THE VALUATION OF WATER RIGHTS: CONVENTIONAL VALUATION AND ARTIFICIAL INTELLIGENCE

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Abstract

«Estimated value is only... a logical proposition....» (1). Following this rule, Part I of this paper demonstrates the appraisal of a river by conventional income capitalization. While the estimate of value conforms to recommended capitalization techniques — a logical proposition — Part II illustrates valuation by artificial intelligence. Though the appraisal model covers farm land valuation, it is suggested that artificial intelligence may be applied to value water rights and, indeed, other land and income property. The conclusion recommends ways to use artificial intelligence for general valuation purposes.

Résumé

«Estimer une valuer consiste... à formuler une construction logique....» (1). Suivant cette règle, la première partie de cet exposé montre l'estimation de la valeur d'une rivière d'après les techniques conventionnelles de la capitalisation du revenu, tandis que la deuxième partie illustre l'évaluation au moyen d'un système expert.
Bien que le deuxième modèle de l'estimation concerne l'évaluation d'une propriété, l'on propose l'application de l'intelligence artificielle également pour l'évaluation des droits sur les eaux ainsi que d'autres propriétés foncières et donnant un revenu. La conclusion suggère différentes modalités d'emploi de l'intelligence artificielle aux fins de l'évaluation.

The water rights in question were owned by Milliken Industrials, Inc. which was a textile plant located in Exeter, New Hampshire, U.S.A. (less than 100 miles north of Boston, Massachusetts, U.S.A.). This textile plant owned all water rights to the river conveyed in a deed dated February 15,1828. The textile plant was to be closed and the rights to all water of the river were to be transferred to the city of Exeter, New Hampshire. The city proposed to use the river as a domestic water supply. Therefore, the valuation problem was to determine the water rights owned by Milliken Industrials, Inc., which was to be conveyed to the city of Exeter.

The textile company claimed all water rights under a 1828 deed that granted.

All dam rights, rights of flowage, rights of water usage and any other rights of record and otherwise which the grantor may have in and into the river beds, the water's end and channels of Squamscott River, Exeter River, Little River, and tributaries in the towns of Exeter, Kinsington, Brentwood and otherwise wherever situated.

The deed further gave the mill the right of: drawing and using the water flowing through said gate (of the Upper Falls Dam) at all times when the water at said falls shall flow over the top of the dam as it now is or as it may be, would in addition to its height not exceed one foot....

According to the best legal advice, the textile mill acquired rights to all of the water in the Exeter River except for the surplus which ran over the dam as it then stood and was formerly owned by the 1828 seller.

The appraisal problem then was to determine the market value to use 4.0 million gallons a day (MGD), a safe yield, from the Exeter River. The city of Exeter had a current demand of 3.0 MGD which was being satisfied by ground water with a high hydrogen sulfide content. Further, the ground water exceeded the maximum limit for manganese. Because of the high mineral content, the city water was difficult to treat, had a poor taste, and a bad odor. Therefore, the city had a high demand for water from the Exeter River. Projections indicated the city would eventually need 6.5 MGD. Consequently, it was dctermined that there was a demand for the 4.0 MGD of water from the Exeter River.

Market value was estimated by treating the water as a source of net income which could be capitalized to estimate market value. Hence, the main problem was to document the estimate of gross income, annual expenses of operation, and the capitalization rate. In other words, *water from the river was treated as a source of net income which had a current market value.*

In the state of New Hampshire, domestic water supplies for cities, towns and villages are typically furnished by private companies that are granted monopoly privileges by the state of New Hampshire. As a state regulated monopoly, water companies must report annual operating results including profit and loss statements, balance sheets and other data to the state regulatory agency that establishes maximum water rates that companies may charge.

Such companies supply water from ground or surface sources. The general rule is that companies that supply a monopoly service, namely domestic water, may charge fees based on a reasonable return on their investment in the water system: pumps, pipes, distribution system, wells, meters, purification plants and the like.

To determine the potential revenue to be gained from water from the Exeter River, financial reports of 147 private water companies operating in the state of New Hampshire were analyzed. From these reports, three companies were selected that served communities of comparable population and secured water from surface (river) sources. From these records, the typical investment needed to distribute 4 MGD to domestic users was calculated. Based on the allowable rate of return established by state regulators, the potential revenue was estimated after operating expenses. Given the estimated sale of some 4 MGD, the market value was estimated by applying the prevailing capitalization rate or annual yield on invested capital allowed by the state of New Hampshire.

