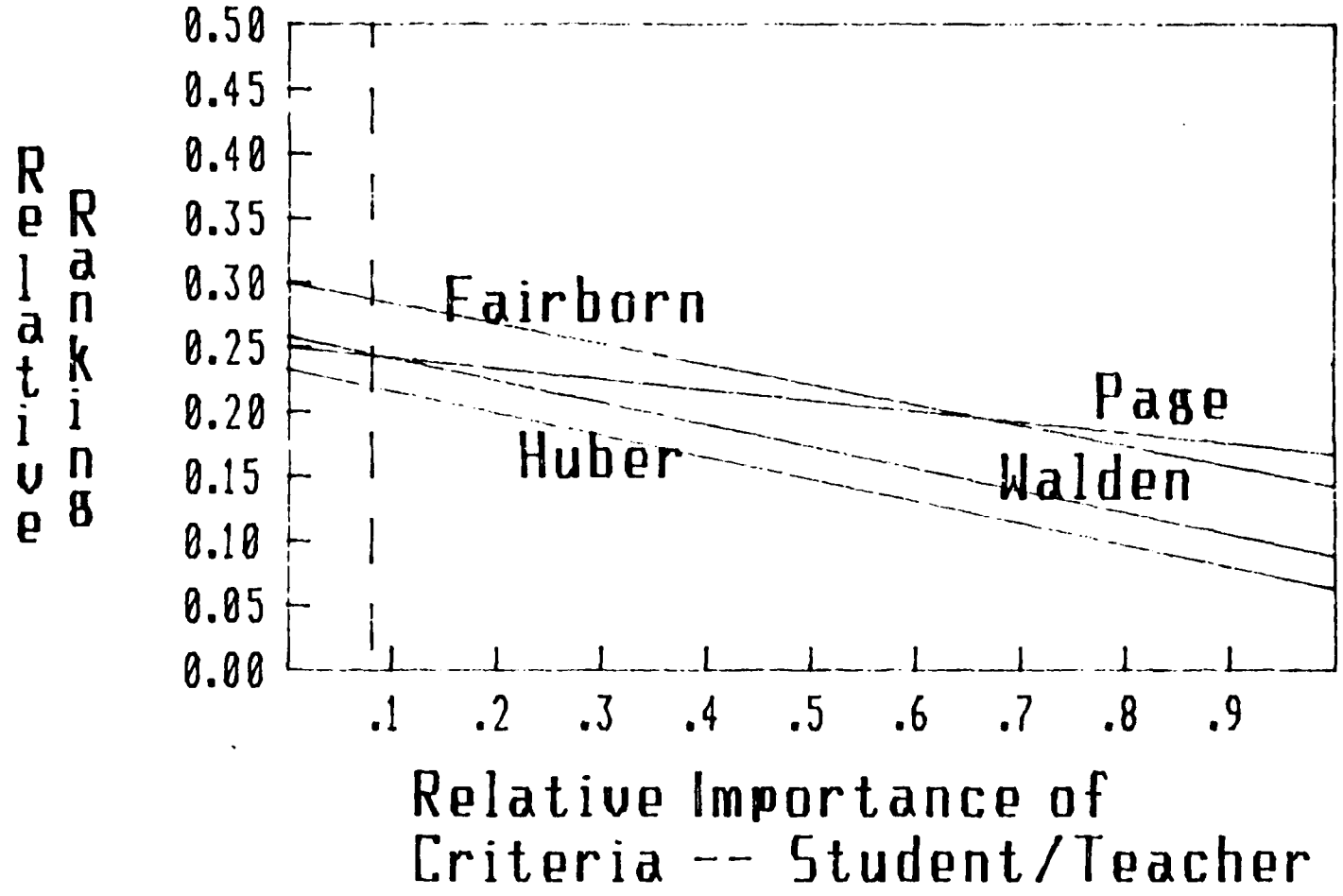

Figure 56: Sensitivity Chart for Subcriteria Student/Teacher Ratio in Pass 2

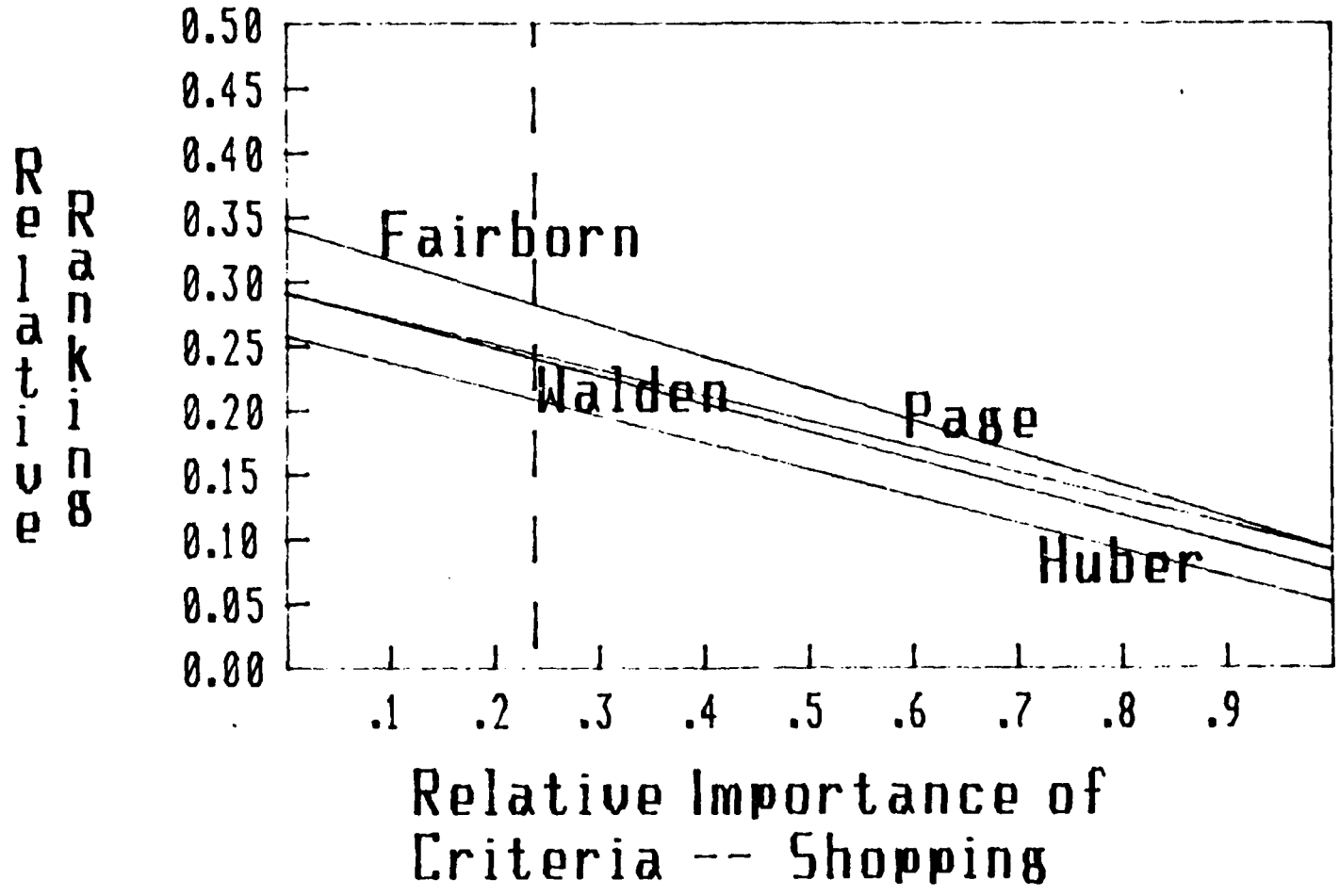

Figure 57: Sensitivity Chart for Subcriteria Shopping in Pass 2

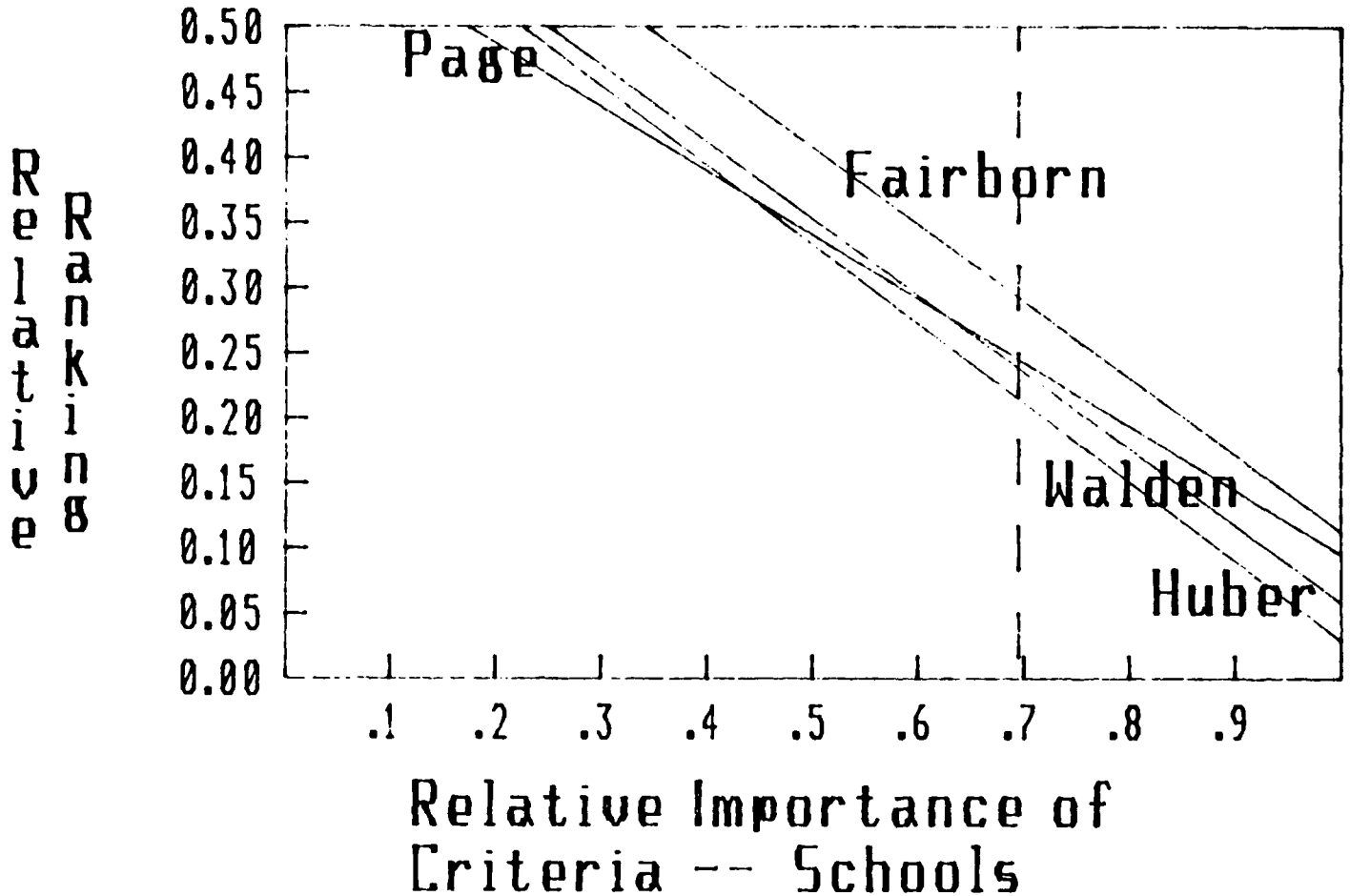

Figure 58: Sensitivity Chart for Subcriteria Schools in Pass 2

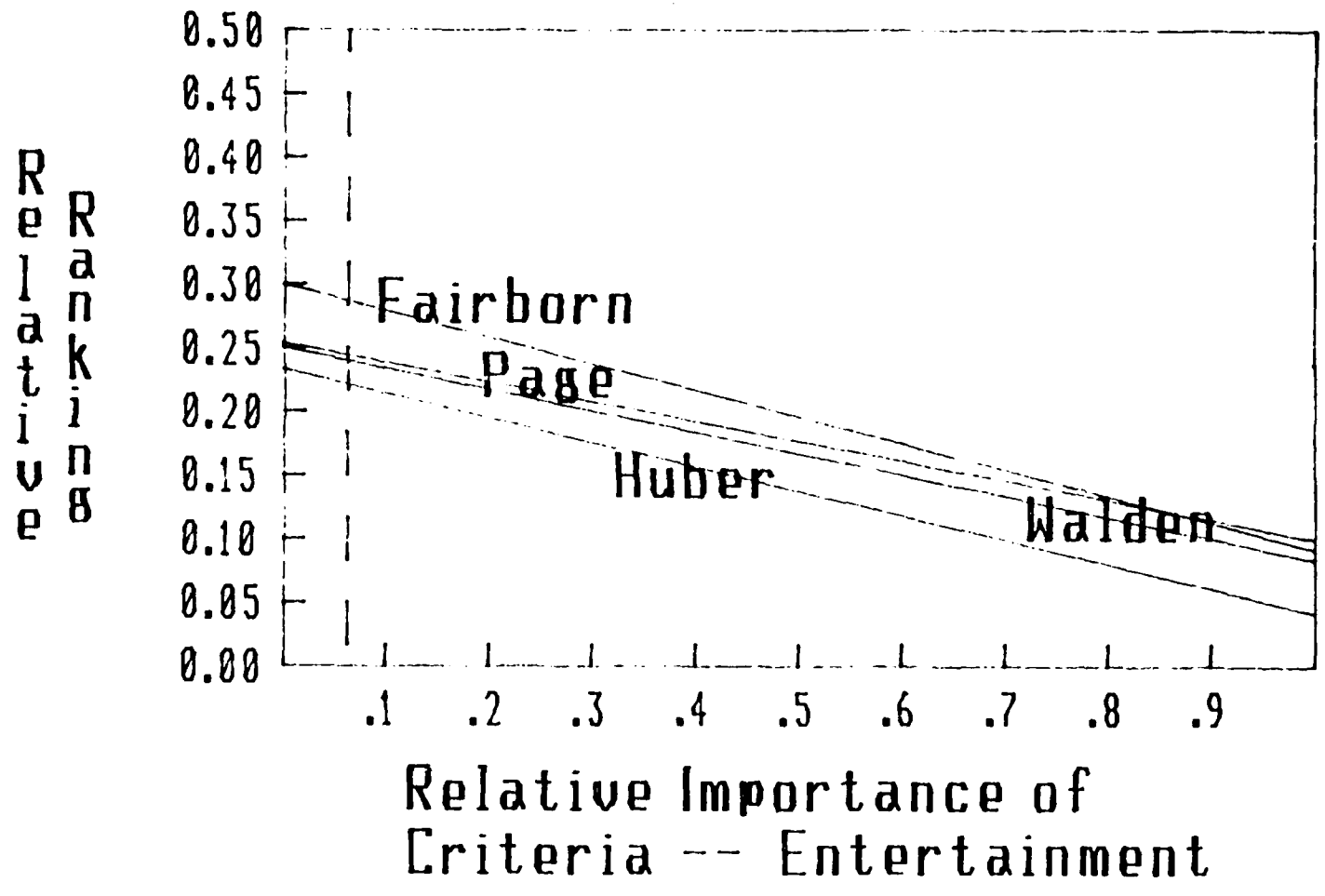

Figure 59: Sensitivity Chart for Subcriteria Entertainment in Pass 2

