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# How can OR/MS Educators Benefit From Creating and Using Taxonomies?

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## Abstract

After listing various approaches used over the years to teach OR/MS and quantitative methods and showing sample references for each, this paper suggests that taxonomies, combined with any other approach, can uniquely serve an important educational objective - showing the overall picture of the subject matter. The paper argues for using taxonomies in basic courses and in graduate education as they provide a framework in which the material to be taught, reviewed, or researched can be organized. When made explicit, the framework helps students organize knowledge gained in their own minds. Productivity Analysis (PA) is used to illustrate a taxonomy's educational potential. Lastly, for those interested in so enhancing their approach to teaching, a bibliography of publicly available taxonomies for various theoretic and applied OR/MS sub-disciplines is provided.

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## 1. Introduction

In the beginning, the first formal educational program in Operations Research was inaugurated at the Naval Post Graduate School in 1951. It was taught by modeling real-world military operations "using the only text available - a declassified 1946 document by Morse and Kimball (1951)" (Schrady, 2001).

Over time at the introductory levels, we taught OR/MS, decision sciences and quantitative methods via *models*, we have used *case studies*, Bodily (1996); *problem-based learning* Boyle (1999); *cooperative learning* Magel (1998); *team learning*, Koppenhaver and Shrader (2003); *thematic assignments*, Grinde and Kammermeyer (2003); *expert systems* and *artificial intelligence* as learning tools Moore (1996) and Meyer, et al, (1999), Lester, et al (1997); *spreadsheets*, Plane (1994), Evans (2000), Winston (1996), Bell (2000); other *packaged software* such as SIMLIB, Huffman, J.B. (2001); *Web based simulation* Dessouky, et al (2001); *interactive tutorials* Aberson et al, (2002); *virtual factories* Dessouky, et al, (1998); *games and puzzles* Sniedovich, M. (2002); *computer aided games* Reisman et al, (1977, 1980); *industry-specific service-learning projects* and *critical thinking exercises* Cox, and Bobrowski (2003); *questioning strategies* Nadler and Chandon (2003); *analogies* Martin, (2003). We incorporated *laboratory experiments* in undergraduate courses Martinez-Dawson, (2003); the *Ideals* approach to problem solving had been used for decades at both undergraduate and graduate levels by Nadler (1973) and with various degrees of success many of us have been involved in *team teaching* at one time or another.

Moreover we have used the *constructionist* approach in optimization type modeling and the *reductionist* approach in teaching regression and other statistical tools Lazaridis (1999).

We have tried using various combinations of the above approaches including, but certainly not limited to, incorporating *spreadsheets* into a *case-based* (MBA) quantitative methods as in Carraway, and Clyman (2000); *modeling and puzzles* as in Chlond and Toase (2002); and *spreadsheets, cases and project work* as in an OR capstone course, Armacost and Lowe (2003) and have offered *teaching management science summer faculty workshops*, in which many of the above teaching methods presumably were discussed Grossman (2001).

All of these approaches to teaching OR/MS when used individually or in any combination have their virtues and their own unique shortcomings. None however provides the novice a global perspective on the subject discussed - often not even a clue. A good taxonomy(1) does precisely that and based on the author's own experience(2) does not take much class-time. away from what the instructor wants or is curriculum-bound to teach Reisman (2004), irrespective of whether the subject being taught involves a theoretic domain e.g., queuing or inventory theory or an application area e.g., human resources planning. No matter which aspect of OR/MS is involved, taxonomies allow one to see and to show the big picture very effectively and very efficiently. They can be used to provide a framework in which the material to be taught can be organized. The framework, if made explicit to the students, helps them organize the material in their own minds, Liebman (1998), West, et al., (1991). Significantly, taxonomies can help in curriculum planning. However, when so used there is a significant danger that professors will try to cram all possible material into a single course. Information overload is a common problem in university courses and is detrimental to student learning. Perhaps for course planning purposes, there should be an added attribute of importance; that is, elements of the taxonomy could be color-coded to represent levels of importance with respect to the levels of the students and the purpose of the course.

## 2. Illustrative example:

With outsourcing being a major practice in all sectors (including government) of developed economies, productivity is becoming a major strategic or policy issue in the Century-XXI global economy. At the same time there are many calls for the OR/MS education and research community to increase its relevance to the real world(3) In industry, commerce, the non governmental organizations (NGOs) and the public sectors, usage of the subject matter currently dominating OR/MS education, e.g., optimization, simulation, decision analysis, or project management, etc., are but a few of the means to the end of improving productivity. So, let us imagine that we were given the challenge to design a unique course, curriculum or program dealing *comprehensively* with PA. A number of questions would surface immediately. One might be what topics should be included? This might lead to the question of what is the scope of PA? Which in turn might lead to who is involved in PA? Is it just managers? Clearly not! Engineers, economists, accountants, social scientists, policy formulators, and others have an interest in PA. Do they have differing approaches to PA? You bet they do. Is PA concerned with efficiency? It is to some. What about others? Well, they worry about issues of effectiveness. Does efficiency mean technical efficiency? It does for some. What about others? Some are concerned with allocative efficiency, others with economic (cost) efficiency. Is PA performed on the individual worker, shop-floor, company/institution, industry, sector, or cross sector levels? All of the above. Are PA measures absolute or relative? Yes and Yes. Are they objective or subjective? Yes and Yes. Are they theoretical or empirical? Yes and Yes. Unidimensional or multidimensional? Yes and Yes. Ratios, indices, econometric models, data envelopment analysis or stochastic frontier approaches? All of the above.

