Getting Published

Basic Principles to Get You Started

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About myself…

- Qualifications:
  - ✓ BS and MS ChE, PhD ME (DLSU)
  - ✓ **100+** papers published in ISI-indexed journals
  - ✓ **130+** publications and ***h-index* = *27*** in Scopus
  - ✓ Recipient of multiple awards from **CHED, NAST** and **NRCP**
  - ✓ Recipient of commendations from **IChemE, UK** for multiple highly cited articles in ***Trans. IChemE Parts A and B*** and ***Comp. & Ch.E.***
  - ✓ Member of the editorial board of the ISI-indexed Springer journal ***Clean Technologies & Environmental Policy***
  - ✓ Editor of the book ***Recent Advances in Sustainable Process Design and Optimization***
- Areas of work:
  - ✓ Research (life cycle analysis, process systems engineering)
  - ✓ Education
  - ✓ Advice for career & professional development

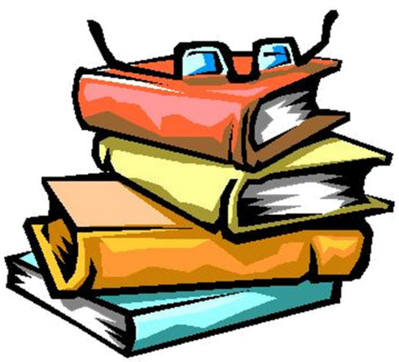
Lecture overview

- Knowledge creation in academia
- Research output as a social good
- What makes a good journal article?
- Research conceptualization, execution and documentation
- Writing up a good paper
- Final thoughts

The Social Rationale for Research

Research in academia

- Academic institutions have three main functions:
  - ✓Transmit knowledge
  - ✓Create knowledge
  - ✓Act as a public knowledge resource



Research in academia

- Peer-reviewed journals are the principal means of dissemination of rigorous scientific knowledge.
- There are other secondary means of "publication" including:
  - ✓ Journals
  - ✓ Conferences
  - ✓ Books
  - ✓ Gray literature (e.g., project reports)

Rationale for Publications

Type of Scholarly Work	Main Function
Reports, theses, working papers and other "gray literature"	Primarily for internal consumption
Conference papers	Broader dissemination of preliminary work
Short notes	Fast publication of important preliminary research outputs
Articles	Publication of essentially "complete" findings
Reviews	Account of recent developments in a field of study
Book chapters and edited books	Broader dissemination of mature ideas and research findings
Reference books and monographs	Broad dissemination of a mature body of research work
Textbooks	Mainstream dissemination of established ideas