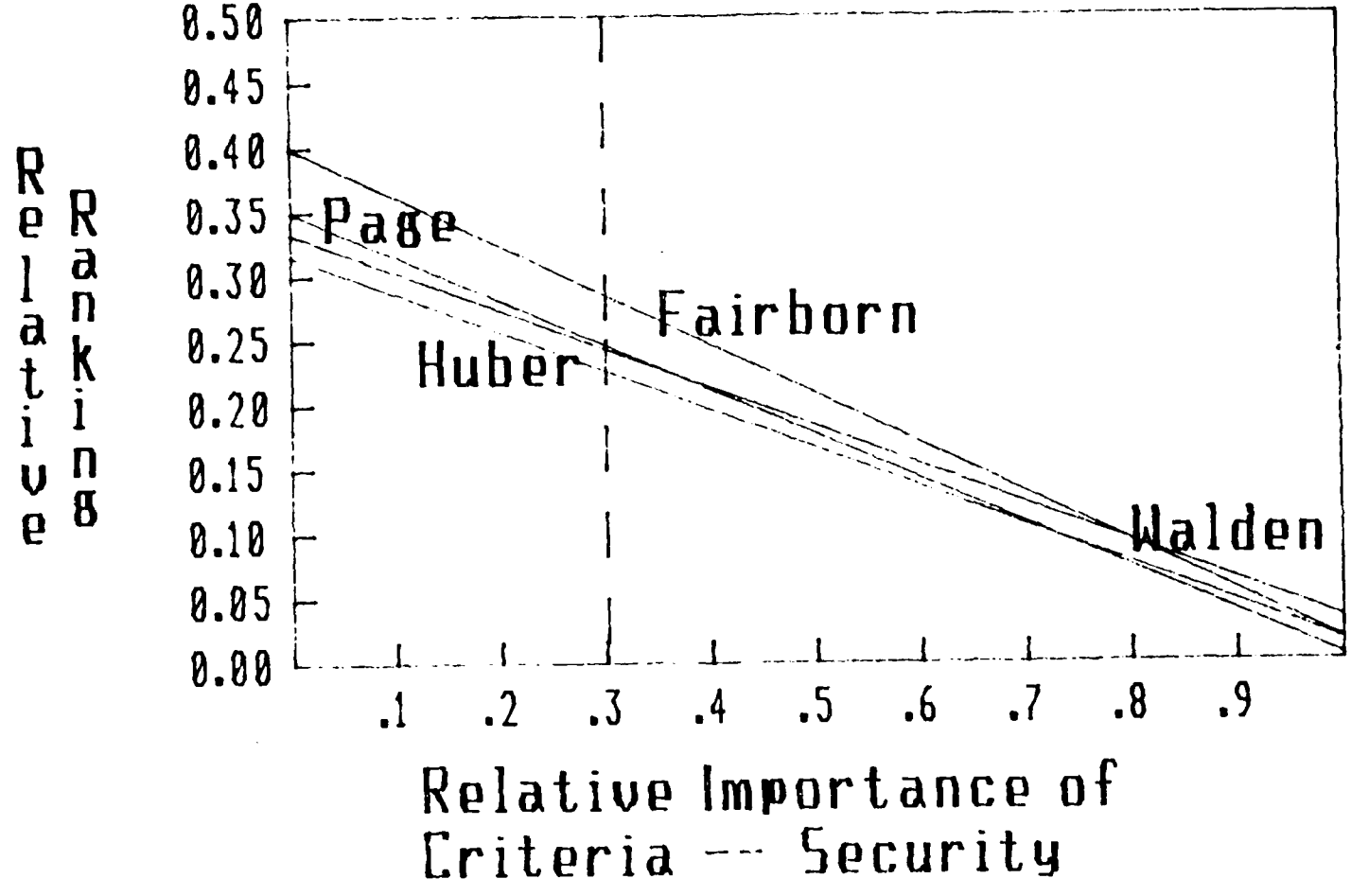

Figure 60: Sensitivity Chart for Subcriteria Security in Pass 2

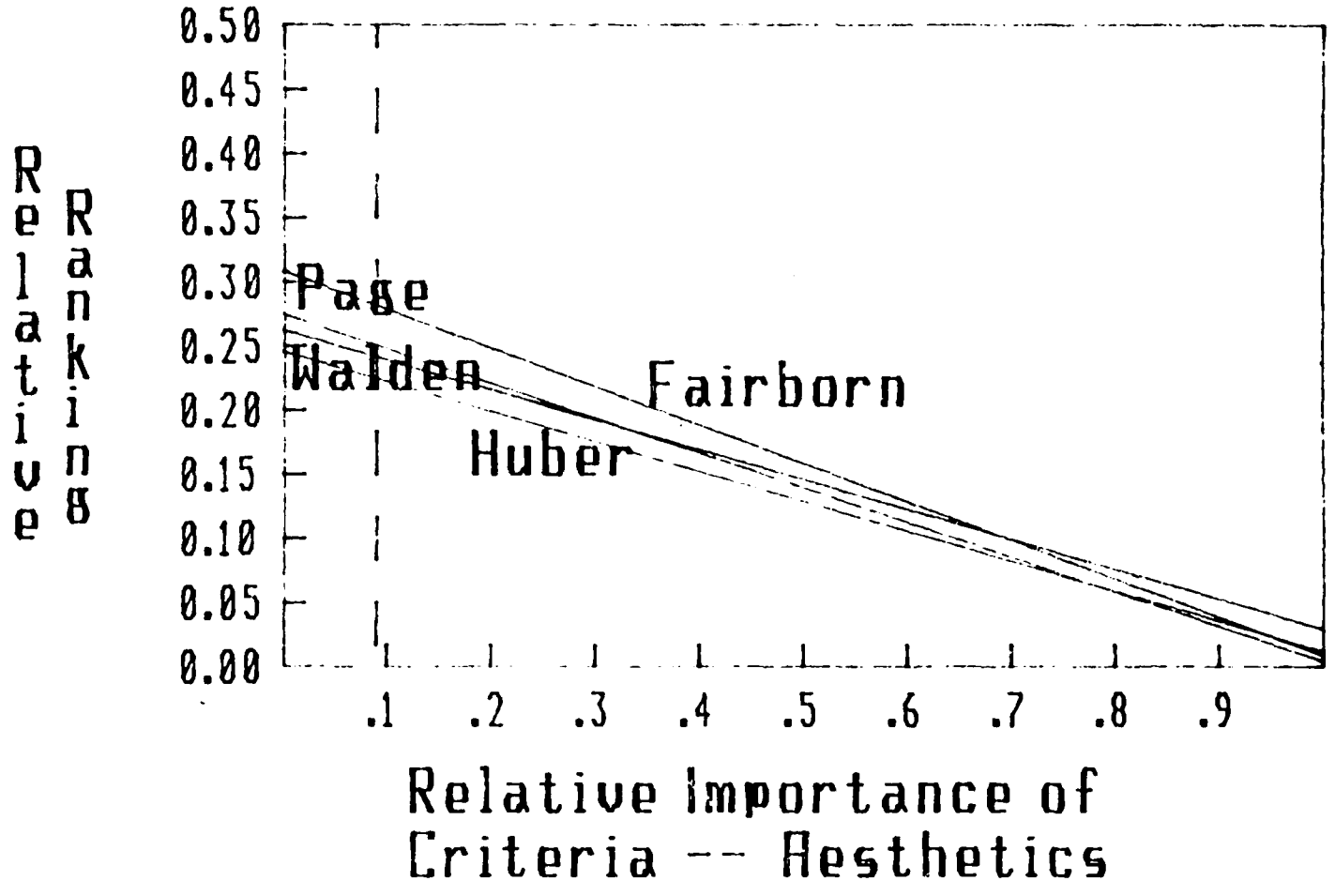

Figure 61: Sensitivity Chart for Subcriteria Aesthetics in Pass 2

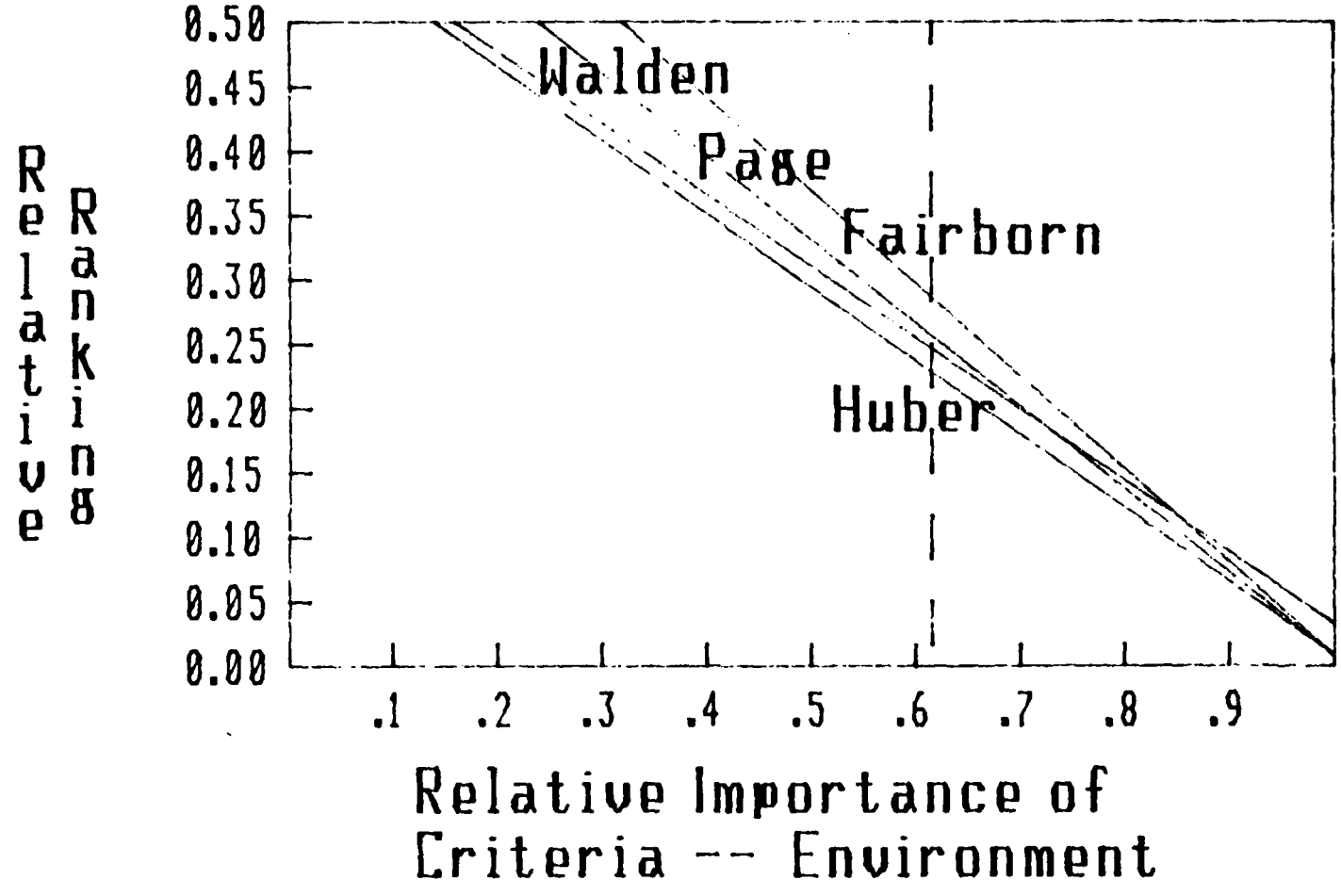

Figure 62: Sensitivity Chart for Subcriteria Environment in Pass 2

Appendix D. *Sensitivity Charts for Pass 3*

The following charts are the sensitivity charts for the third pass of the hierarchy.