At this point we might realize that more heads are better then one or two; so a panel or group of knowledgeable people might be organized and called in to participate in a *brainstorming* session. This session might result in a number of ideas which when analyzed can be organized into a taxonomy. And so it came about that Figure 1 was created(4).

(1) See Reisman (1992) for a more general discussion of the usefulness of taxonomies.

(2) The author has used taxonomies in his teaching starting with the (1962) publication of the Reisman and Buffa article. Over the years this approach was incorporated into teaching MBA quantitative methods and systems analysis courses, undergraduate courses in managerial and engineering economics as well as research methods seminars for PhD students in operations research and in industrial engineering. The introduction and discussion of a taxonomy and its usefulness in any given course typically does not take up more than four hours of lecture time. At best, it should be introduced early in the course so that the students have a context for all that follows. Moreover when introducing a significantly new or major topic the instructor should reinforce the context by referring to the taxonomy presented.

(3) Hall, and Hess (1978); Horner, (2003); Blumstein (1987); Abbott, (1988); Corbett, and Van Wassenhove (1993); Cooper and McAllister (1999); Grossman, (2001); Geoffrion, (1992); Pierskalla, (1987); Powell, (1998); White (1991). And, there are many more.

(4) Figure 1 resulted from an impromptu brainstorming session at the end of a faculty seminar on meta research conducted by this author at the Industrial Engineering and Management faculty, Istanbul Technical University, during the 2002-2003 academic year. Said Gattoufi contributed to its refinement. For a taxonomically formatted pros-and-cons discussion of state-of-the-art productivity measurement research, see Singh et al, (2000)

**A TAXONOMY FOR PRODUCTIVITY ANALYSIS**

1. Productivity Analysis
    1.1. Effectiveness Analysis
        1.1.1. Cost/Effectiveness
        1.1.2. Cost /Benefit
    1.2. Efficiency Analysis
        1.2.1. Technical Efficiency
        1.2.2. Allocative Efficiency
        1.2.3. Economic (Cost) Efficiency

2. Relativity of Measurement
    2.1. Absolute Measures
    2.2. Relative Measures

3. Objectivity of the Productivity Analysis
    3.1. Subjective
        3.1.1. Individual
            3.1.1.1. Expert
            3.1.1.2. Non expert
        3.1.2. Group
            3.1.2.1. Experts
            3.1.2.2. Non experts
            3.1.2.3. Both
    3.2. Objective

4. Organizational Level for the Analysis
    4.1. Unit level
        4.1.1. Individual
        4.1.2. As part of an Organization
        4.1.3. As part of a Sector
        4.1.4. As Part of a Cross-Sectoral grouping
    4.2. Organization Level
        4.2.1. As part of an Organization
        4.2.2. As part of a Sector
        4.2.3. As Part of a Cross-Sectoral grouping
    4.3. Sector Level
        4.3.1. Individual
        4.3.2. As Part of a Cross-Sectoral grouping
        4.3.3. Cross Sector Level
    4.4. Nation
    4.5. Cross-nation

5. Domain
    5.1. Engineering
        5.1.1. Design
        5.1.2. Production
        5.1.3. Operations
    5.2. Management
        5.2.1. Finance
        5.2.2. Marketing
        5.2.3. Human resources
    5.3. Economics
        5.3.1. Macroeconomics
        5.3.2. Microeconomics
    5.4. Political Science
    5.5. Anthropology
        5.5.1. Social
        5.5.2. Cultural

6. Models
    6.1. Econometric, or parametric
    6.2. Nonparametric
    6.3. Single input – Single output
    6.4. Multi input – Multi output
    6.5. Single period
    6.6. Multi period
    6.7. Deterministic
    6.8. Stochastic
        6.8.1 Stationary
        6.8.2 Non-stationary

*Figure 1:*

With a draft taxonomy in hand the next step is its validation. In the words of Vogel and Weterbe (1984):

> **The key to taxonomy effectiveness rests on criteria of comprehensiveness, parsimony and usefulness. Obviously, to be effective, a taxonomy must represent the full spectrum of the research [subject domain] chosen for categorization. Thus, comprehensiveness is a necessary condition for effectiveness. It is, however, not sufficient. To further be effective, a taxonomy should be parsimonious. It should not include unnecessary categories. Finally, to be considered effective, the taxonomy should be robust and generally useful. The categories should be reasonably if not mutually exclusive, i.e., non-overlapping, reasonably distinct, meaningful, commonplace, and descriptive to allow utilization by a wide variety of interested persons.**

Next, does the "taxonomy represent the full spectrum of the research or subject domain chosen for categorization"? To answer this question it is necessary to seek out a number of very diverse papers from the open literature of the field and apply the classification procedure(5). This will either validate the taxonomy's comprehensiveness as well as its parsimony or indicate a need for some modification. This may involve adding attributes and/or combining some existing ones.

After a few such iterations the taxonomy is ready to go - at least it is for the a-priori assumed boundaries of the field's domain.

