The Aristotle Index:
Measuring Complexity in the Twenty-First Century

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As is well-known, Aristotle introduced inference into the history of human thought through the syllogism: a three-statement sequence, where a conclusion is drawn from two prior statements.

More than 1400 years after Aristotle, Abèlard was able to replace the three-statement sequence with a single statement, expressed in terms of antecedent and consequent, laying a linguistic basis for the application of George Boole's algebra, which would appear over 700 years later.

While Boole's algebra provided a symbolic base for expressing inference on a much broader scale than that given by Aristotle, it drew very little support in terms of practical applications because its linguistic appeal was very limited. In the same time period, Augustus De Morgan discovered and published the theory of relations, which laid a conceptual basis for creating very large structures of relationship, but this theory also drew very little support in terms of practical applications, for the same reason.

More than a hundred years after Boole and De Morgan, the graph theorist, Frank Harary, discovered a Boolean reachability matrix and an equation that encapsulated the combined essences of the work of Aristotle, Abèlard, Boole, and De Morgan, taking advantage of the matrix theory of Arthur Cayley, adapted to Boolean algebra.

With the benefit of Harary's apparatus, I developed a process called "Interpretive Structural Modeling", shortened to "ISM". With the ISM process, it became possible for groups of people to engage together with a computer to construct patterns of interaction among sets of problems.

These patterns of interaction came to be labeled "problematiques". This nomenclature fits very well into the concept promoted by Michel Foucault, who expressed the point of view that history ought to be written as a compound of the recordables of the time, together with an analyst's perspective on the problematique that the actors were striving to resolve by whatever historical events they undertook to precipitate. The first table to be shown summarizes this history

Bringing history into immediacy, groups have been applying ISM to problematic situations of substantial variety since about 1974 when ISM was first announced. The second table to be shown illustrates several examples of these situations and anticipates the values of their Aristotle Indexes.

Recently it has been discovered that a measure of complexity called the "Aristotle Index" can be computed by combinatorial analysis of a problematique. This enables different situations to be compared based on the relative size of the Index. When problematiques are applied to gain insights into system designs, it has been found that designs having lower values of Aristotle Index tend to be preferable to those with higher values. Thus concepts that are well over 2000 years old, once again provide insights into issues of importance today.

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Summary Table of Historical Background

APPROXIMATE TIME PERIOD	PERSON(S)	EVENT
350 B. C.	Aristotle	Created the syllogism: formalizing inference: requiring 3 statements
1100 A. D.	Abelard	Replaced the syllogism with a single statement: antecedent, consequent, and reference
1700 A. D.	Leibniz	Used circles to represent logic statements, and overlapping to represent partial joint inclusion (preceding Euler and Venn)
1847 A. D.	Boole	Published the algebra of propositions, allowing statements to be represented by symbols
1847 A. D.	De Morgan	Published the theory of relations, allowing relations to be represented by symbols; recognized the restriction of the syllogism to transitive relationships
1875 A. D.	Cayley	Developed matrices, expanding the symbolic dimensionality and mathematical manipulation of representations
1965 A. D.	Harary	Integrated the work of Cayley, De Morgan, and Boole and transformed the integrative results into a theory of digraphs, showing the graphical representation of transitive relations, and the necessary and sufficient conditions that a relationship be consistent
1974 A. D.	Warfield	Used Harary's analysis to develop Interpretive Structural Modeling (ISM), a computer-assisted method for groups to construct structural models of problematic situations (situations involving complexity)
1983 A. D.	Foucault	Gave the name "problematique" to the description of the problematic situation, where a set of linked problems describes the situation
1980 A. D. -present	many groups	Constructed problematiques for their situations
2002 A. D.	Warfield	Published a book[1] containing many examples of problematiques contributed by various individuals This book introduced the *Aristotle Index*.

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[1] John N. Warfield (2002), *Understanding Complexity: Thought and Behavior*, Palm Harbor, FL: Ajar.

TABULATED VALUES OF ARISTOTLE INDEX RANKED FOR VARIOUS SITUATIONS

SITUATION	VALUE
Cyprus Reconciliation between Greek and Turkish Cypriots	774
Effective Communication in Problem-Solving Groups-Type 1	123
Categorization in U. S. Defense Acquisition	113
The Decline in Membership in the Church of England	97
Ford Motor Co. computerized powertrain design-Type 1	97
Quality Control in John Deere Pump Manufacturing	87
Ford Motor Co. computerized powertrain design-Type 2	81
Ford Motor Co. Manual transmission design	26
Teaching fractions to second-grade students in Japan	18
Gender issues	16
Effective Communication in Problem-Solving Groups-Type 2	8
Improving competitiveness, state of Nuevo Leon, MX-Type 2	7

NOTE: Values for Type 2 problematiques are normally much smaller than for Type 1 problematiques, because the Type 2 are structuring categories only and, as the saying goes, "the devil is in the details". There is no firm rule, however, for as the Ford power train experience shows, the Type 2 index is almost as large as the Type 1 index. This is readily explained in the book[2] where the two problematiques are compared.

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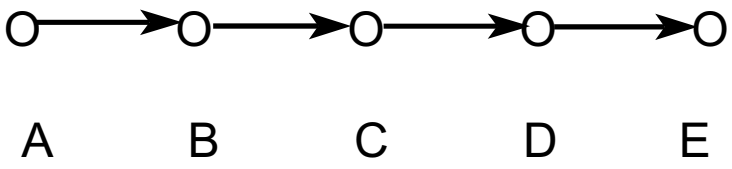
[2] John N. Warfield (2002), *Understanding Complexity: Thought and Behavior*, Palm Harbor, FL: Ajar.