The annual income statements for three companies are shown in absolute amounts, percentages, and in dollars per MGD. By reducing income and expenses to percentage figures and by showing revenue and expenses per MGD capacity, ratios may be established to value water rights. For example, **table 1** showing the annual income for the Hampton Water Works Company reveals a gross income of $ 242,928 per MGD. Total expenses of operation per MGD equaled $ 184,906 or 76.0 percent of total water revenue. In this case, water operating income equals $ 58,023 per MGD capacity or an annual income of 24.0 percent of total gross income. Note that these data are based on a capacity of 3.73 MGD comparable to the water flow from the Exeter River.

In the second example shown in **table 2**, total operating gross revenue equals $ 397,962 per MGD. In this case, expenses amount to 70.1 percent of total gross revenue or $ 119,399 per MGD. It is reasoned that the higher operating income, 30 percent, results from economies of scale and economies of higher utilization. In this example, the safe yield of 7.8 MGD is almost double the yield of the Exeter River. The relatively higher expense of operation, 29.9 percent of gross revenue, is largely accounted for by the higher depreciation expenses

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(1) Giuseppe Medici, *Principles of Appraisal* (Ames, Iowa, USA: The Iowa State College Press, 1953), p. 19.

and federal income taxes shown in **table 2**. See **table 3** for the Hudson Water Company with a safe yield of 3.8 MGD. Total operating revenues of $ 811,751 equaled $ 270,584 per MGD. Expenses of $ 150,359 MGD show expenses of 56.0 percent of total revenue. The net water operating income of $ 360,673 indicates an income per MGD capacity of $ 120,224 or a net operating ratio of 44.0 percent.

To assist in the estimate of income and operating expenses, certain financial ratios were calculated for the three utilities in **tables 1 2**, and **3**. See **table 4**. The first three financial ratios indicated a fairly high degree of uniformity in operating results. Similarly, the gross revenue per MGD ranging from $ 242,928 to $ 397,962 fell within fairly narrow limits. These data strongly suggested that an allowance for gross income per MGD of $ 300,300 would be appropriate to value water rights to 4 MGD derived from the Exeter River.

Similarly, the operating expenses per MGD ranged from $ 147,550 to $ 322,532. Allowing for a 65 percent expense ratio resulted in a total annual expense ratio of 65 percent or $ 195,000 per MGD. This estimate is considered reasonable in the light of data of **table 4**.

Allowing a net profit of 35 percent of gross income or $ 105,000 per MGD is also considered consistent with the data of **table 4**. The net profit per MGD of $ 26,442 for the Hampton Water Works resulted from a higher expense ratio (76 percent) relative to the two remaining examples. An expense ratio of 65 percent was above the Hudson expense ratio of 56 percent. A 65 percent expense ratio consequently was deemed appropriate.

After the review of **tables 1** to **3**, a pro forma income statement was calculated for revenues derived from the 4 MGD, safe yield, of the Exeter River. These data are summarized in **table 5**. Note that the net operating profit of $ 420,000 provides for a 35 percent operating profit ratio which seems reasonably supported from the three examples selected for comparison. Analysis of the profit and loss statements for the three companies showed a rate of return on capital assets of 10.1 to 11.4 percent. The state of New Hampshire Public Utility Commission, the regulatory agency, concluded that a 10.7 capitalization rate was appropriate for water and public utilities. Based on earnings realized and findings of the New Hampshire Public Utility Commission, the estimate of market value was based on a 10.5 percent rate of capitalization.

Note that the value estimate was based on certain premises:

1. The river provided a safe yield of 4 MGD of surface water suitable for domestic use. The city of Exeter had a current demand for all water from the Exeter River for domestic purposes.
2. The water flow was treated as an asset that produced an annual net operating income. Operating results of private water sys-