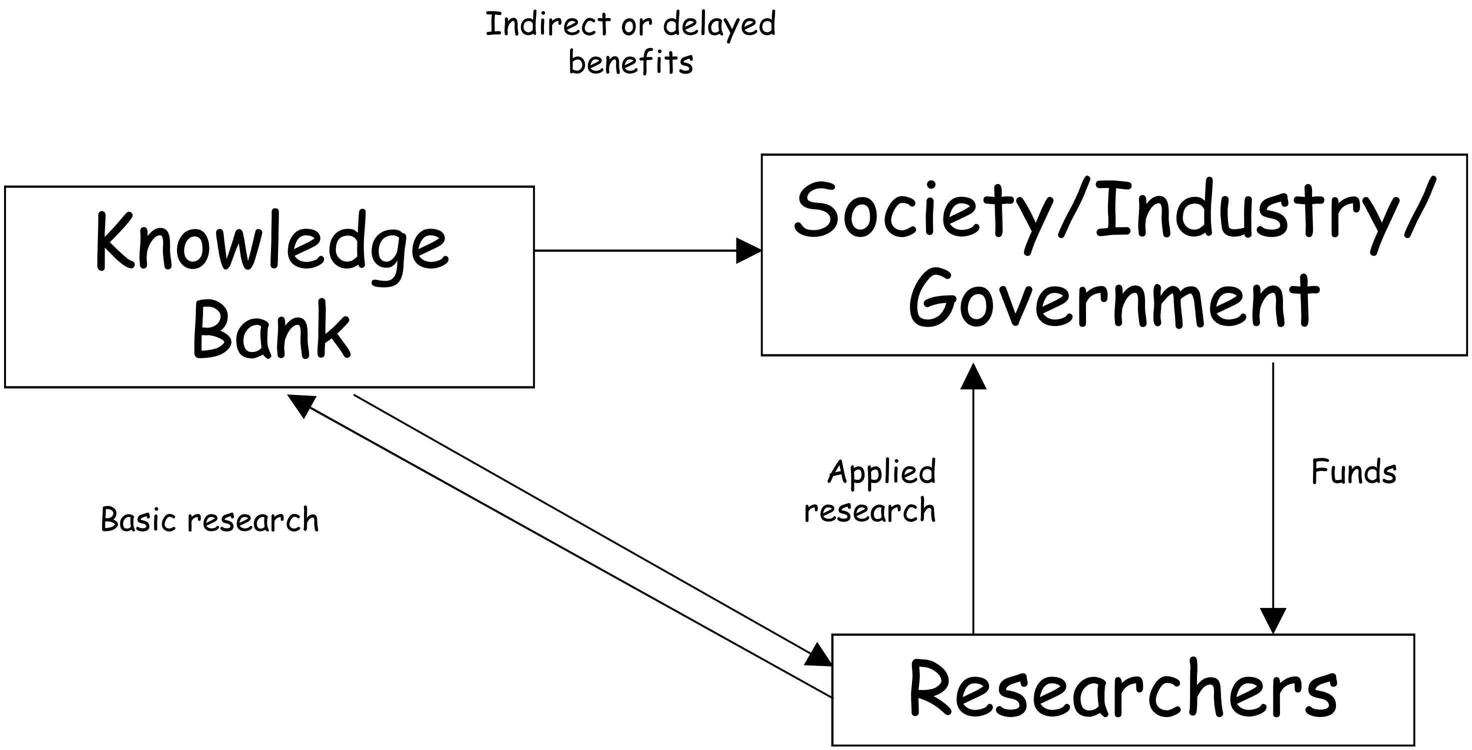
Elements of Research as a Global Enterprise

- **Peer review** provides some quality assurance through scientific scrutiny
- **Publication** ensures broad dissemination to reach the appropriate audience
- **Citation** provides a means of tracking incremental contributions that (cumulatively) lead to major breakthroughs.

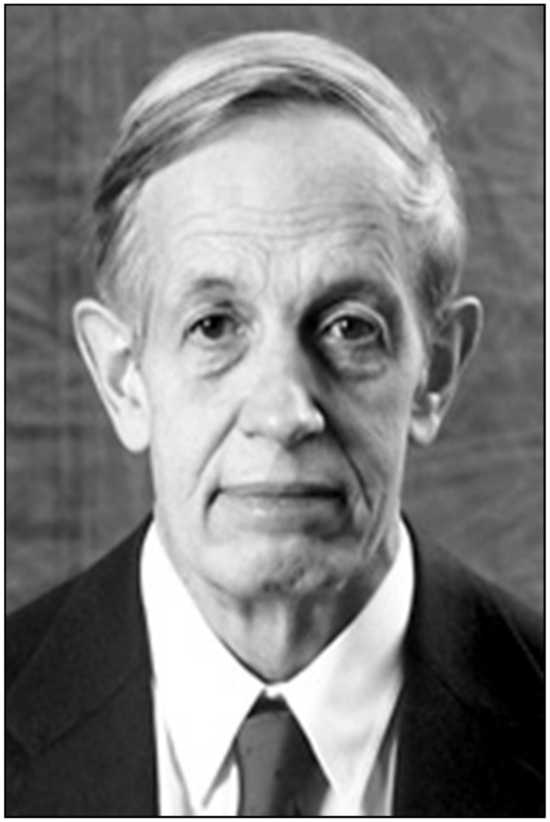
Some myths and excuses

- Publishing is very difficult
- Peer review stifles free exchange of ideas
- Publishing can be very expensive
- Publishing does not have significant beneficial impact on society at large
- My **English** is poor
- Etc.

The research cycle



Nobel Prize winning research and the value of great ideas



- How did game theory avert a **global nuclear holocaust**?
- The Nash equilibrium keep the Cold War from getting "hot" in the 1960s – 1980s.