Having a satisfactory taxonomy allows one to return to the design of a curriculum for the intended unique course, or program dealing *comprehensively* with PA. The taxonomy of Figure 1 gives us the blue print or the specs for topics to be covered. Conversely, any existing program of study can be evaluated for comprehensiveness of its PA-specific content coverage using the taxonomy of Figure 1.

If a comprehensive textbook or even an encyclopedia on PA is to be written, then the taxonomy of Figure 1 delineates the topics to be covered.

If a doctoral student is to be examined for his or her knowledge of PA, then the taxonomy of Figure 1 gives the student a context of what to prepare for and the examiner a menu of leads to be pursued.

When the above doctoral student does a comprehensive literature review of PA literature for his dissertation, then the taxonomy of Figure 1 gives us the blue print or the specs for topics to be covered as had been done in a number of PhD dissertations, most recently

(5) In some areas of OR/MS it is possible to find pre-existing taxonomies. These often are fairly coarse in granularity or concern only a subset of the domain being addressed. By all means they should be used in making make sure that the newly established framework is robust enough to subsume each and all. Such was indeed the case in validating the taxonomies of Reisman (2004), Reisman et al., (2003) and Capari et al (2004)

by Dr. Gattoufi in *Data Envelopment Analysis* (DEA). The result apart from his technical contribution, has been no fewer then four published papers, Gattoufi et al, (2004a, 2004b, 2004c, and 2004d).

When the same doctoral student wants to find a research topic in PA for his or her dissertation, a comprehensive literature search and classification of the extant papers based on the taxonomy of Figure 1 will identify voids in the literature and hence, potential topics to work on, Reisman (1988, 1989, and 1992). It is worth reinforcing the fact that a topic so identified is easier to defend as a contribution.

At the graduate level, literature reviews are playing an increasingly important role in social and therefore OR/MS scientists' definition of knowledge (Cooper, 1988, 1998). "Integrative reviews are clearly the most useful reviews as they show the similarities and the differences between the individual contributions" (Cooper, 1984) and if based on a taxonomic framework they can be used to identify voids in the domain of knowledge under consideration (Reisman, 1988, 1989, and 1992).

For example, in an integrative literature review it may be noted that a DEA based model allowing for "data uncertainty" (as recent extensions do) applied to a bank's branches to study human resources' utilization at any point in time (single period), would be classified using the Figure 1, taxonomy as: **1.2.2/2.2/3.2/4.1.2/5.2.3/ 6.2/6.4/6.5/6.8.1** However when the very same model is applied to compare human resources' utilization in all private versus all state owned commercial banks in a given country it is then classified as: **1.2.2/2.2/3.2/4.1.3, 4.4/5.2.3/ 6.2/6.4/6.8.1** If applied to a cross-country analysis of commercial **4.5** merely replaces the **4.4** part of the code designation. No taxonomy dealing only with PA models would pick up such major differences in application.

On the other hand, when the same real-world situations are addressed using models of parametric statistics **6.2** will be replaced by **6.1** and **2.1** will typically replace the **2.2** in the above classifications.

This way of classifying extant literature in any give OR/MS subject area is computer friendly. This allows for quickly culling out any desired subset of the literature and as is shown in Reisman et al, (2003) in many ways is superior to relying on *key words*.

Taxonomies for OR/MS subject matter can take on alternative formats. This is discussed in Reisman (1992) and can be seen by perusing the publicly available taxonomies listed in the Appendix. However, the format adopted for Figure 1, lends itself to being transformed into rows of a table where the columns can take on various attributes. These attributes could represent the importance of the row-item to some prespecified course or curriculum. A column may be dedicated to citing seminal contributions/papers; the most recent contributions; the off-the-shelf software that can best handle the model/methodology so identified; Websites dedicated to the subject matter such as the UK based (DEA Website[(6)]) is for *DEA* ; research networks such as *PARN*, the Danish based (moa@sam.sdu.dk) worldwide research network is for *Productivity Analysis* ; business cases; or real-world applications involving the row methodology. Clearly, the latter can be subdivided into applications within the public versus the private sector and, the private sector may in turn, be subdivided into manufacturing versus services and so on. It may specify the number of teaching hours to be dedicated, or the lecture dates, for the subject. In a team-taught course it may specify the lead teacher for each segment. Similarly, in a graduate seminar it may specify the name of the participant who will lead the discussion. It may reflect an evaluation of the adequacy of coverage in the existing literature or anything else that is dictated by a specific need.

For illustrative and any other purposes the reader may have, Figure 1, was entered into a spreadsheet (Figure 1.xls[(7)]). The *importance* of each row's subject to each of two types of courses e.g., an undergraduate business course and a *Graduate OR course in Productivity Analysis* was color-coded6. Clearly, the prioritization shown reflects this author's opinion and should not be otherwise considered.