Table 1 ***Annual income statement: Hampton Water Works Company.***

		Total	MGD (*)	Percent of Total
General sales-metered	$ 736,645		$ 197,224	81.2
General sales-unmetered	14,845		3,980	1.6
Public hydrant rentals	117,466		31,492	13.0
Sales to public authority	13,230		3,547	1.4
Water service revenues		$ 881,186	$ 236,243	97.2
Customers' forfeited discounts and penalties	$ 10,550		$ 2,828	1.2
Miscellaneous water revenues	14,386		3,857	1.6
Other water revenues		$ 24,936	$ 6,685	2.8
Total operating revenue-water		$ 906,122	$ 242,928	100,0
Production expenses	$ 121,537		$ 32,584	13.4
Transmission and distribution expenses	105,146		28,189	11.6
Customers' accounting and collection expenses	60,141		16,124	6.6
Sales and business expenses	(17)		(5)	0.0
Administration expenses	189,871		50,904	21.0
Total operation and maintenance		$ 476,678	$ 127,796	52.6
Depreciation-water	$ 59,214		$ 15,875	6.5
Taxes-water 153,806			41,235	17.0
Total other operation expenses		$ 213,020	$ 57,110	23.5
Total revenue deductions		$ 689,698	$ 184,906	76.0
Water operating income		$ 216,424	$ 58,023	24.0
Water operating income (brought forward)		$ 216,#24	$ 58,023	24.0
Net operating property income		30,591	8,021	3.0
Gross income		$ 247,015	$ 66,224	27.0
Deductions from gross income		148,387	39,782	16.0
Income balance transferred to earned surplus		$ 98,628	$ 26,442	11.0

(*) A safe yield of 373 millions gallons per day.

Table 2 ***Annual income statement: Pennichuck Water Works.***

		Total	MGD (*)	Percent of Total
General sales-metered	$ 2.352.386		$ 301.588	75.8
General sales-unmetered	68,624		8,798	2.2
Public hydrant rentals	$ 626,520		80,323	20.1
Sales to public authority	29,658		3,802	1.0
Water service revenues		$ 3,077,188	$ 394,511	99.1
Miscellaneous water revenues		$ 26,919	3,451	.9
Total operating revenue-water		$ 3,104,107	$ 397,962	100,0
Production expenses	$ 356,618		$ 45,720	11.5
Transmission and distribution expenses	256,295		32,858	8.3
Customers' accounting and accounting expenses	44,111		5,655	1.4
Administration expenses	337,257		43,238	10.9
Total operation and maintenance	$ 994,281		$ 127,472	32.1
Depreciation-water	$ 265,247		$ 34,006	8.5
Taxes-water	915,473		117,368	29.5
Total other operation expenses		$ 1,180,720	$ 151,374	38.0
Total revenue deductions		$ 2,175,001	$ 278,846	70.1
Water operating income		$ 929,106	$ 119,116	29.9
Operating rents-net		$ 3,160	$ 405	.1
Net water operating income		$ 932,266	$ 119,399	30.0

(*) A safe yield of 7.8 millions gallons per day.

Table 3 ***Annual income statement: Hudson Water Compnay.***

		Total	MGD (*)	Percent of Total
Operating revenues-water		$ 811,751	$ 270,584	100.0
Operating and main tenance-water	$ 339,994		$ 133,331	49.0
Depreciation-water	44,409		14,803	6.0
Taxes-water other than income taxes	66,673		22,224	9.0
Total revenue deductions		$ 451,978	$ 150,359	56.0
Net utility operating income		$ 360,673	$ 120,224	44.0
Revenues form non-operating property	$ 7,908		$ 2,636	1.0
Miscellaneous non-operating revenues	522		174	0.9
Non-operating property revenues		$ 8,430	$ 2,810	1.0
Income balance transferred to earned surplus		$ 369,103	$ 123,034	45.0

(*) A safe yield of 3.8 millions gallons per day.

tems, operating under state regulation, indicated the probable income that could be derived from the sale of domestic water.
3. The expected net income was capitalized at the prevailing rate of return earned on comparable public water systems.
In sum, the valuation of water rights was equal to the present value of net income. The capitalized value of annual net income was based on empirical evidence of the market: namely, the operating experience of comparable water utilities. In this sense, the appraisal was based on a logic proposition.

Table 4 ***Financial Ratios: water utilities.***

	Hampton	Pennichuck	Hudson
Current asset ratio	2.432	1.547	.03
Fixed asset to capital stock	5.238	4.902	6.819
Debt to equity ratio	2.495	1.413	2.835
Gross revenue per MGD	$ 242,928	$ 397,962	$ 270,584
Operating expense per MGD	$ 216,486	$ 322,532	$ 147,550
Net profit per MGD	$ 26,442	$ 75,430	$ 123,034