EQUILIBRIUM POINTS IN N-PERSON GAMES

By John F. Nash, Jr.*

Princeton University

Communicated by S. Lefschetz, November 16, 1949

One may define a concept of an n-person game in which each player has a finite set of pure strategies and in which a definite set of payments to the n players corresponds to each n-tuple of pure strategies, one strategy being taken for each player. For mixed strategies, which are probability

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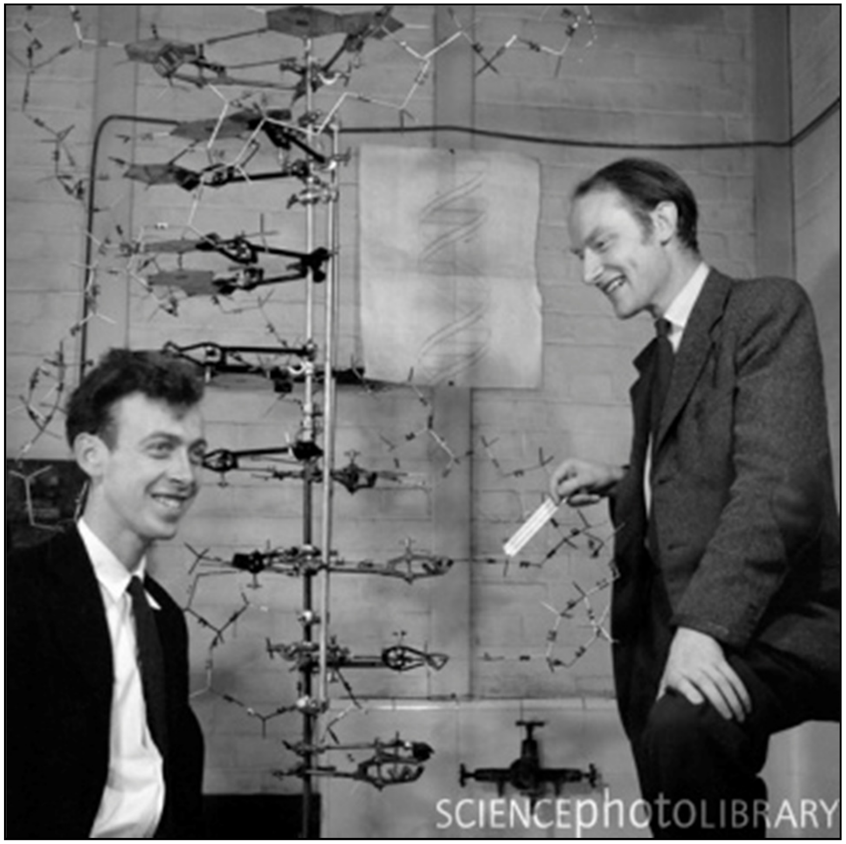
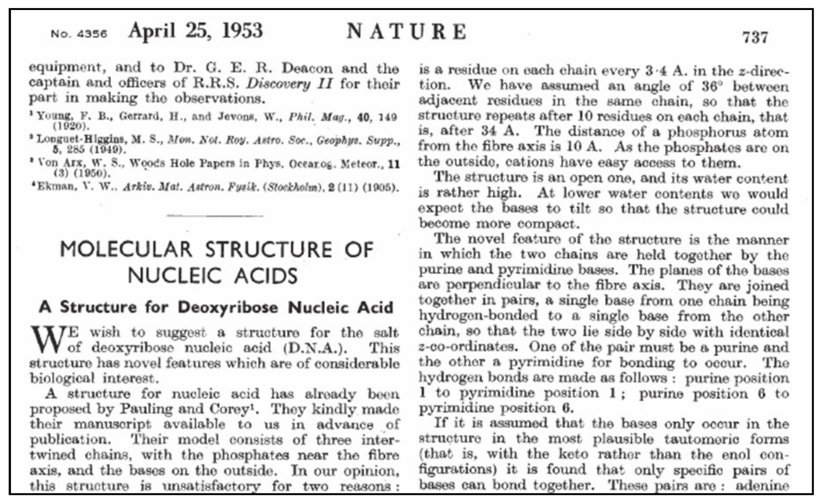


- How did a Ph.D. student's "side research" create a technological revolution?
- Watson and Crick's discovery of the structure of DNA paved the way for the 21st Century **biotech age!**



No. 4356 April 25, 1953 NATURE 737

equipment, and to Dr. G. E. R. Deacon and the captain and officers of R.R.S. *Discovery II* for their part in making the observations.