No taxonomy, no matter how well conceived, should ever be considered as final. Rather, it should be thought of as a stepping-stone to more comprehensive, more discriminating, more parsimonious, and/or more

(6) http://www.deazone.com
(7) http://ite.pubs.informs.org/Vol4No3/Reisman/Figure1.xls

manageable classifications of the subject. It should not be treated as binding or constraining the definition and/or scope of the field of knowledge it addresses. As the subject emerges, either in depth or in breadth, the taxonomic work must follow. In the best of circumstances taxonomies lead to such expansions and/or extensions. There is no better example of the above admonitions than the *Periodic Table of Chemical Elements*, Mendeleyev (1889). It has no equal as an aid to educating neophytes yet it has guided chemical research for well over a century. However, at various developmental stages in chemistry the Table had to be reviewed and revised. This process, it is safe to say, is still ongoing. So it is and should be for any domain of knowledge circumscribed by a given taxonomy.

## 3. Concluding remarks:

In a call for shifting the established OR/MS paradigm, Thom Saaty (1998) raised the issue of creativity as "a pressing need" by saying:

> **"[W]e are better at *deductive* "creativity," by which I mean the ability to face a new application instance to which we might bring to bear past knowledge of similar situations. What I am calling for is *inductive* creativity, which looks at all experience and attempts to induce from it a description of the larger system from which the problem instances flow."**

Creating taxonomies requires inductive creativity. Once created, a taxonomy provides a description of the "larger system" referred to above. Not many OR/MS courses provide students the "inductive creativity" experience called for by Saaty. Involving students in creating and validating a taxonomy for some subject of concern to OR/MS might provide a means to that end.

Most instructors use very crude7 taxonomies like linear vs. nonlinear, deterministic vs. stochastic, hard vs. soft problem or data, single facility vs. multiple facility, discrete vs. continuous, deterministic vs. stochastic, single vs. multiple objectives etc. The only taxonomy accepted more or less universally is the (Kendall notation)8 queueing taxonomy.

Lastly, advantages of using taxonomies in the teaching of OR/MS and quantitative methods are generic even though this paper based most of its arguments on a productivity analysis example. The *Appendix* lists several publicly available taxonomies for various theoretic and applied areas of OR/MS. Try using one or two in your teaching, in your research, or in proposal writing. You may even wish to create one to serve your needs. Best wishes. If you have any questions send a quick message to: Reismana@cs.com. Alternatively, you may wish to enrich this paper by citing additional methodologies used to teach OR/MS, or suggest other publicly available taxonomies. Do not hesitate to send me such inputs.

## References

Abbott, A., (1988), *The System of Professions: An Essay on the Expert Division of Labor*, University of Chicago Press, Chicago, IL.

Aberson, C. L., D.E. Berger, M. R. Healy, and V. L. Romero (2002), "An Interactive Tutorial for Teaching Statistical Power," *Journal of Statistics Education*, Vol. 10, No. 3, http://www.amstat.org/publications/jse/v10n3/aberson.html

Armacost, A. P. and J. K. Lowe (2003), "Operations Research Capstone Course: A Project-Based Process of Discovery and Application," *INFORMS Transactions on Education*, Vol. 3, No. 2, http://ite.pubs.informs.org/Vol3No2/Armacost-Lowe/index.php

Bell, P.C. (2000), "Teaching Business Statistics with Microsoft Excel," *INFORMS Transactions on Education*, Vol. 1, No. 1, http://ite.pubs.informs.org/Vol1No1/Bell/

Blumstein, A. (1987), "The current Missionary role of OR/MS," *Operations Research*, Vol. 35, No. 6, pp. 926-929.

Bodily, S.E. (1996), "Teaching MBA Quantitative Business Analysis with Cases," *Interfaces*, Vol. 26, No. 6, pp. 132-138.

Boyle, C.R. (1999), "A Problem-Based Learning Approach to Teaching Biostatistics," *Journal of Statistics Education*, Vol.7, No.1, http://www.amstat.org/publications/jse/secure/v7n1/boyle.cfm

Capari, I., F. Ulengin, and A. Reisman (2003), "A Taxonomy for Supply Chain Management Literature," A paper presented at the 10 th World Conference on Transport Research (*WCTRS* ) held July 4-8, 2004 in Istanbul. Submitted to

*JORS* Available from Reismana@cs.com and at: http://ssrn.com/abstract=531902 , http://ssrn.com/author=161264%20

Carraway, R. L. and D.R. Clyman (2000), "Integrating Spreadsheets into a Case-based MBA Quantitative Methods Course: Real Managers Make Real Decisions," *INFORMS Transactions on Education*, Vol. 1, No. 1, http://ite.pubs.informs.org/Vol1No1/Carraway/

Chlond, M. J. and C. M. Toase (2002), "IP Modeling of Chessboard Placements and Related Puzzles," *INFORMS Transactions on Education*, Vol. 2, No. 2, http://ite.pubs.informs.org/Vol2No2/Chlond-Toase/

Cooper, C.M. (1998), *Synthesizing research: A Guide for Literature Reviews*. SAGE Publications, London

Cooper, C.M. (1988), "Organizing Knowledge Syntheses: A Taxonomy of Literature Reviews," Knowledge in Society, Vol. 1, No. 1, pp. 104-126.

Cooper, C.M. (1984), *The Integrative Research Review: A Systematic Approach*, SAGE Publications, Beverly Hills, CA.

Cooper, W.W., L. McAllister (1999), "Can Research be Basic and Applied? You Bet It Better Be for B Schools," *Socio-Economic Planning Sciences*, Vol. 33, No. 4, pp. 257-276.