Table 5 ***Pro forma income statement: Exeter river water.***

	Annual Amount per MGD		Annual Total		Percent of Total
Water operating income		$ 300,000		$ 1,200,000	100
Less expenses					
Production expenses	$ 30,000		$ 120,000		10
Transmission expenses	27,000		108,000		9
Collection expenses	21,000		84,000		7
Sales expenses and administration	63,000		252,000	21	
Taxes	30,000		120,000		10
Depreciation	24,000		96,000	8	
Total expenses		– 195,000		– 780,000	65
Annual net profit		$ 105,000		$ 420,000	35

Valuation by artificial intelligence

While the preceding valuation followed fairly standard procedures, appraisers have the option of basing valuation estimates on artificial intelligence: a system which relies on logic, a database and computer routines that solve problems. Before developing techniques to value land by artificial intelligence, it seems worthwhile to review the concept of (1) expert systems, (2) appraisal logic, and (3) programming in logic.
To understand these terms, a distinction must be made between *procedural* and *declarative* knowledge systems. Computer programs are normally based on *procedural routines* in which each program line constitutes a procedure that the computer executes. Thus an expert system may consist of procedures that the computer executes to produce a given result. Procedural knowledge systems, then, are based on procedures that are executed to reach a solution.
Declarative knowledge works by computer routines that solve problems. Thus, declarative knowledge is not based on routines that depend on solutions on *how to do* a task, but they are based on routines that *solve a declared problem*. In sum, a declarative knowledge system consists of two components: (1) a database of facts; for example, the date of sale, the sale price, type of property, location and similar data; and (2) a set of rules based on relations between objects in the database ([2]).
The appraiser using a declarative knowledge system would, *first*, construct a database that shows relations between property characteristics and value and, would *secondly*, form rules based on inferences about the database. Such inferences, in turn, are based on logical relationships derived from the database.

Expert systems

Expert systems are computer programs that imitate a human expert. They require procedures that the computer executes. Expert systems, for example, include a database on diseases in which the computer uses to diagnose diseases. Similarly, computer programs have been developed that execute procedures followed by appraiser experts to calculate value. Appraisal experts, in this case, develop computer procedures that execute instructions, i.e., the capitalization of income. Such expert systems are usually based on procedural programs designed by experts.

Appraisal logic

Logic has been defined as the study of *consistent sets of beliefs*.
Beliefs are said lo be consistent if they are compatible with each other. Put differently, a set of beliefs is consistent if these beliefs could all be true together in some possible situation ([3]).
For example, I may reason that land in the Comune Ronciglione (Lazio) has a value of 6,300,000 lira per hectare because land sold in 1986 used for filbert trees, owner operated, in District 6, had an average value of 6,300,000 lira. Thus it is reasoned that land has value if it has those characteristics that indicate an average value of 6,300,000 lira per hectare. The appraiser establishes the database and the rules that define value according to relations between objects in the database. Under these arguments, *the market value estimate would be valid if there is no possible situation in which the valuation premises are true and the conclusion is not true*.
For example, it may be reasoned that land sold in 1986, in Dictrict 3 in the Ronciglione Comune, used for filbert trees, with a cadastral tax of 100,000 lira per year has a value of 6,300,000 lira per hectare. Given these conditions of sale, value follows from the typical value of land having similar characteristics. An appraisal based on these premises would be valid since the premises are said to determine the conclusion.
Therefore, the appraiser who estimates value on the basis of recent sales of land having given characteristics infers value from the premises. To be sure, all appraisals require such logical reasoning. The appraiser who estimates value from the capitalization of net income presumably has followed acceptable rules of logic. However, the central question turns on whether the appraiser has used deductive or inductive reasoning.
Under *deductive* logic, the appraiser establishes the general principle, a capitalization rate of 12 percent; then estimates value by capitalizing at the 12 percent capitalization rate. That is, value follows from the *general principle*, a 12 percent capitalization rate, which is applied, to a *specific case* to estimate market value. The appraiser reasons from the general case to the specific case. While this system follows deductive logic, it may also follow the principle of ipse dixit - it is so because I say it is so.
A valuation system based on programming logic, in contrast, follows inductive reasoning: from repeated observations of the market (the database), the appraiser estimates market value. Here, the appraiser reasons from repeated observations of *specific cases* to the *general case*: market value. Given these propositions, the next step is to consider programming logic.