[1] Young, F. B., Gerrard, H., and Jevons, W., *Phil. Mag.*, **40**, 149 (1920).
[2] Longuet-Higgins, M. S., *Mon. Not. Roy. Astro. Soc., Geophys. Supp.*, **5**, 285 (1949).
[3] Von Arx, W. S., Woods Hole Papers in Phys. Oceanog. Meteor., **11** (3) (1950).
[4] Ekman, V. W., *Arkiv. Mat. Astron. Fysik. (Stockholm)*, **2** (11) (1905).

MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid

WE wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey[1]. They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons :

is a residue on each chain every 3·4 A. in the *z*-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats after 10 residues on each chain, that is, after 34 A. The distance of a phosphorus atom from the fibre axis is 10 A. As the phosphates are on the outside, cations have easy access to them.

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical *z*-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows : purine position 1 to pyrimidine position 1 ; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can bond together. These pairs are : adenine

Measuring research productivity

Research Metrics
(Researchers)

- Number of published papers
  - ✓Annual publications
  - ✓Cumulative career publications
- Number of citations
  - ✓Scientific progress is incremental in nature
  - ✓Citations of one's research in the formal publications of other researchers provides an important measure of scientific value
  - ✓*h*-index

Research Metrics
(Institutions)

Criteria	Weight (%)
Academic peer review	40
Employer review	10
Faculty-student ratio	20
Citations per faculty	**20**
International faculty	5
International students	5