Corbett, C.J., L. N. Van Wassenhove (1993), "The Natural Drift: What Happened to Operations Research?," *Operations Research*, Vol.41, No.4 , pp. 625-640.

Cox, P. L. and P.E. Bobrowski (2003), "Critical Thinking Exercise: Causes of Premature Death in America," *The Decision Sciences Journal of Innovative Education*, Vol 1, No. 1, pp. 145-149.

Dessouky, M. M., D.E. Bailey, S. Verma, S. Adiga, G. E. Bekey, and E. J. Kazlauskas (1998), "A Virtual Factory Teaching System in Support of Manufacturing Education," *Journal of Engineering Education*, Vol. 87, No. 4, pp. 459-467.

Dessouky, M. M., S. Verma, D. Bailey, and J. Rickel (2001), "A Methodology for Developing a Web-based Factory Simulator for Manufacturing Education," *IIE Transactions*, Vol. 33, No. 3, pp. 167-180.

Evans, J.R. (2000), "Spreadsheets as a Tool for Teaching Simulation," *INFORMS Transactions on Education*, Vol. 1, No. 1, http://ite.pubs.informs.org/Vol1No1/Evans/

Gattoufi, S., M. Oral, and A. Reisman (2004a), "Data Envelopment Analysis Literature: A Bibliography Update (1996-2001)," *Socio-Economic Planning Sciences*, Vol. 38, No. 2-3, pp159-229. *Available online from* http://www.sciencedirect.com/science

Gattoufi, S., M. Oral, and A. Reisman (2004b), "A Taxonomy for Data Envelopment Analysis," *Socio-Economic Planning Sciences*, Vol. 38, No. 2-3, pp.141-158. *Available online from* http://www.sciencedirect.com/science

Gattoufi, S., M. Oral, A. Kumar, and A. Reisman (2004c),"Epistemology of Data Envelopment Analysis and Comparison with Other Fields of OR/MS for Relevance to Applications," *Socio-Economic Planning Sciences*, Vol. 38, No. 2-3, pp.123-140. *(Presented at the sixteenth triennial conference of the International Federation of Operational Research Societies, July, 8-12, 2002, Edinburgh UK). Available online 23 July 2003 from* http://www.sciencedirect.com/science%20

Gattoufi, S., Oral, M., and Reisman, A. (2004d) "Content Analysis of Data Envelopment Analysis Literature and Comparison with Other Fields of OR/MS for Relevance to Applications" Forthcoming in the *Journal of the Operational Research Society. Available on request from Reismana@cs.com*

Geoffrion, A. M.(1992), "Forces, Trends, and Opportunities in MS/OR," *Operations Research*, Vol. 40, No. 3, pp. 423-445.

Grinde R. B. and J.A. Kammermeyer (2003), "Experiences Using Thematic Assignments in an Undergraduate Management Science Course," *INFORMS Transactions on Education*, Vol. 4, No. 1, http://ite.pubs.informs.org/Vol4No1/GrindeKammermeyer/

Grossman, T.A., Jr. (2001), "Causes of the Decline of the Business School Management Science

Course," *INFORMS Transactions on Education*, Vol. 1, No. 2, http://ite.pubs.informs.org/Vol1No2/Grossman/Grossman.php

Hall, J.R. and S. W. Hess (1978), "OR/MS: Dead or dying? RX for survival," *Interfaces*, Vol. 8, No. 3, pp. 42-44.

Horner, P. (2003), "The Science of Better," *OR/MS Today*, Vol. 30, No. 6 http://www.lionhrtpub.com/orms/orms-12-03/frmarketing.html

Huffman, J.B. (2001), "An Object-Oriented Version of SIMLIB (a Simple Simulation Package)," *INFORMS Transactions on Education*, Vol. 2, No. 1, http://ite.pubs.informs.org/Vol2No1/Huffman/

Koppenhaver, G. D. and C. B. Shrader (2003), "Structuring the Classroom for Performance: Cooperative Learning with Instructor-Assigned Teams," *The Decision Sciences Journal of Innovative Education*, Vol. 1, No. 1, p. 1.

Lazaridis, E.N. (1999), "Constructionism and Reductionism: Two Approaches to Problem-Solving and Their Implications for Reform of Statistics and Mathematics Curricula," *Journal of Statistics Education*, Vol. 7, No. 2, http://www.amstat.org/publications/jse/secure/v7n2/lazaridis.cfm

Lester, J.C., S.A. Converse, B.A. Stone, S.E. Kahler, and S.T. Barlow (1997), "Animated Pedagogical Agents and Problem-Solving Effectiveness: A Large-Scale Empirical Evaluation," *Proceedings of the Eighth World Conference on Artificial Intelligence in Education*, pp. 23-30, IOS Press.

Liebman, J. (1998), "Teaching Operations Research: Lessons from Cognitive Psychology," *Interfaces*, Vol. 28, No.2, pp. 104-110.