Programming logic

Computer programs that solved problems by declarative procedures were introduced

([2]) Adrian Walker, «Knowledge Systems: Principle and Practice». Adrian Walker, et al, *Knowledge systems and Prolog* (Reading, Massachusetts: Addison-Wesley Publishing Co., Inc., 1987) pp. 2-3.
([3]) Wilfred Hodges, *Logic: An Introduction to Elementary Logic* (New York: Penguin Books, Inc: 1988), p. 13.

by Alain Colmerauer in the 1970's ([4]). The computer program «Prolog» stands for «programming in logic» based on inferences drawn from the database and the rules established by the programmer. The method is based on *predicate logic* which takes the arguments:
All men are mortal. Socrates is a man. Hence Socrates is mortal.
This reasoning assumes the form that all A are B. S is an A, hence S is a B. Predicate logic indicates only whether the premises imply the conclusion ([5]).

Prolog

Prolog, which requires a database, includes an inference engine which is a process of reasoning logically about information.
Applied to appraisal problems, the program requires a set of facts (comparable sales and their characteristics) and rules of valuation. Thus in Prolog, the relation between land and value is called a fact. The value per hectare would be shown by the phrase
Land value equats 6,300,000 lira per hectare.
In programming logic, this relationship would be shown as
Value (hectare, 6,300).
The fact expressed in this relationship indicates that the sale price or value equals 6,300 lira per hectare. The facts would include selected characteristics of each real estate sale recorded as part of the database. The appraiser would then establish rules allowing inferences to be drawn from facts. Rules would be equivalent to conclusions known to be true if one of more conclusions or facts are true.
Prolog uses a database consisting of a collection of facts and rules. The database could be a set of real estate sales with their individual characteristics or a database of income property showing income and operating expenses and rates of return or yield. From a list of several hundred or thousands of sales, the appraiser would select rules that allow the computer to estimate value given user input on the property to be appraised. In this sense, the computer is merely following established rules applied in conventional appraisals.
Prolog permits the appraiser to quantify appraisal rules. That is, rules are based upon inferences drawn from repeated observations of market data. It is believed that such rules drawn from actual cases are superior to deductive logic based upon subjective, personal value judgments.
A few selected examples will show how these concepts are applied. To illustrate, how do you know if two persons are sisters? To answer this question, you establish two rules: to be sisters, (1) two people must be females and (2) they must have the same parents. By the same token, how do you know the market value of farmland? Suppose the land you are appraising has the following characteristics:
Location: Ronciglione, Lazio
Land use: filbert trees
Owner operated: Yes
Date of valuation: 1985.
The Prolog program will then search all land sales with these characteristics (or any other set of characteristics in the database) and calculate the median value per hectare. Based on the number of hectares for the property under valuation, the market value equals the median value of land with similar characteristics (a rule).
In other words, the computer starts with a database of land sales showing detailed characteristics for each sale. The appraiser then establishes the rule that market value equals the median value per hectare for land having a stated set of characteristics. That is, the Prolog program calculates the median land value, given the set of land characteristics for the property under appraisal. The median value per hectare for this set of characteristics is then applied to the property appraised. The median value per hectare, therefore, varies and is dependent on the characteristics of the property to be appraised.
Note carefully that valuation accuracy depends on the database. Sales data must include variables significant to the value of land. Accuracy also depends on rules that lead to a logical conclusion: the market value estimate is in error if the database does not include significant variables and if the correct rules of valuation have not been applied.
Given the required database, rules may be established to value income property, vacant land, farmland or other complex properties. At this point, Prolog has been used to value single family dwellings, warehouses, and vacant land. In these applications, the appraiser enters a database of real estate sales with detailed property characteristics shown for each sale. In the case of single family dwellings, the appraiser must establish rules showing market value for houses of different characteristics. In sum, the appraiser, to apply Prolog, must identify accepted rules that lead to market value. For example, a house with two bathrooms has a higher value than a house with one bathroom. A house with two high quality bathrooms will have a greater value than a house with average bathroom fixtures. The program can be refined to the degree justified by appraisal requirements. There is virtually no limit to the number of variables or rules available to the appraiser. The accuracy of the valuation, then, rests on the quality of the database and appraisal rules. Again, rules are based on inferences drawn from the relation between property characteristics and value.