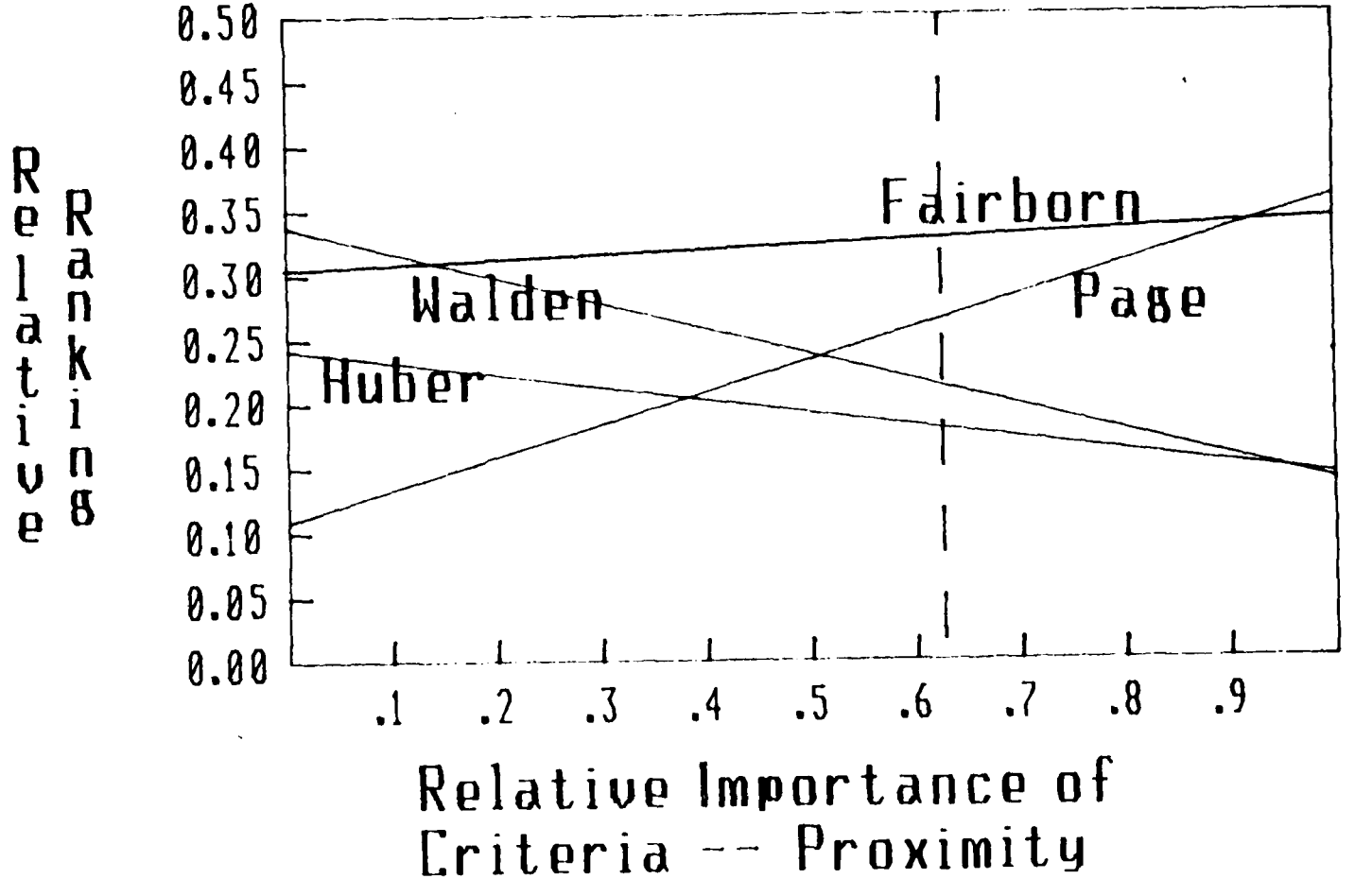

Figure 63: Sensitivity Chart for Main Criteria Proximity in Pass 3

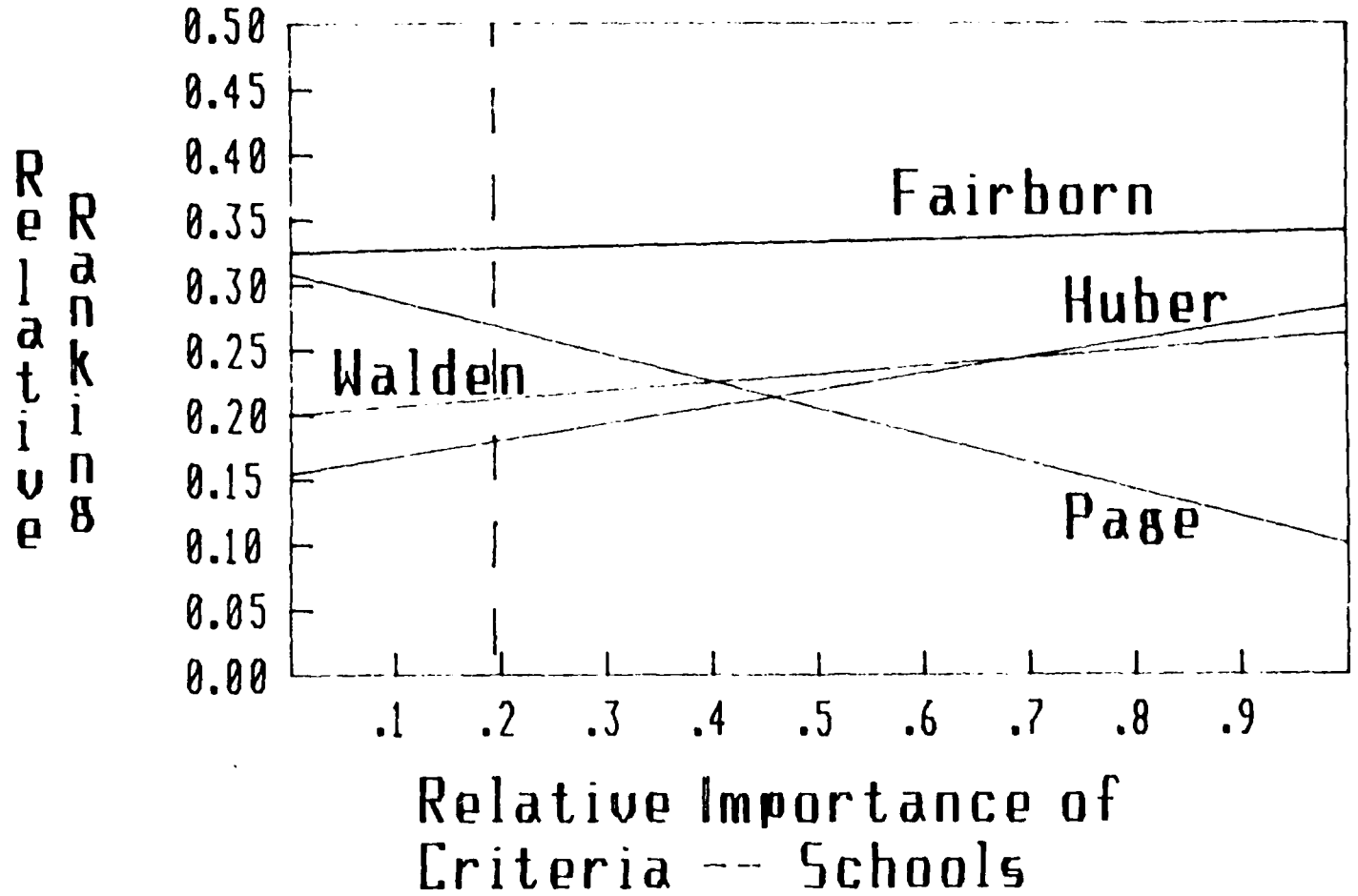

Figure 64: Sensitivity Chart for Main Criteria Schools in Pass 3

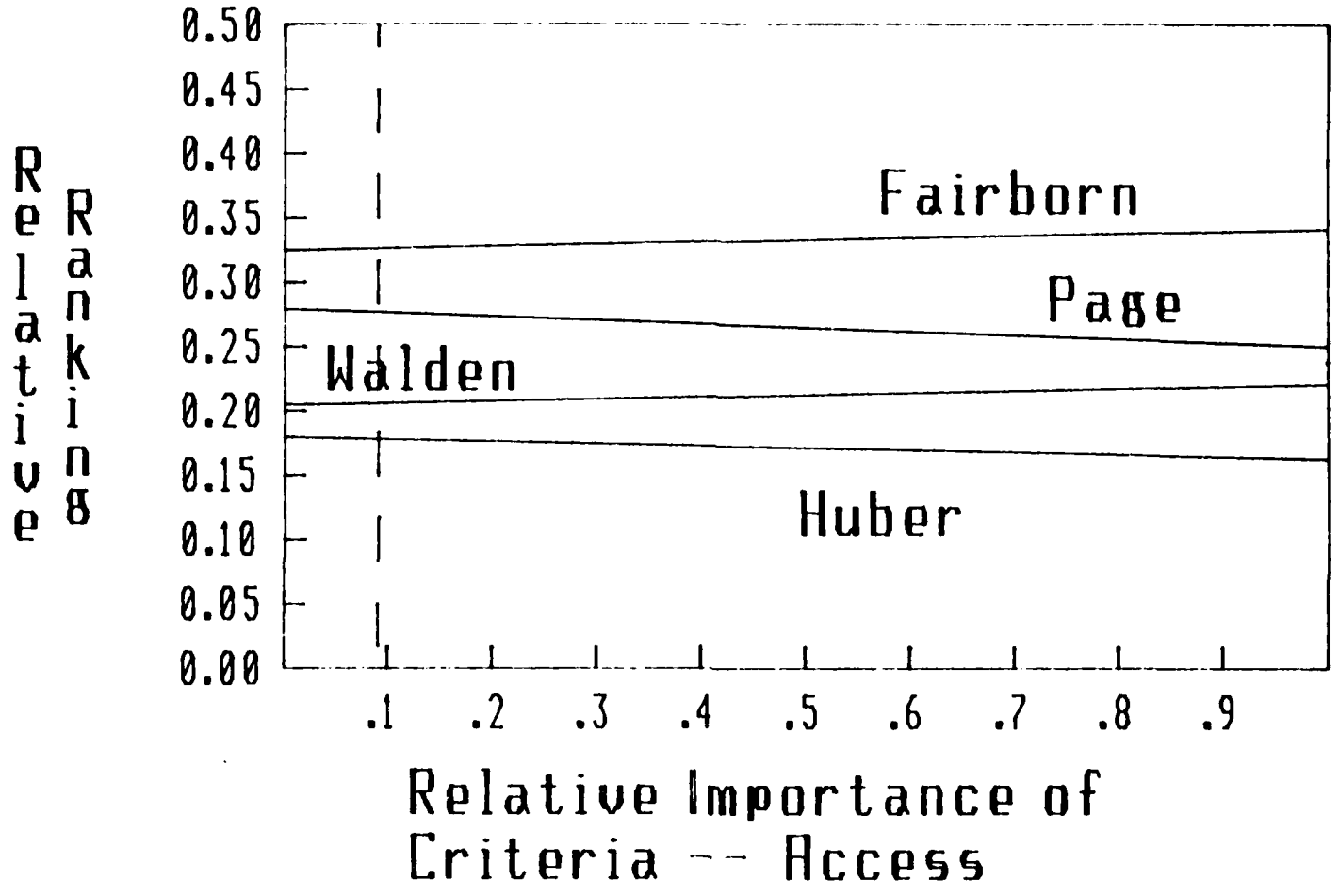

Figure 65: Sensitivity Chart for Main Criteria Access in Pass 3