Magel, R.C. (1998), "Using Cooperative Learning in a Large Introductory Statistics Class," *of Statistics Education*, Vol. 6, No. 3, http://www.amstat.org/publications/jse/v6n3/magel.html

Martin, M.A. (2003), "It's like... you know: The Use of Analogies and Heuristics in Teaching Introductory Statistical Methods," *Journal of Statistics Education*, Vol. 11, No. 2, http://www.amstat.org/publications/jse/v11n2/martin.html

Martinez-Dawson, R. (2003), "Incorporating Laboratory Experiments in an Introductory Statistics Course," *Journal of Statistics Education*, Vol. 11, No. 1, http://www.amstat.org/publications/jse/v11n1/martinez-dawson.html

Mendeleyev, D.I. (1889), "The periodic law of chemical elements (Faraday lectures)," *Journal of the Chemical Society*, Vol. 55, pp. 643-656.

Meyer, T.N., T.M. Miller, K. Steuck, and M. Kretschmer (1999), "A Multi-Year Large-Scale Field Study of a Learner Controlled Intelligent Tutoring System," *Proceedings of the Ninth International Conference on Artificial Intelligence in Education*, pp. 191-198, IOS Press.

Moore, J. D. (1996), "Making Computer Tutors More Like Humans," *Journal of Artificial Intelligence in Education*, Vol. 7, No. 2, pp. 181-214.

Morse, P. M. and G. E. Kimball (1951), *Methods of Operations Research*, MIT Press and John Wiley & Sons, NY.

Nadler G. (1973), *Production System D esign: With the IDEALS Concept*, Industrial and Commercial Techniques Ltd.

Nadler G. and W.J. Chandon (2003), *Ask the Right Questions: Creating Answers That Work*, Paperback

Pierskalla, W.P. (1987), "Creating Growth in OR/MS," *Operations Research*, Vol. 35, No. 1, pp. 153-156.

Plane, D. R. (1994), *Management Science: A Spreadsheet Approach*, Boyd & Fraser, Danvers, MA.

Powell, S. G. (1998), "Requiem for the Management Science Course?," *Interfaces*, Vol. 28, No. 2, pp. 111-17.

Reisman, A. (l988), "Finding Researchable Topics Via a Taxonomy of a Field of Knowledge," *Operations Research Letters*, Vol. 7, No.6, pp. 295-301.

Reisman, A. (1989), "A Systems Approach to Identifying Knowledge Voids in Problem Solving Disciplines and Professions: A Focus on the Management Sciences," *Knowledge in Society: The International Journal of Knowledge Transfer*, Vol. 1, No. 4, pp. 67-86.

Reisman, A. (1992), *Management Science Knowledge: It's Creation, Generalization and Consolidation*, Quorum Books Publishing Company, Westport, CT.

Reisman, A. (2004), "Transfer of Technologies: A Cross-disciplinary Taxonomy," An invited paper for presentation at the "Caucasus and Central Asia in the Globalization Process" International Conference Qafqaz University, May 12-13 2003, Baku-Azerbaijan. Forthcoming in *OMEGA: An International Journal of Management Science*.

Reisman, A., H. Emmons, S. Morito, J. Rivaud, A. Chaudhuri, E. Green (1977), "Dental Practice Management Game: A New Tool for Teaching Practice Management," *Journal of Dental Education*, Vol.41, No.5, pp.262-267.

Reisman, A., P. Frieder, L. Orfirer, E. Mulcahy, S. Morito, K. Mathur, S. Kulkarni (1980), "Computer-Aided Practice Management for the Medical Profession," *Proceedings of the International Conference Systems "Science and Health Care"*, Vol.2, 1981.

Reisman, A, B.C.Konduk, and M. Oral (2003), "A Taxonomy of Meta Research in OR/MS and Classification of the Literature". Working Paper. Available by request at reismana@cs.com

Reisman, A. and E. S. Buffa (1962), "A General Model for Investment Policy", *Management Science*, Vol.8, pp.304-310, April. Also, *Models for Production and Operations Management*, E.S. Buffa, Wiley, 1963, pp.402-416; and *Models and Analysis for Production Management*, M.P. Hottenstein, International Textbook Company, Scranton, PA., pp.53-60, 1968

Saaty, T. L. (1998), "Reflections and Projections on Creativity in Operations Research and Management Science: A pressing Need for a Shift in Paradigm," *Operations Research*, Vol. 46, No. 1, pp. 9-16.

Schrady, D.A. (2001), "Golden Anniversary: Fifty Years of Graduate Education in Operations Research at the Naval Postgraduate School," *OR/MS Today*, Vol. 28, No. 1. Also published in *Alumni @ NPS*, Alumni Relations Office, Naval Postgraduate School, Summer 2001.

Singh, H., J. Motwani, and A. Kumar (2000), "A Review and Analysis of the State-of-the-art Research on Productivity Measurement," *Industrial Management & Data Systems*, Vol. 100, No. 5, pp. 234-241.

Sniedovich, M. (2002), "OR/MS Games: 2. Tower of Hanoi," *INFORMS Transactions on Education*, Vol. 3, No. 1, http://ite.pubs.informs.org/Vol3No1/Sniedovich/

Vogel, D.R. and J.C. Weterbe (1984), "MIS Research: A Profile of Leading Journals and Universities," *Data Base*, Vol. 16, No. 1, pp. 3-14.

West, C. K., J.A. Farmer, P.M. Wolff (1991), *Instructional Design: Implications from Cognitive Science*, Allyn and Bacon, Boston, Massachusetts.