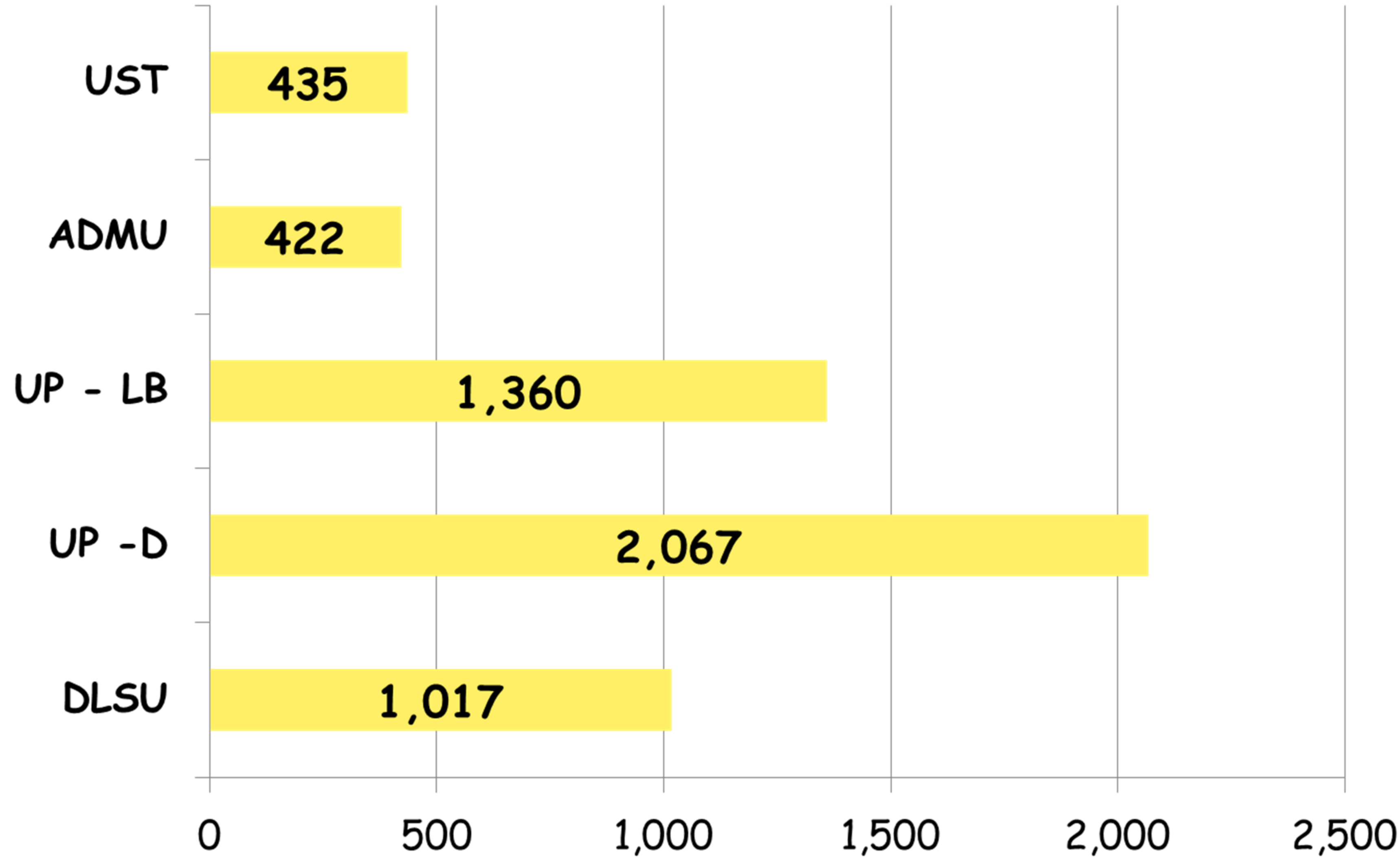
QS World University Rankings™

"Citations, evaluated in some fashion to take into account the size of institution, are the best understood and most widely accepted measure of *research strength*."