Programming logic errors

Turning next to the proposition of Medici that an appraisal must be logical, it is worthwhile to review possible errors in appraisal logic. To be effective, artificial intelligence appraisal routines must avoid logic errors. The more common appraisal logic errors may be summarized in six points.
1. Inconsistent conclusions. If all appraisal conclusions based on given premises are not true, the appraisal conclusion is inconsistent and therefore invalid. Suppose for example that the database shows, that for a given location, land type and other characteristics, a median value of 6.300.000 lira per hectare. If you conclude from these premises that market value equals 10.000.000 lira per hectare, your conclusions would be inconsistent. *Appraisals based on Prolog avoid inconsistent conclusions.*
2. Ambiguous conclusions. Appraisal conclusions would be ambiguous if more than one conclusion follows from appraisal premises. For example, suppose the appraiser values the same property at 6.300.000 lira per hectare to buyer A and 10.000.000 lira per hectare to buyer B. Because, under the given valuation premises, there is only one market value, the conclusion of more than one value from the same set of premises leads to an ambiguous conclusion. *Appraisals based on Prolog avoid ambiguity.*
3. Misleading conclusions. Consider the man who boasted that, «at the party, all the girls kissed me». In fact, however, there were no girls at the party. The statement is misleading. Likewise, consider the appraiser who states that, in general, land sells for 7.000.000 lira per hectare in the Ronciglione Comune. If, in fact, no land sold for more than 2.000.000 lira per hectare, the conclusion is misleading. *Appraisals based on Prolog avoid misleading conclusions.*
4. Overextension of data. The valuation conclusion would be overextended if conclusions are unwarranted based on the available appraisal data. For instance, suppose the appraiser has evidence showing that a building of 300 square meters has a value of 585,000 lira per square meter. It does not follow, however, that a building of 1,000 square meters would have the same per unit value of 585,000 lira. By applying the per unit value of a 300 square meter building to the 1,000 square meter building, the appraiser has overextended the data. *Appraisals based on Prolog avoid the overextension of data.*
5. Non sequitur errors. Suppose the appraiser has determined that olive orchards are bought and sold on the basis of a six percent capitalization rate. However, it does not follow that a fish farm, to cite an extreme example, would be appraised according to a six percent capitalization rate. That is, it does not necessarily follow that because buyers and sellers accept a six percent rate of return for olive orchards that the same rate of return would be acceptable for a fish farm. *Appraisals based on Prolog avoid non sequitur errors.*
6. Nonrepresentation errors. These errors typically occur in valuing property bv sale comparisons. For example, the database

([4]) Colmerauer, A. (1975) *Les Grammaires de Metamorphose*, internal report, Groupe d'Intelligence Artificielle, Univ. d'Aix-Marseille, Luminy, France.

([5]) For an explanation of mathematical logic, see Elliott Mendelson, *Introduction to Mathematical Logic*, 3rd edition (Monterey, California: Wadsworth & Brooks/Cole Advanced Books & Software, 1987).

may show that filbert orchards with trees less than *eight years old* generally sell for 5.000.000 lira per hectare. Such data would obviously be nonrepresentative of the value of a filbert orchard with 25 *year-old* trees. Such sales data used to draw such a valuation conclusion are nonrepresentative. *Appraisals based on Prolog avoid nonrepresentation errors.*

With these qualifications, it is then deemed appropriate to illustrate the valuation of vacant land by artificial intelligence and then consider an extension of this technique to value water rights (6).

Valuation by programming logic: a case study

The valuation of land by artificial intelligence was tested by listing a database covering 297 land sales in the commune of Ronciglione, Lazio Province, completed from 1976 to 1986. For each transaction, the following data were recorded:

Sales price
Square meters
Distance in meters from the nearest village
Land type by 5 categories
The cadastral value
Land use
The tax per hectare
Owner operated (yes or no)
Buyer operated (yes or no)

The land use was coded according to five values, O - poor land, 1 - dry land for farming, 2 - vacant land, 3 - newly- planted fruits, 4 - filbert trees (7). The market value was based upon the rule according to the formula below:

$$MV = \left[\frac{1}{n}\sum_{i=1}^{n} \times 1\right] \text{ [metri quadri]}$$

where:
MV = market value
n = number of cases which have same variable characteristics
x = unit land prices that have the same variable characteristics.

The valuation rule indicates that market value is calculated by the average unit price of land which has the same characteristics as the property appraised. Two models were constructed, one based upon the *mean value*, as above, and another model based on the *median value*. Because of the small number of cases, the median value model produced the most valid results (8).

To apply this model, given the database, the appraiser must make the following inputs on inquiry by the computer.