White J.A. (1991), "An existence theorem for OR/MS," *Operations Research*, Vol. 39, No. 2, pp. 183-193.

Winston, W. L. (1996), *Simulation Modeling Using @RISK*, Duxbury, Belmont, CA.

# Appendix

Balinsky W. and A. Reisman (1972), "Some Manpower Planning Models Based on Levels of Educational Attainment," *Management Science*, Application Series, Vol.18, No.12, pp.691-705.

Balinsky W. and A. Reisman (1973), "A Taxonomy of Manpower-Educational Planning Models," *Socio-Economic Planning Sciences*, Vol.7, pp.13-17.

Capari, I., F. Ulengin, and A. Reisman (2004), "A Taxonomy for Supply Chain Management Literature," Working Paper SUGSM-03-12, Sabanci University, Istanbul. Available at: http://ssrn.com/abstract=531902

WCooper, C.M. (1988), "Organizing Knowledge Syntheses: A Taxonomy of Literature Reviews," *Knowledge in Society*, Vol. 1, No. 1, pp. 104-126.

Erkut, E., S. Neuman (1989), "Analytical Models for Locating Undesirable Facilities," *European Journal of Operational Research*, Vol. 40, No. 3, pp. 275-291.

Escueta, E., K. Fiedler, A. Reisman (1986), "A New Hospital Foodservice Classification System," *Journal of Foodservice Systems*, Vol.4, No.2, pp.107-116.

Ganeshan R., E. Jack, M.J. Magazine, and P. Stephens (1998) "A Taxonomic Review of Supply Chain Management Research," *Quantitative Models for Supply Chain Management*, Chapter in book, Kluwer Academic Publishers.

Gattoufi, S., M. Oral, and A. Reisman (2004a), "Data Envelopment Analysis Literature: A Bibliography Update (1996-2001)," *Socio-Economic Planning Sciences*, Vol. 38, No. 2-3, pp.159-229. *Available online from* http://www.sciencedirect.com/science

Gattoufi, S., M. Oral, and A. Reisman (2004b), "A Taxonomy for Data Envelopment Analysis," *Socio-Economic Planning Sciences*, Vol. 38, No. 2-3, pp.141-158. *Available online from*

Gattoufi, S., M. Oral, A. Kumar, and A. Reisman (2004c), "Epistemology of Data Envelopment Analysis and Comparison with Other Fields of OR/MS for Relevance to Applications". Presented at the sixteenth triennial conference of the International Federation of Operational Research Societies, July, 8-12, 2002, Edinburgh UK. *Socio-Economic Planning Sciences*, Vol. 38, No. 2-3, pp. 123-140. *Available online 23 July 2003 from*
http://www.sciencedirect.com/science

Gattoufi, S., M. Oral, and A. Reisman (2004d), "Content Analysis of Data Envelopment Analysis Literature and Comparison with Other Fields of OR/MS for Relevance to Applications," Forthcoming in the *Journal of the Operational Research Society. Available on request from Reismana@cs.com*
http://www.sciencedirect.com/science

Harland, C.M., R. C. Lamming, J. Zheng, and T. E. Johnsen (2001), "A Taxonomy of Supply Networks," *Journal of Supply Chain Management*, Vol. 37, No. 4, pp.21-27.

Johnson M.E. and E. Whang (2003), "E-Business and Supply Chain Management: An Overview and Framework," *Production and Operations Management*, Vol. 11, No. 4, pp. 413-423.

Kehoe, D., N. Boughton (2001), "Internet Based Supply Chain Management: A Classification of Approaches to Manufacturing and Control," *Internet Journal of Oerations and Production Management*, Vol. 21, No. 4, p. 516.

Kumar, A., J. Motwani and A. Reisman (1996), "Transfer of Technologies: A Classification of Motivations," *The Journal of Technology Transfer*, Vol. 21, No 1-2, pp. 34-42.

Reisman A. (1971), *Managerial and Engineering Economics*, Allyn & Bacon Publishing Company of Boston, 530 pages

Reisman A. (1992), *Management Science Knowledge: It's Creation, Generalization and Consolidation*, Quorum Books Publishing Company, Westport, CT, 495 pages

Reisman, A. (1987), "Expansion of Knowledge via Consolidation of Knowledge," presented at the Second International Symposium on Methodologies for Intelligent Systems, Charlotte, N.C., October 14-18,. ISMIS-87 Proceedings, pp.159-172, ONR L -6417, Oak Ridge National Laboratory.

Reisman, A. and E.S. Buffa, (1964) "A General Model for Production and Operations Systems," *Management Science*, Vol. 1, No. 11, pp. 64-79. Also pp.53-77 in *Readings in Production and Operations Management*, edited by E.S. Buffa, John Wiley & Sons, Inc., New York

Reisman, A. (1966), "The Cost of Capital: A Reconciliation of Some Existing Theories Through Generalization," *Mississippi Valley Journal of Business and Economics*, Vol. 1, No.2, pp.67-82.

Reisman, A. (1968), "Unification of Engineering Economy: The Need and a Suggested Approach," *The Engineering Economist*, Vol.14, No.1, pp.1-24, Fall, and the American Society of Mechanical Engineers, ASME paper 68-WA/MGT-9.