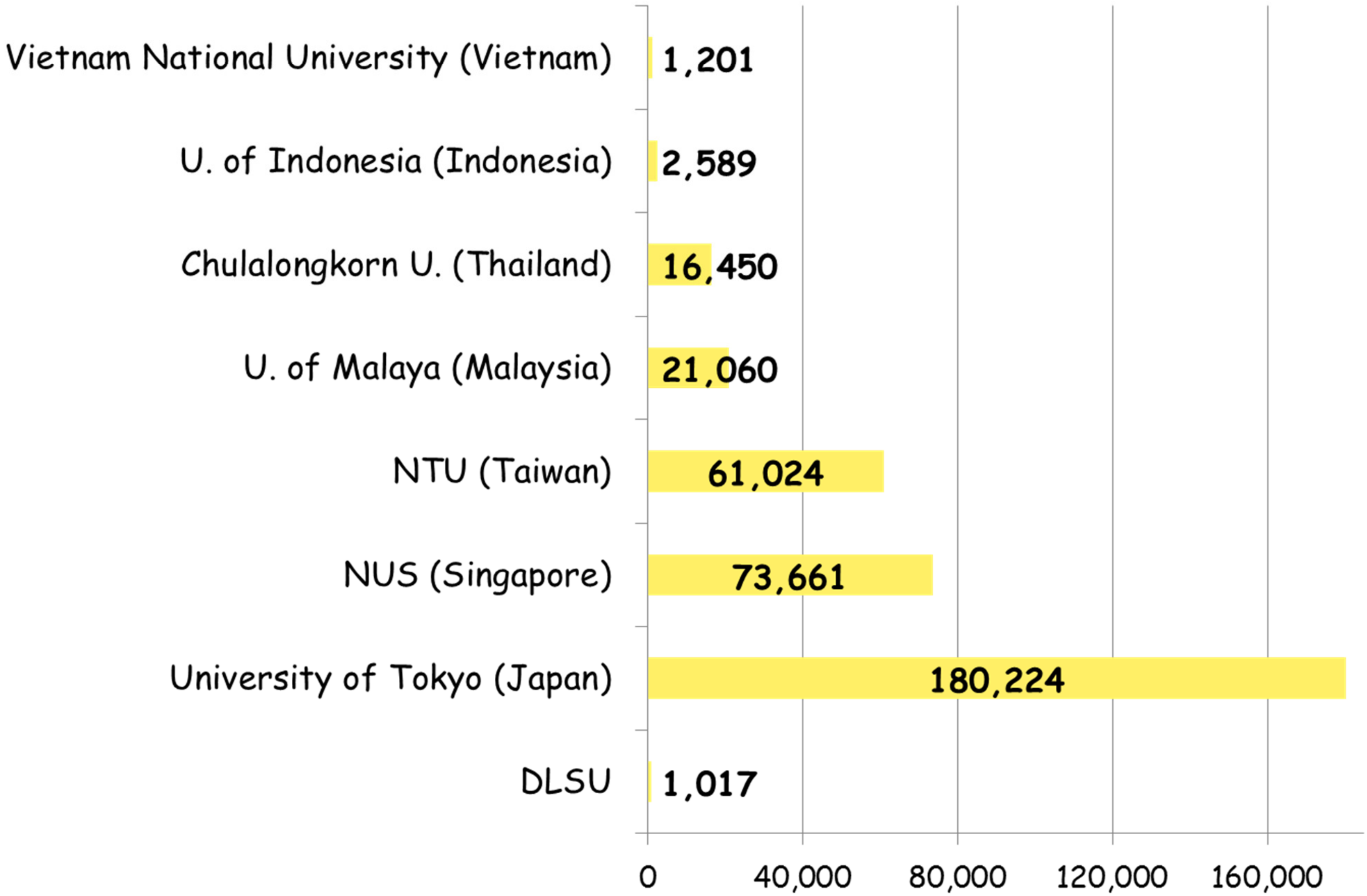
The *h*-index

- A metric that accounts for both **quality** & **quantity**
- The **number of papers** of an author being **cited at least *h* times**.
- Example:
  - ✓An author has 10 papers listed in Scopus;
  - ✓3 of these papers have been cited >3 times;
  - ✓*h*-index = 3.

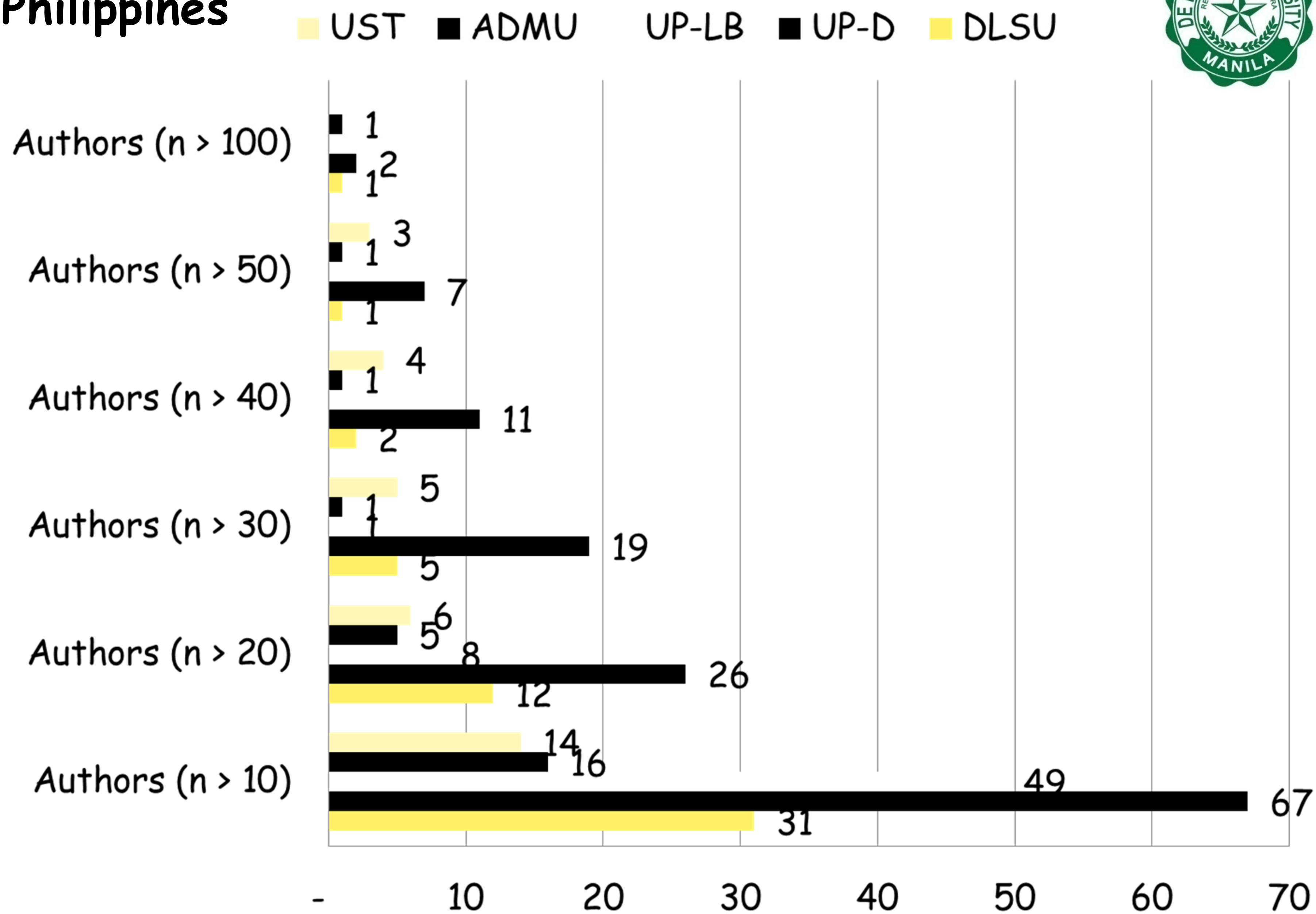
Cumulative Scopus-Listed Publications of Universities in the Philippines