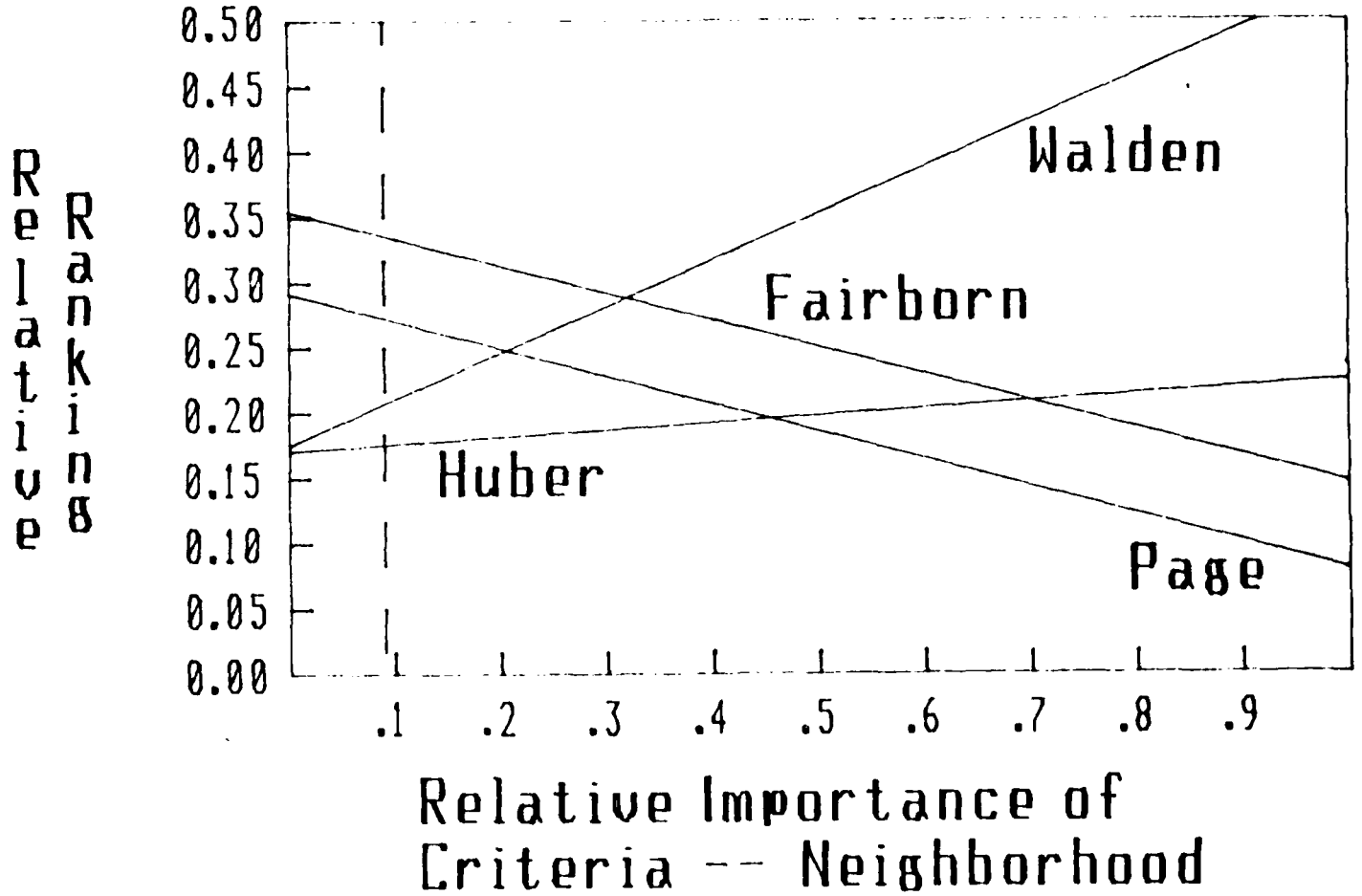

Figure 66: Sensitivity Chart for Main Criteria Neighborhood in Pass 3

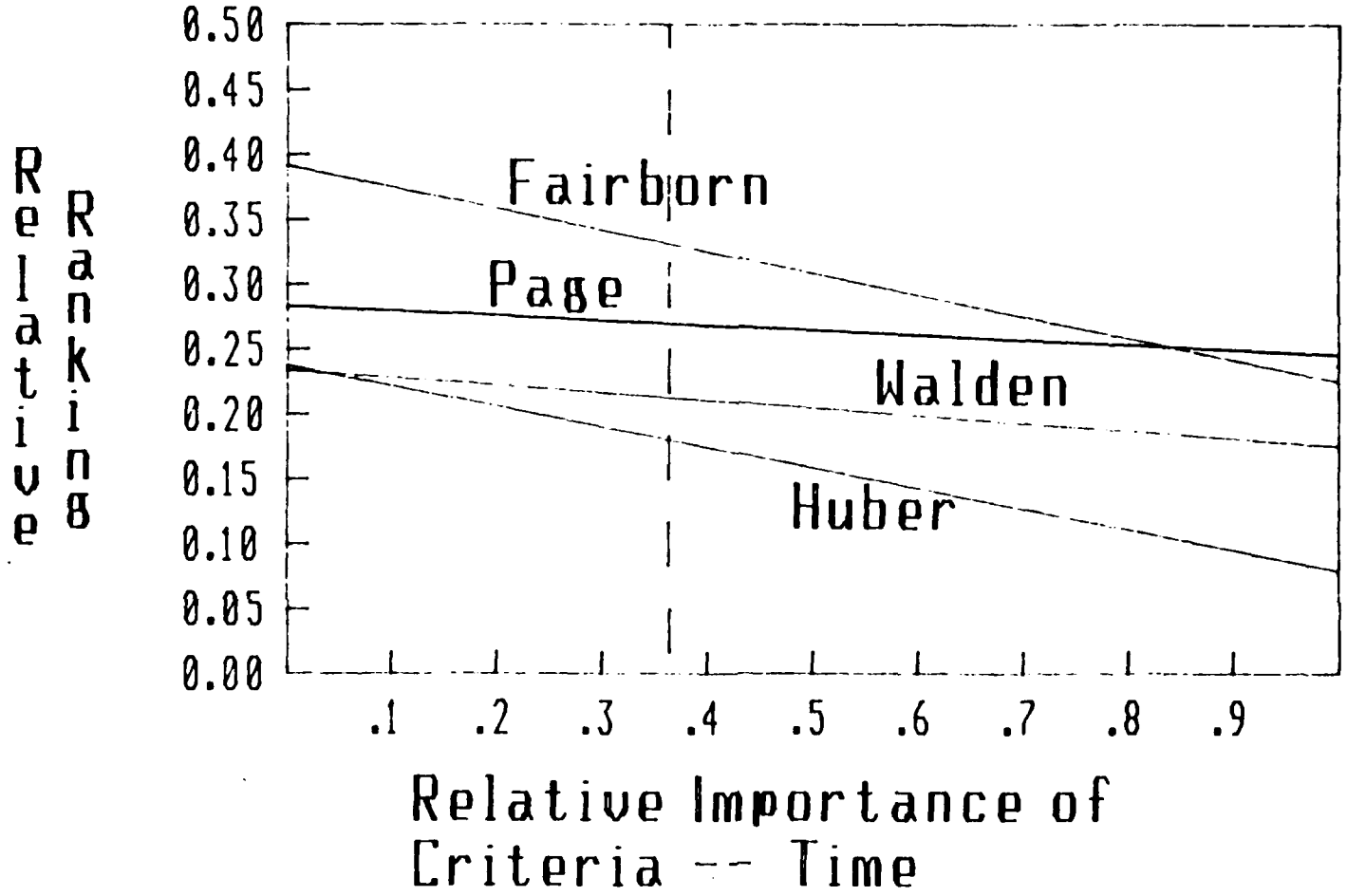

Figure 67: Sensitivity Chart for Subcriteria Time in Pass 3

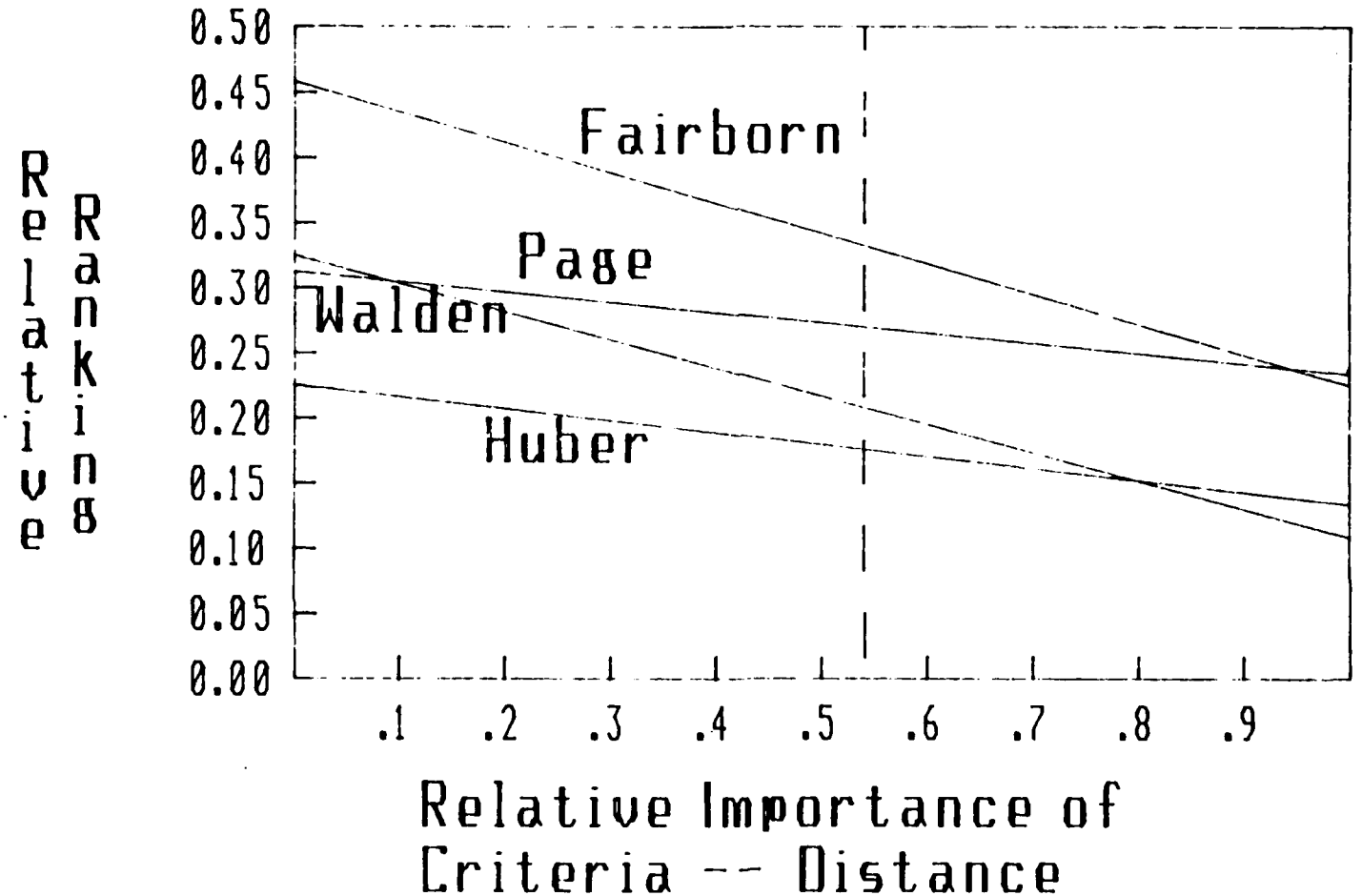

Figure 68: Sensitivity Chart for Subcriteria Distance in Pass 3

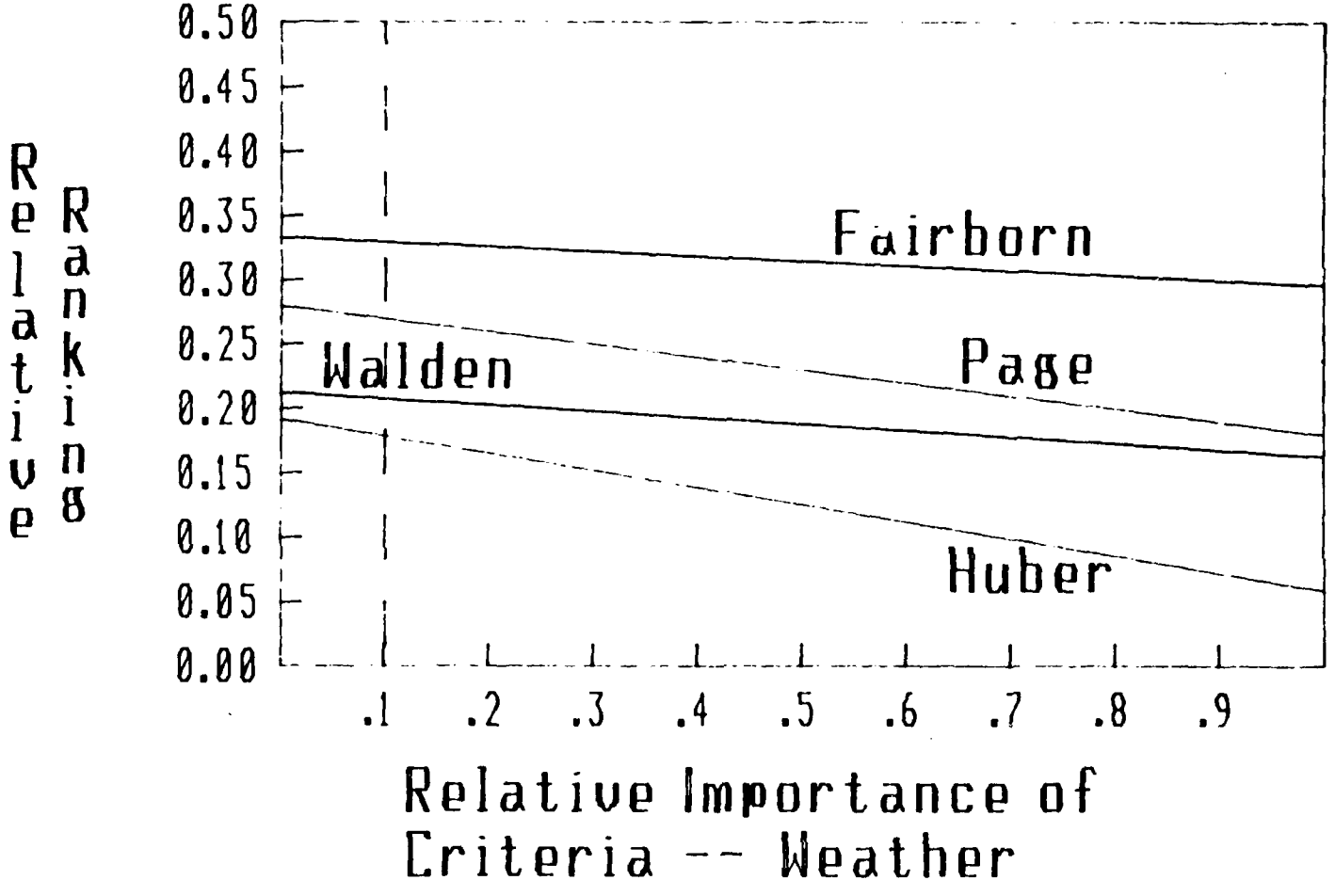