THE ARISTOTLE INDEX IS A PROPERTY OF A STRUCTURE

TO COMPUTE IT, WE FIRST COUNT THE NUMBER OF SYLLOGISMS ON THE STRUCTURE, AND THEN DIVIDE BY TEN.

THE FOLLOWING STRUCTURE IS THE REFERENCE STRUCTURE.

ITS ARISTOTLE INDEX IS 1.0.



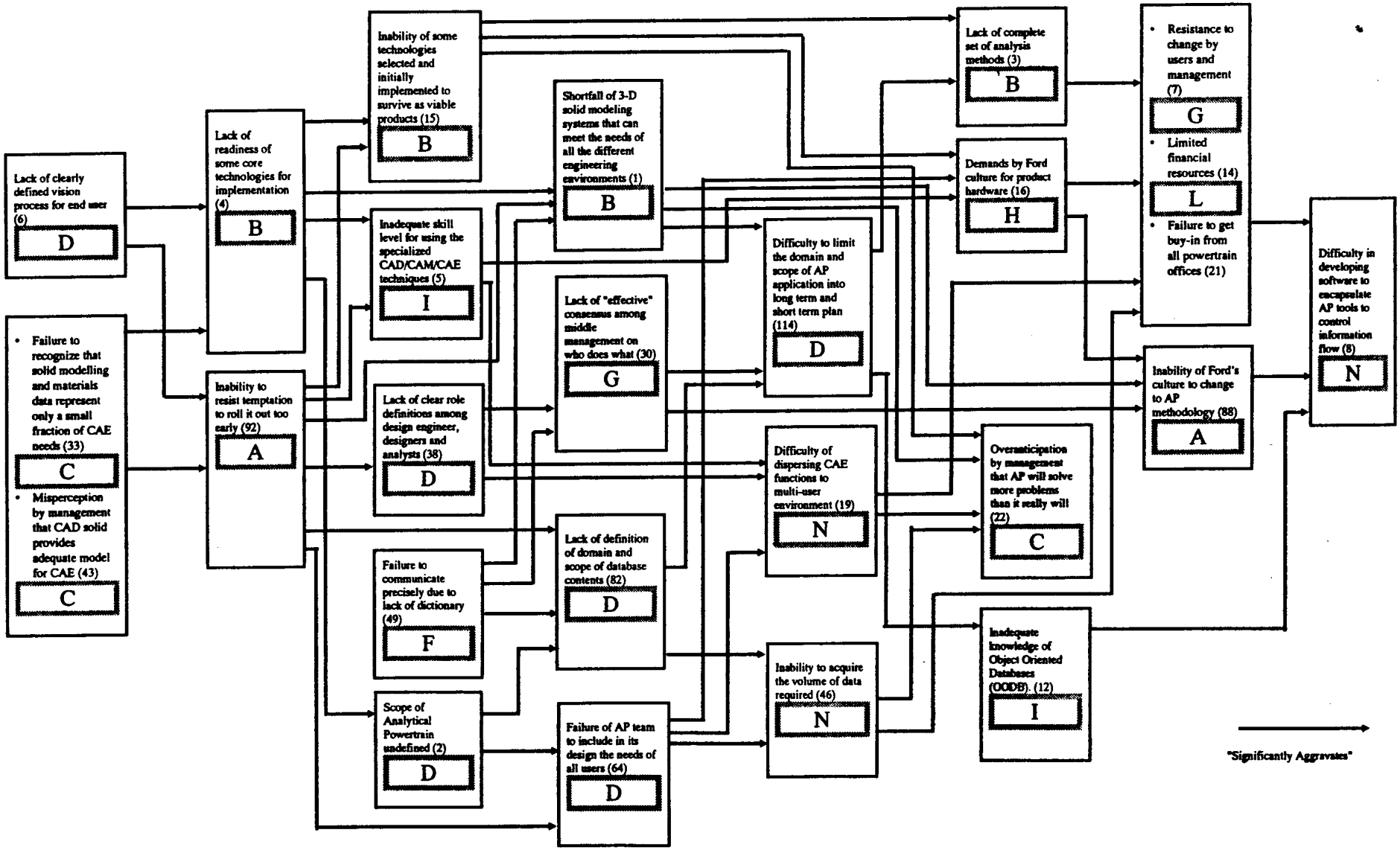
The syllogistic patterns are:

A,B,C A,B,D A,B,E A,C,D A,C,E

A,D,E B,C,D B,C,E B,D,E C,D,E

so, with 10 syllogisms represented here, dividing by 10 we get the Aristotle Index to be 1. This corresponds roughly to the limit of human interpretation of the contents of a problematique with one relationship and five problems being linearly related by that relationship.

Fig. D-4 Problematique for Developing and Implementing Analytical Powertrain (with Categories)apt1is2.chp



EXAMPLE: ONE GRAPHICAL SYLLOGISM ON A PROBLEMATIQUE

Problem 6 aggravates Problem 4. Problem 4 aggravates Problem 15. Problem 6 aggravates Problem 15 (via Problem 4). Also a problem in Category D aggravates a problem in Category B, which aggravates a problem in Category I.