Cumulative Publications of Universities in Asia-Pacific



Human Resource Profile from Universities in the Philippines



What makes a good journal?

Choosing a journal

- Has the journal published articles similar to yours in the past 2 – 3 years?
- Does the journal name appear often in your reference list?
- Does the journal description scope match your work? **Check their website/inside the cover (for hard copies)**

Abstracting/Indexing

- **Abstracting** services were developed to facilitate rapid search of scientific literature
- **Indexing** services were also developed to keep track of the utilization of information (e.g., through citation statistics)
- These provide a means by third parties to identify **"journals that matter"**
- Over the years *Thomson Reuters Web of Science* (a.k.a., "ISI") has become the industry gold standard but others have emerged (e.g., Scopus, Google Scholar)

Checking for Indexing

- ISI maintains the ff. citation indices:
  - ✓ Science Citation Index (SCI)
  - ✓ Social Science Citation Index (SSCI)
- You can do a query via www.isinet.com using:
  - ✓ ISSN
  - ✓ Title
  - ✓ Key words
- Note: Just because a journal is included in the *Thomson Master Journal List* does not mean it is indexed.

Publishers

- Major Commercial Publishers
  - ✓ e.g., Springer, Elsevier, Wiley, etc.
- Major Professional Organizations and Societies
  - ✓ e.g., NAS, Royal Soc. ACS, ASME, AIChE, IEEE
- University-based Publishers
  - ✓ e.g., Berkeley Electronic Press, Cambridge University Press
- Other Small-Scale Publishers
  - ✓ e.g., IFRF, ISEIS, Japan Institute of Energy
- **Watch out for internet scams by *predatory publishers* of dubious "journals"**

Predatory Publishing

- Predatory publishing has emerged in recent years as a form of phishing, preying on academics.
- Bogus journals with low credibility and which charge page fees for publication have undermined the growth of open access (see **Beall's List**)
- Nevertheless, legitimate open-access publishers exist, but it is often difficult to distinguish these from predatory ones.
- Large commercial publishers now offer open access options.

ISI & impact factor

- The Institute for Scientific Information (ISI) lists the top scientific journals in the world
- An **Impact Factor (IF)** indicates the "importance" of a journal - **the average no of times a paper is cited within 2 years of publication in the journal**.
- See www.isinet.com for details. IF is updated yearly in the ***Journal Citation Report***

IF of sample journal

What makes a good journal article?