Land area, square meters: 1,000
Distance from village: 5,500 (meters)
Land type: 1 (poor land)
Land use: 5 (filbert trees)
Year of sale: 1985
District number: 24

The program output prints the estimated market value per hectare. The computer output would then read:

The average unit price is 0.52309686667 (lira per square meter)
Market Value is 523.09686667 (lira)

Note that the model does not make adjustments for time. If the appraiser enters the year as 1985, the appraisal will be based on sales prices for the year 1985. The next step would be to incorporate a rule showing how past values indicate current values. This would require the adoption of a rule based on a coefficient that shows how values have varied from some base year. A simple regression routine could also indicate how values have changed from 1976 to the current year. The present model value does not have an adjustment for time.

The model demonstrates that for any combination of the six characteristics entered, the model calculates the median or mean value per hectare to derive the estimated market value. That is, the appraiser has adopted the rule that given a common set of land characteristics, land value follows from the median (or mean) value per hectare for the set of sales showing similar characteristics. While the present example is limited to 297 cases and a limited number of variables, extension of the database beyond these limits would be quite feasible.

Conclusion

First, can market value be estimated by artificial intelligence (Prolog)? Probably. Accurate land valuation requires a detailed database of real estate sales listing characteristics significant to land value. As a minimum, it is suggested that the database for agricultural property include:

Sale price; Date of sale; Location; Province; Comune; District; Distance to: limited access highways, cities or villages, other; Main land use by hectares; Land productivity rating; Topography; Main crops by hectares; Soil types by hectares; Farm dwellings by quality ratings; Farm buildings by quality ratings; Crop yields, by category; Cadastral taxes; Type of orchards by age of trees; Availability of stock water, quality ratings; Other relevant characteristics.

Care must be taken to omit factors irrelevant to determining price as considered by buyers and sellers. Only transactions between private buyers and sellers negotiating freely in the market would be considered. Sales that deviate markedly from a «typical» sale would be omitted from the database.

Secondly, artificial intelligence would seem to have application to income properties. In Part 1, the valuation of water rights was calculated by capitalizing net income. Certainly, artificial intelligence could be used to value the same property given the database of 147 records of profit and loss statements, balance sheets and other financial reports on record in the state of New Hampshire. In this case, the database would consist of financial data for each of the 147 companies. The appraiser would then adopt rules indicating the relationship between financial characteristics and market value. Again, the valuation would follow from a listing of relevant database characteristics and the appropriate valuation rules leading to the market value estimate.

The conclusion follows, therefore, that artificial intelligence has direct application to market value estimates. Suppose, however, that data deficiencies prevent a matching of a given set of data characteristics for property appraised to the database. That is, it may be that the characteristics of the property valued are unique or that the database is inadequate to show that no valuation solution would be possible under the adopted rules. How would artificial routines perform under these circumstances?

The answer is that artificial intelligence routines allow the automatic revision of appraisal rules. If the artificial intelligence model fails because no solution is possible, programs may allow for rule changes.

This is the same problem faced by appraisers valuing a unique property where market data are highly imperfect. Given market data imperfections, the appraiser still estimates market value based upon the most reasonable, logical proposition. The same reasoning could be incorporated into artificial intelligence models.

The present demonstration model, limited as it is, demonstrates the feasibility of developing appraisal databases and quantifying appraisal rules in the interest of appraisal accuracy. Thus, it may be concluded that *water rights, land values, income property* and *farms* may be appraised by artificial intelligence. Such appraisal routines conform to what Medici calls a logical proposition. In the last analysis, artificial intelligence helps appraisers pursue the appraisal objective: to estimate the market value, nothing more than the market value, and nothing less than the market value. ●

(6) A distinction should be made between valuation by multiple regression techniques and by Prolog or predicate logic. Under multiple regression techniques, value is determined by the *statistical* association between sale price and selected property characteristics. Valuation accuracy depends on favorable diagnostic statistics showing the degree of statistical association Prolog, in contrast, gives values based on logical rules as determined by the appraiser. While no statistical relationship is required, the value conclusion must follow acceptable rules of logic.
A comparison of both valuation techniques for the same data set, is the subject of a joint paper by the author and Professor Lorenzo Venzi University of Tuscia, Viterbo, Italy. At this point, the authors favour artificial intelligence over multiple regression.

(7) The database was developed by student assistant, University of Tuscia, under supervision of Professor Lorenzo Venzi.

(8) The preliminary Prolog program, «LandPro» was written by Yeong Gon Kim, a Ph.D. candidate, University of Georgia, under supervision of Dr. William M. Shenkel.

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