Figure 69: Sensitivity Chart for Subcriteria Weather in Pass 3

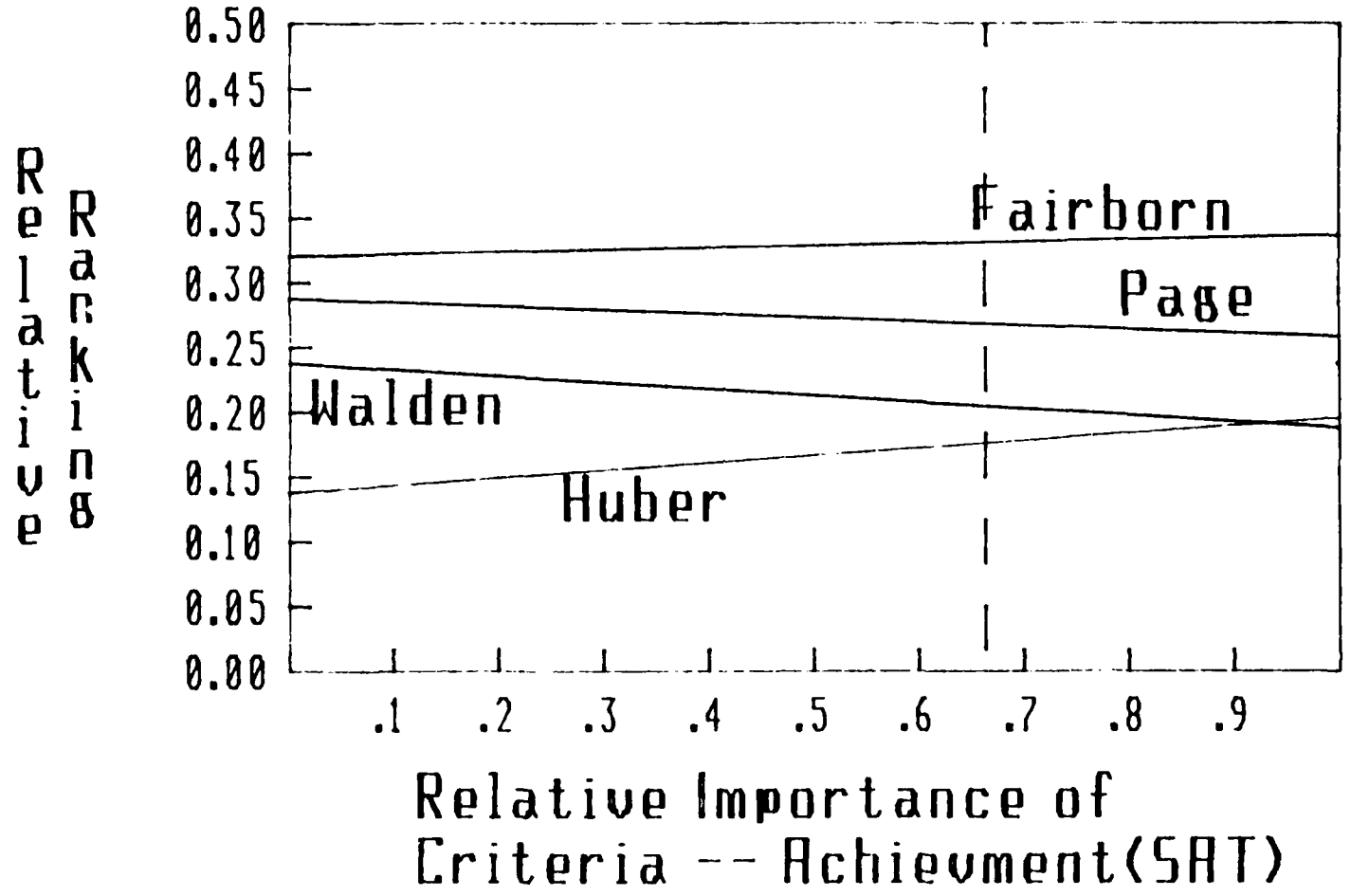

Figure 70: Sensitivity Chart for Subcriteria Achievement Scores(SAT) in Pass 3

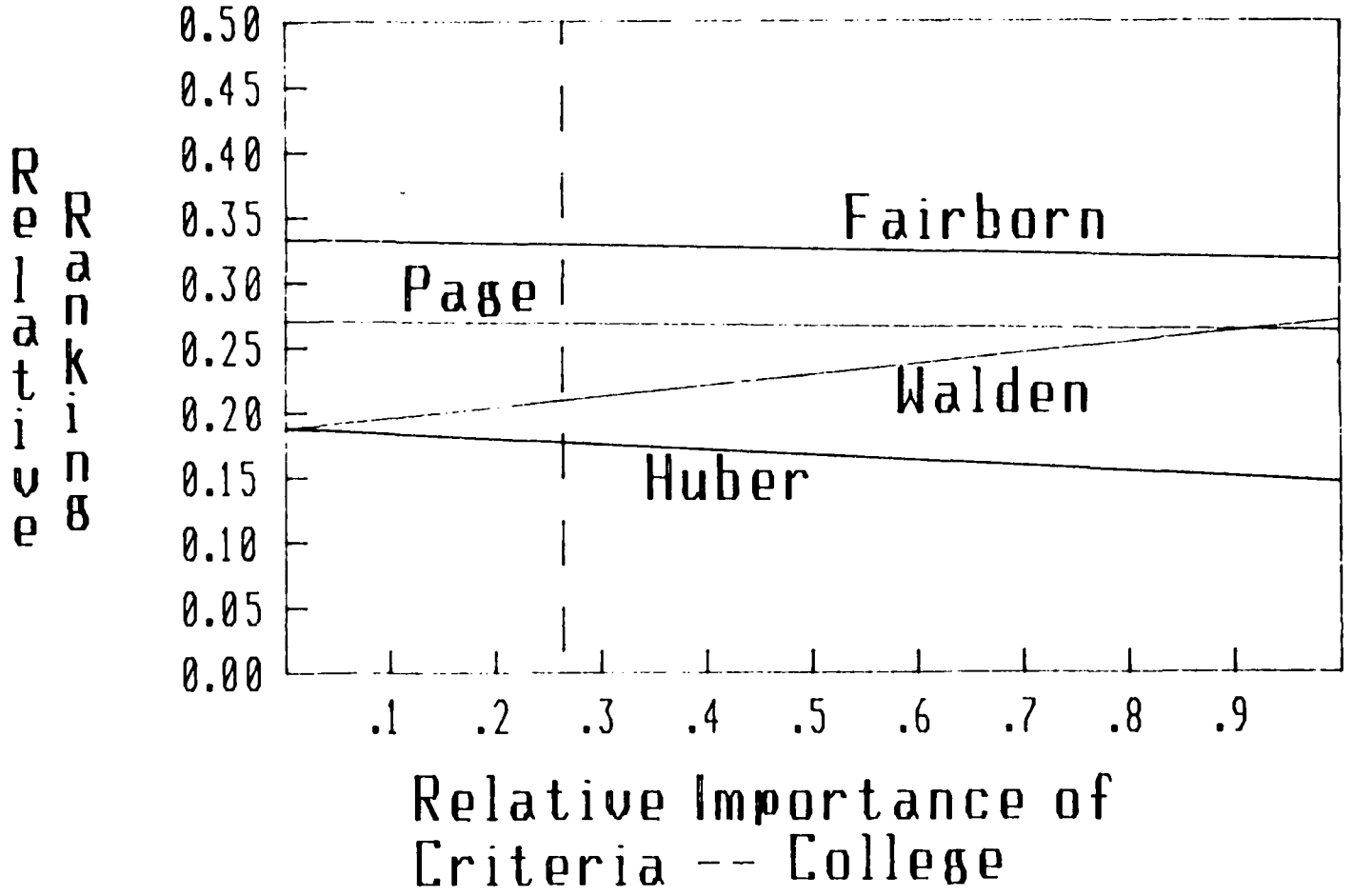

Figure 71: Sensitivity Chart for Subcriteria Percentage of Students Going to College in Pass 3