Reisman, A. (1987), "Some Thoughts for Model Builders in the Management and Social Sciences," *Interfaces, An International Journal of the Institute of Management Sciences* and the Operations Research Society of America, Vol.17, No.5, pp.114-120.

Reisman, A. (1988), "Finding Researchable Topics via a Taxonomy of a Field of Knowledge," *Operations Research Letters*, Vol.7, No.6, pp. 295-301.

Reisman, A. (1988), "On Alternative Strategies for D oing Research in the Management and Social Sciences," *IEEE Transactions on Engineering Management*, Vol.35, No.4, pp.215-221.

Reisman, A. (1989), "Technology Transfer: A Taxonomic View," *Journal of Technology Transfer*, Vol.14, No.3-4, pp.31-36.

Reisman, A. (1989), "A System Approach to Identifying Knowledge Voids in Problem Solving Disciplines and Professions: A Focus on the Management Sciences," *Knowledge in Society*: An International Journal of Knowledge Transfer, Vol.1, No.4, pp.67-86.

Reisman, A. (1993), "Operations Management: Time for Meta Research," in Prospectives in Operations Management: Essays in Honor of Elwood S. Buffa, Kluwer Academic Publishers, Boston, MA, pp.471-482, January

Reisman, A. (1995), "OR/MS Education: A Need for Course Correction," The *International Journal of Operations and Quantitative Management*, Vol. 1, No. 1 pp. 67-76.

Reisman, A. (2004), "Transfer of Technologies: A Cross-disciplinary Taxonomy," An invited paper for presentation at the " Caucasus and Central Asia in the Globalization Process" International Conference Qafqaz University, May 12-13 2003, Baku-Azerbaijan Forthcoming in *OMEGA: An International Journal of Management Science*.

Reisman, A. and E.S. Buffa (1962), "A General Model for Investment Policy," *Management Science*, Vol.8, pp.304-310, April. Also, *Models for Production and Operations Management*, E.S. Buffa, Wiley, 1963, pp.402-416; and *Models and Analysis for Production Management*, M.P. Hottenstein, International Textbook Company, Scranton, PA., pp.53-60, 1968.

Reisman, A. and X. Xu (1994), "Operations Research in Libraries: A Review of 25 Years of Activity," *Operations Research*, Vol. 42, No, 1, pp. 34-40.

Reisman, A. and L. Zhao (1991), "A Taxonomy of Technology Transfer Transaction Types," *Journal of Technology Transfer*, Vol.16, No.2, pp.38-42.

Reisman, A., D.C. Fuh, G. Li (1988), "Achieving an Advantage with Countertrade," *Industrial Marketing Management*, Vol.17, No.1, pp.55-63.

Reisman, A. M. Oral, A. Kumar, B.C. Konduk (2003), "A Taxonomy of Meta Research In OR/MS and Classification of the Literature," Working Paper

Reisman, A., and X. Xu (1992), "On Stages of Knowledge Growth in the Management Sciences," *IEEE Transactions on Management*, Vol.39, No.2, pp.119-128.

Reisman, A., M.H. Song and F. Ikem (1991), "A Taxonomy of Manpower Forecasting and Planning," *Socio-Economic Planning Sciences*, Vol.25, No.3, pp.221-231.

Reisman, A. (1994), Operations Research in Libraries, *Encyclopedia of Operations Research*, Saul Gass and Carl Harris (eds.), Kluwer Publishers, Norwell, MA.

WReisman, A. (1994), "Creativity in MS/OR: Expanding Knowledge by Consolidating Knowledge," *Interfaces*, Vol.24, No.3, pp. 91-99.

Rivett, P. ( 1980), *Model Building for Decision Analysis*. John Wiley & Sons Date Published:, 172 pp

Rivett, P. ( 1994), *The Craft of Decision Modeling* John Wiley & Sons, 304 pp.

Sloane, W.R., and A. Reisman (1971), "Stock Evaluation Theory: Classification, Reconciliation and General Model," *Journal of Financial and Quantitative Analysis*, Vol.3, pp.171-204, June 1968. Also in *Models in Financial Management*, H. Aly and D.M. Albanito, Eds., Holden Day, San Francisco

Spens K. M.and A. H. Bask (2002), "Developing a Framework for Supply Chain Management," *The International Journal of Logistics Management*, Vol. 13, No. 1, pp. 73-89.

Thomas, D. J., P. M. Griffin (1996), "Coordinated Supply Chain Management," *European Journal of Operational Research*, Vol. 94. No. 1, pp. 1-15.

Thrall, R.M. (1985), "A Taxonomy for Decision Models," *Annals of Operations Research*, Vol. 2, pp.23-27.

Vogel, D.R., J.C. Weterbe (1984), "MIS Research: A Profile of Leading Journals and Universities," *Data Base*, Vol.16, No. 1, pp.3-14.

Wu S. D., R. O. Roundy, R. H. Storer, and L. A. Martin -Vega. Manufacturing Logistics Research: Taxonomy and Directions. Department of Industrial and Systems Engineering, Lehigh University, Working Paper.

Zhao, L., and A. Reisman (1992), "Toward Meta Research on Technology Transfer," *IEEE Transactions on Engineering Management*, Vol.39, No.1, pp. 13-21.