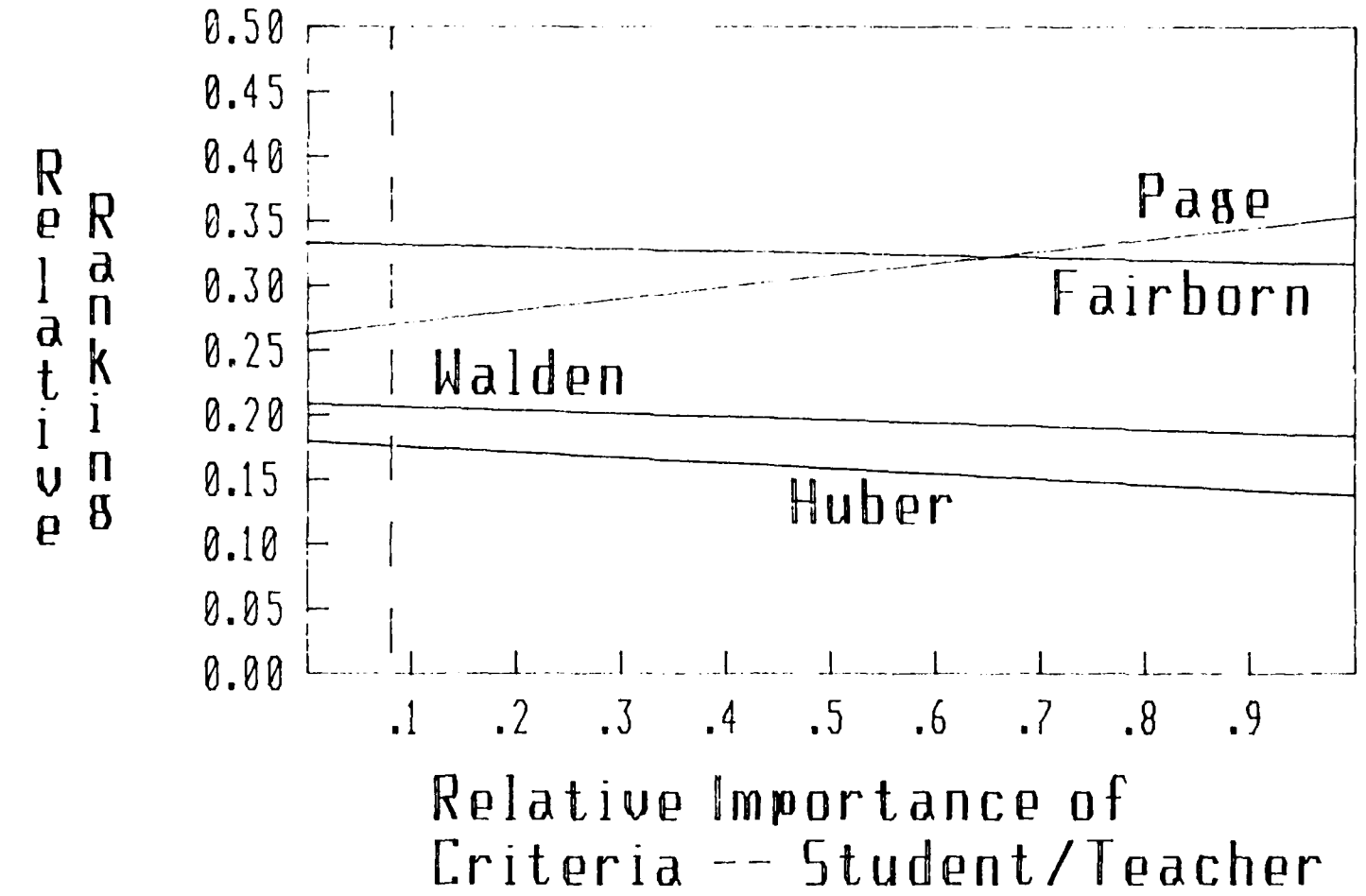

Figure 72: Sensitivity Chart for Subcriteria Student/Teacher Ratio in Pass 3

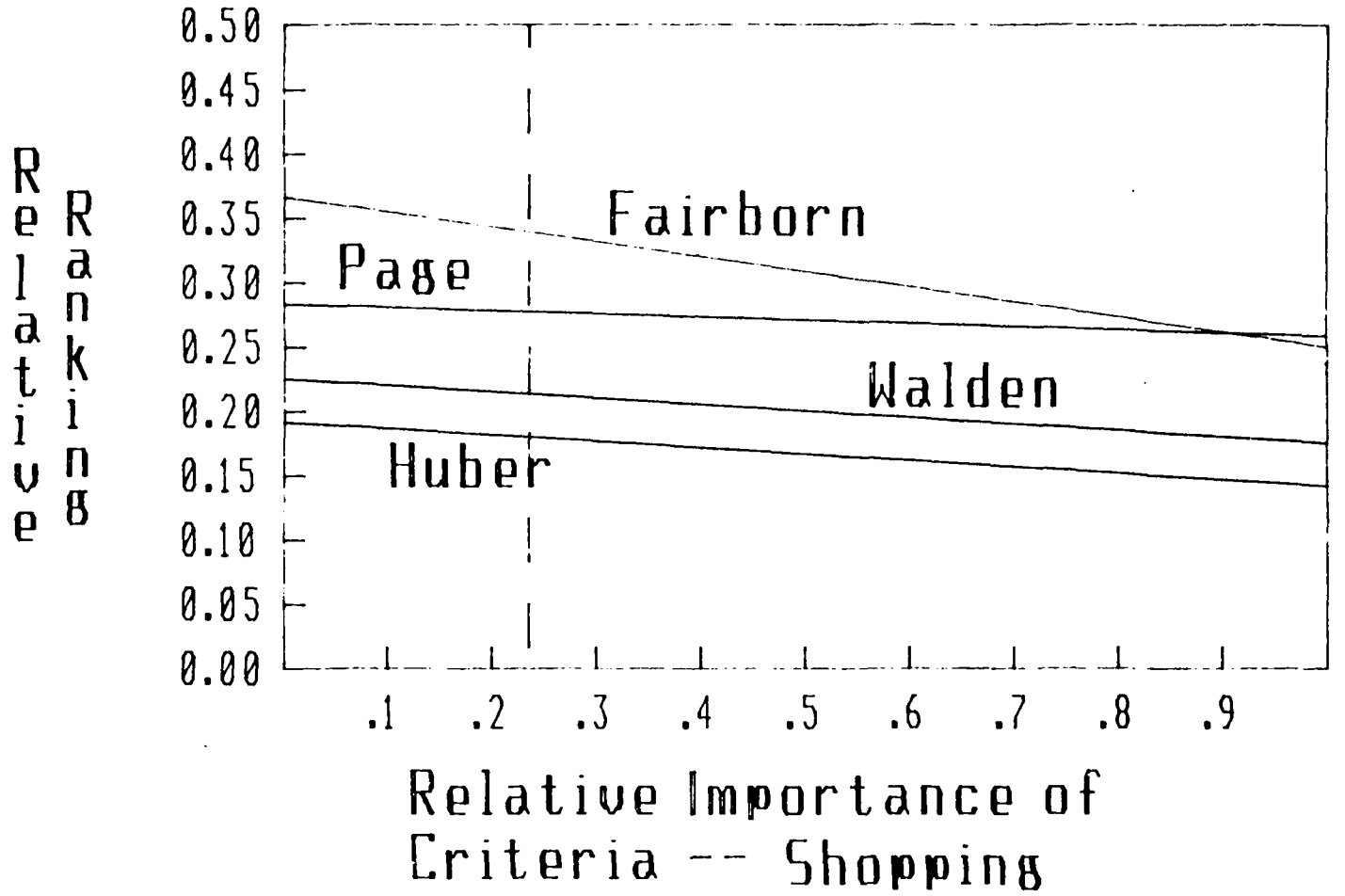

Figure 73: Sensitivity Chart for Subcriteria Shopping in Pass 3

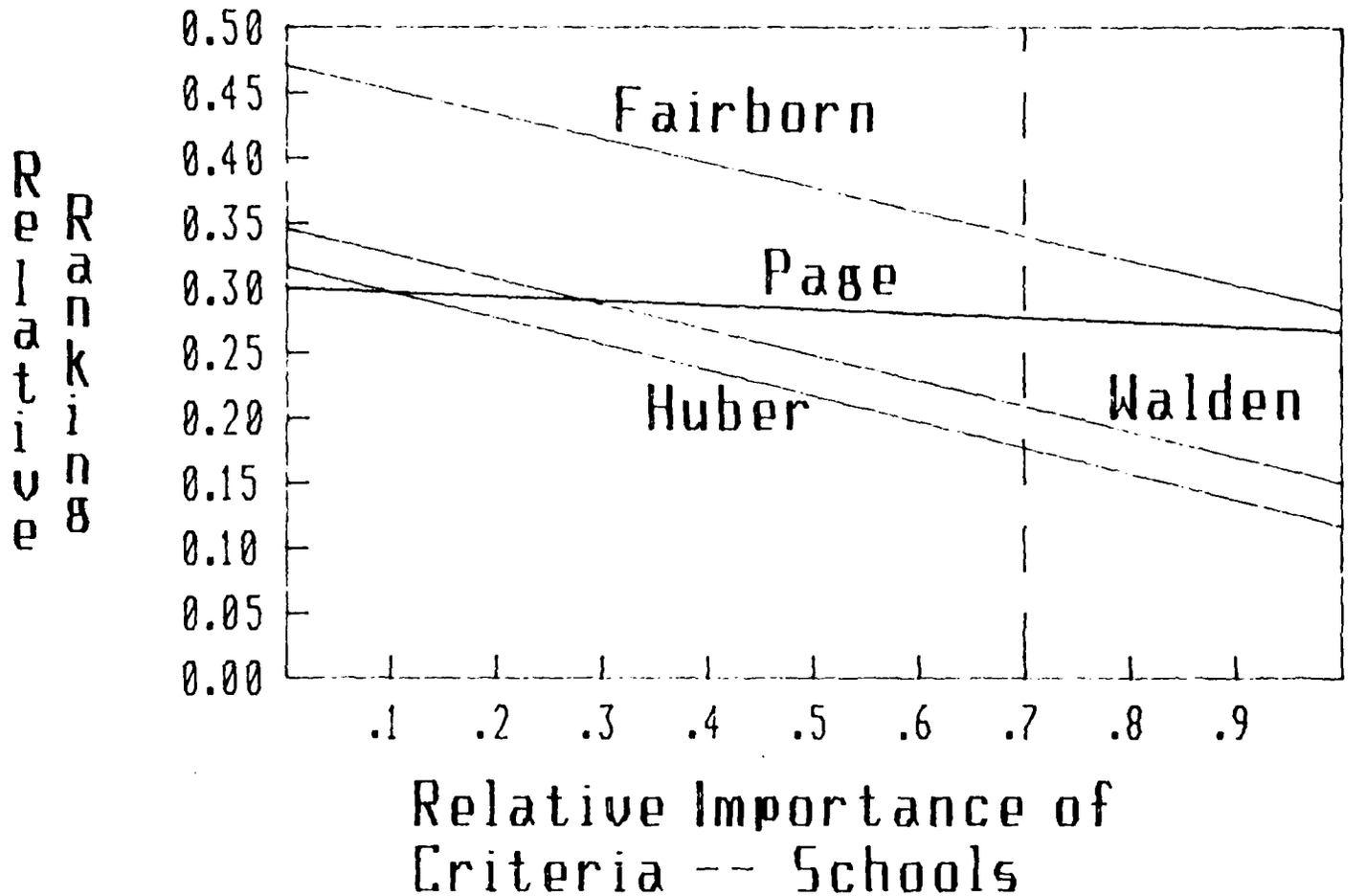

Figure 74: Sensitivity Chart for Subcriteria Schools in Pass 3

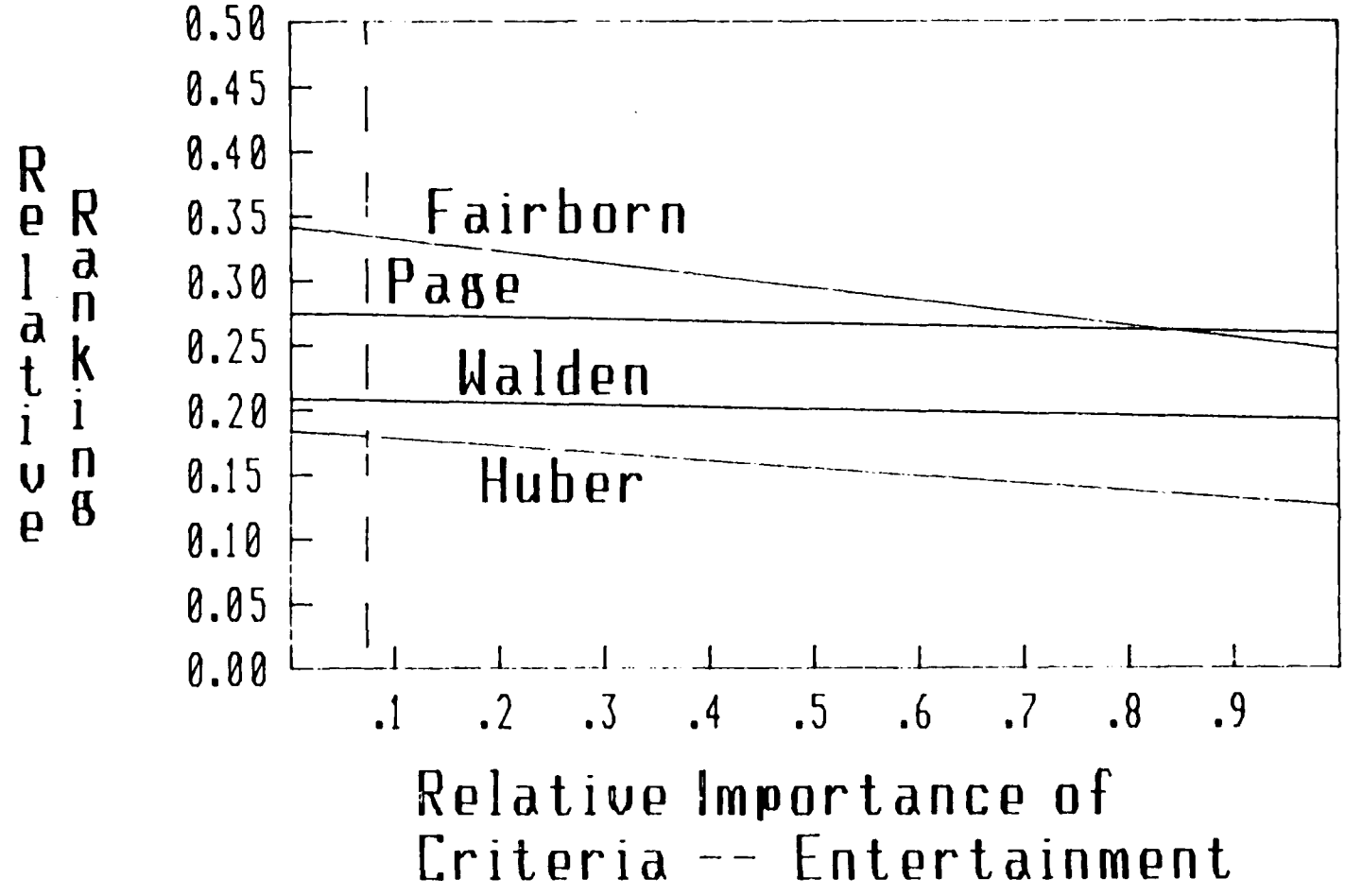

Figure 75: Sensitivity Chart for Subcriteria Entertainment in Pass 3

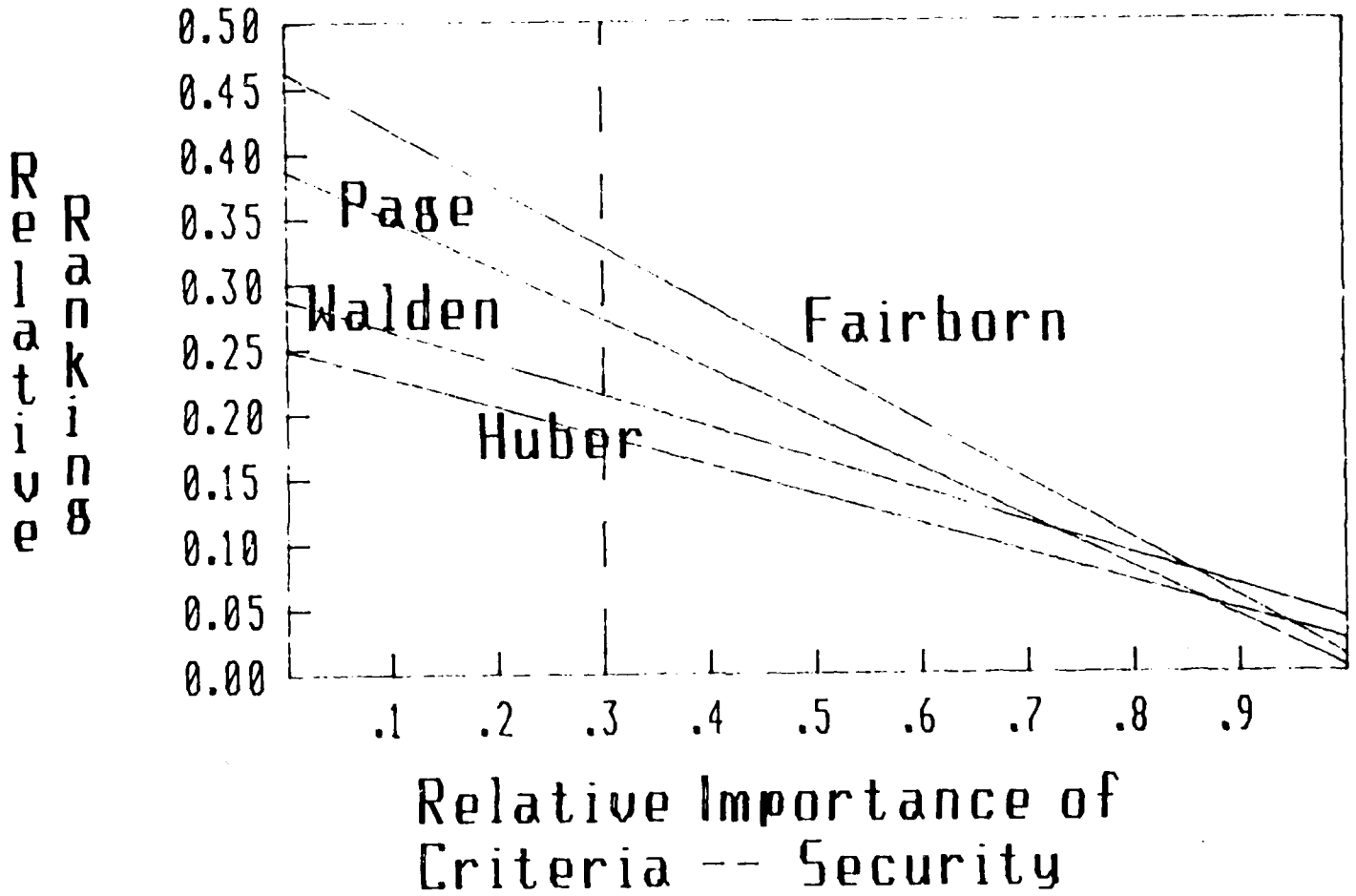

Figure 76: Sensitivity Chart for Subcriteria Security in Pass 3

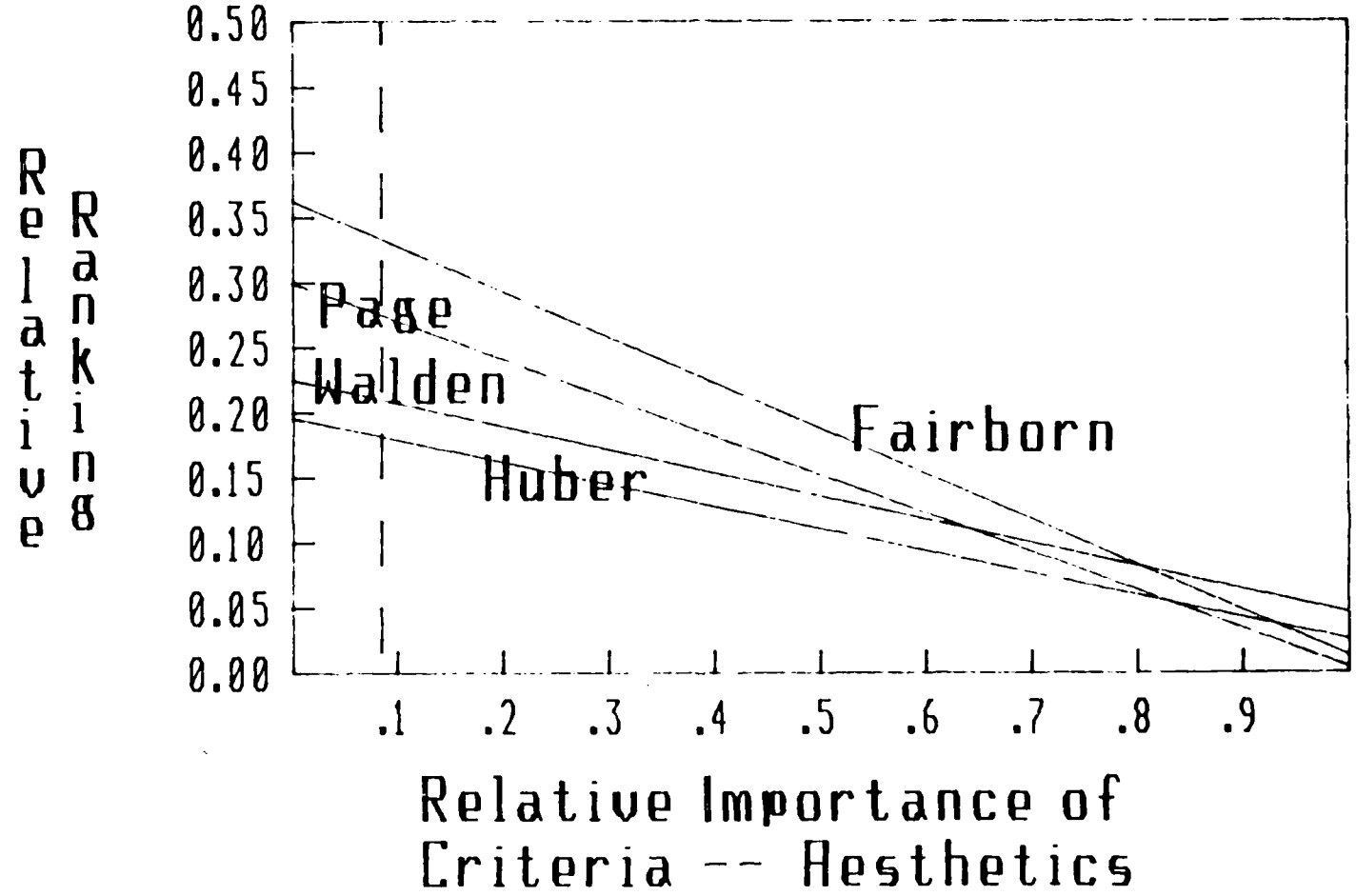

Figure 77: Sensitivity Chart for Subcriteria Aesthetics in Pass 3

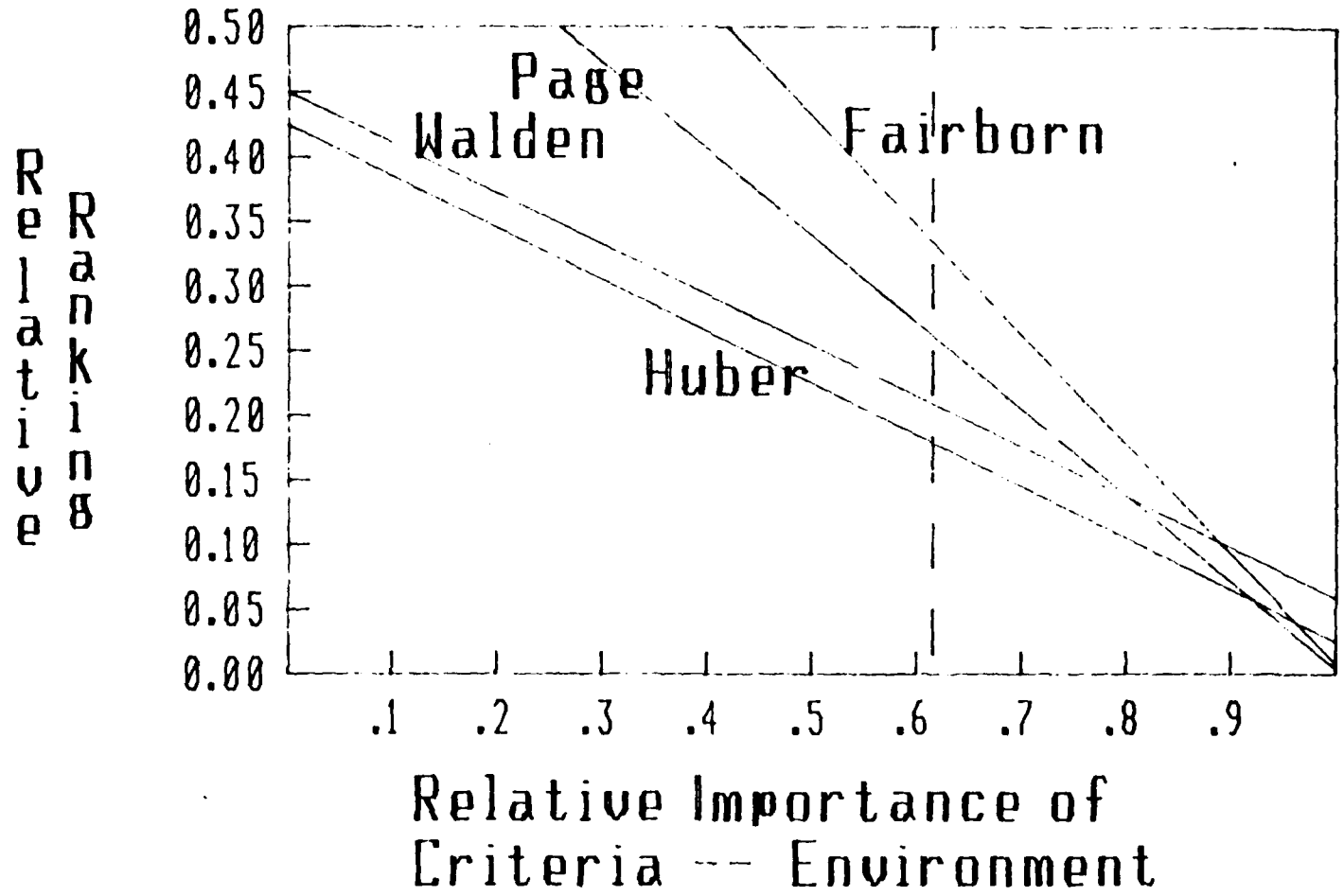

Figure 78: Sensitivity Chart for Subcriteria Environment in Pass 3

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Vita

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19. This study was supported by the Defense Housing Agency (DHA) and was an application of the Analytic Hierarchy Process (AHP) to the decision of where to build military housing.

There are currently many installations that have a deficit of housing. However, Congress has appropriated enough money for future construction that should reduce the deficit to about 1 to 2% of its present value. One decision to be made then is where to place the housing so that the needs of the installation and the personnel are met. This study used the AHP to help in the decision of where to build military housing. To do this, a hierarchy was developed that modeled the decision to be made. This hierarchy included the criteria relevant to the decision of where to build military housing. To get these criteria, the experts from the Army, Navy, and Air Force were interviewed to get their inputs as to the housing needs of the military personnel. Next, the hierarchy was evaluated at Wright-Patterson AFB to show how the AHP works. To evaluate the hierarchy at Wright-Patterson AFB, an assumption had to be made that Page Manor, a large military complex, was going to be relocated. After the assumption was made, candidate locations for the relocation had to be determined. Four locations were found to be suitable for the type of construction needed to build the number of units required. Then, all the criteria were related through pairwise comparisons to get the relative importance of the criteria to the overall goal of deciding where to build military housing. The hierarchy was then synthesized to get the relative ranking of the alternatives.

The conclusion of this study was that the AHP would be a good decision aid at the installation level housing offices. The AHP forces the Decision Maker to evaluate the relative importance of all the criteria before making a final decision.


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