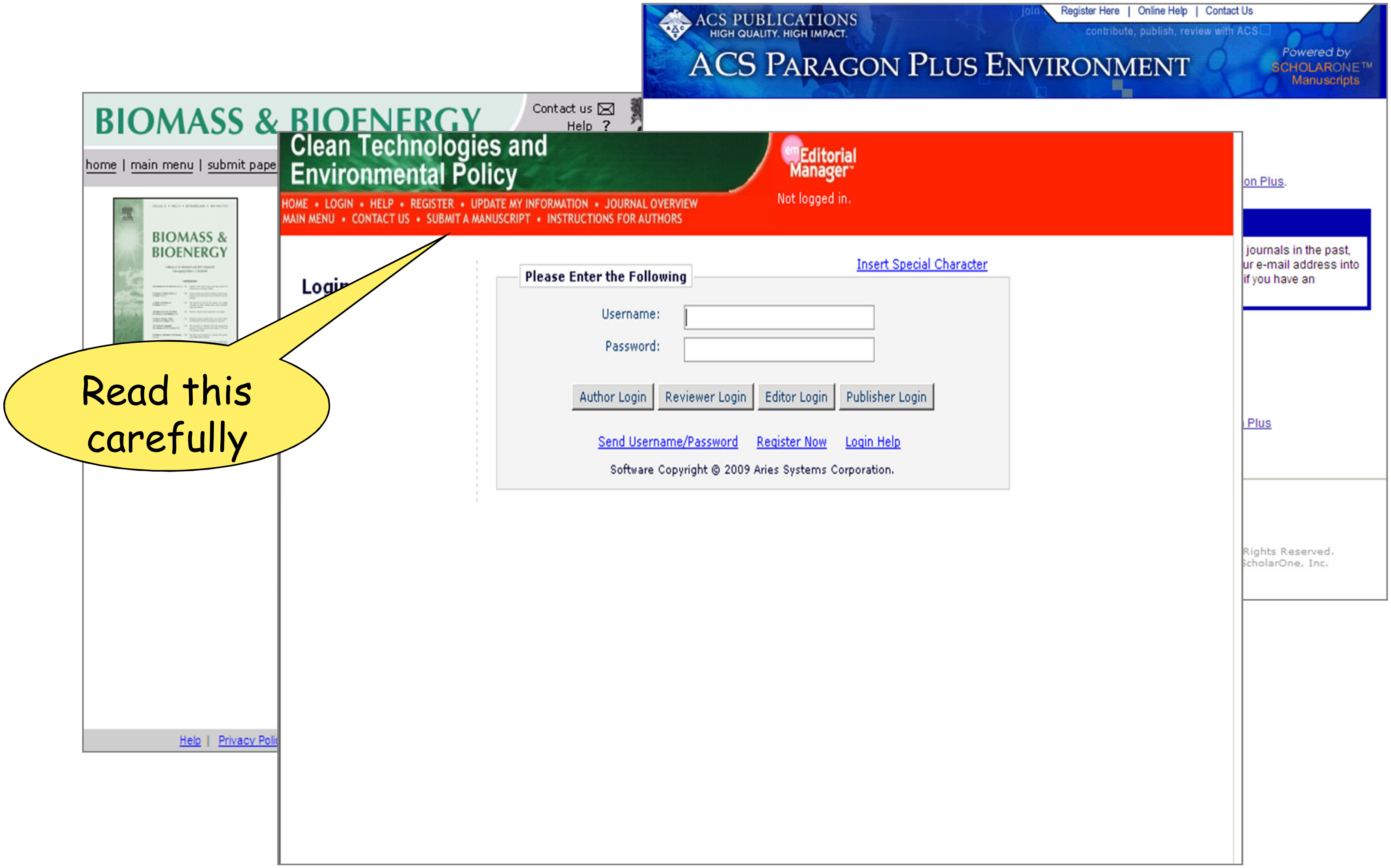
How good is your research?

- It is easy to make unverifiable claims about doing "world class" research…
- But can you prove it?
  - ✓ **Submission** – Are you willing to subject your work to the scrutiny of peer review?
  - ✓ **Publication** – Is your work judged by experts to be worth publishing?
  - ✓ **Citation** – Is your published work an important contribution that **other researchers can use?**

Types of contributions

- Full paper (5 – 25 pages)
- Reviews (15 – 100+ pages)
- Others (2 – 15 pages)
  - ✓ Short communications
  - ✓ Short notes
  - ✓ Technical notes
  - ✓ Letters to the editor
  - ✓ etc.

Electronic submission system



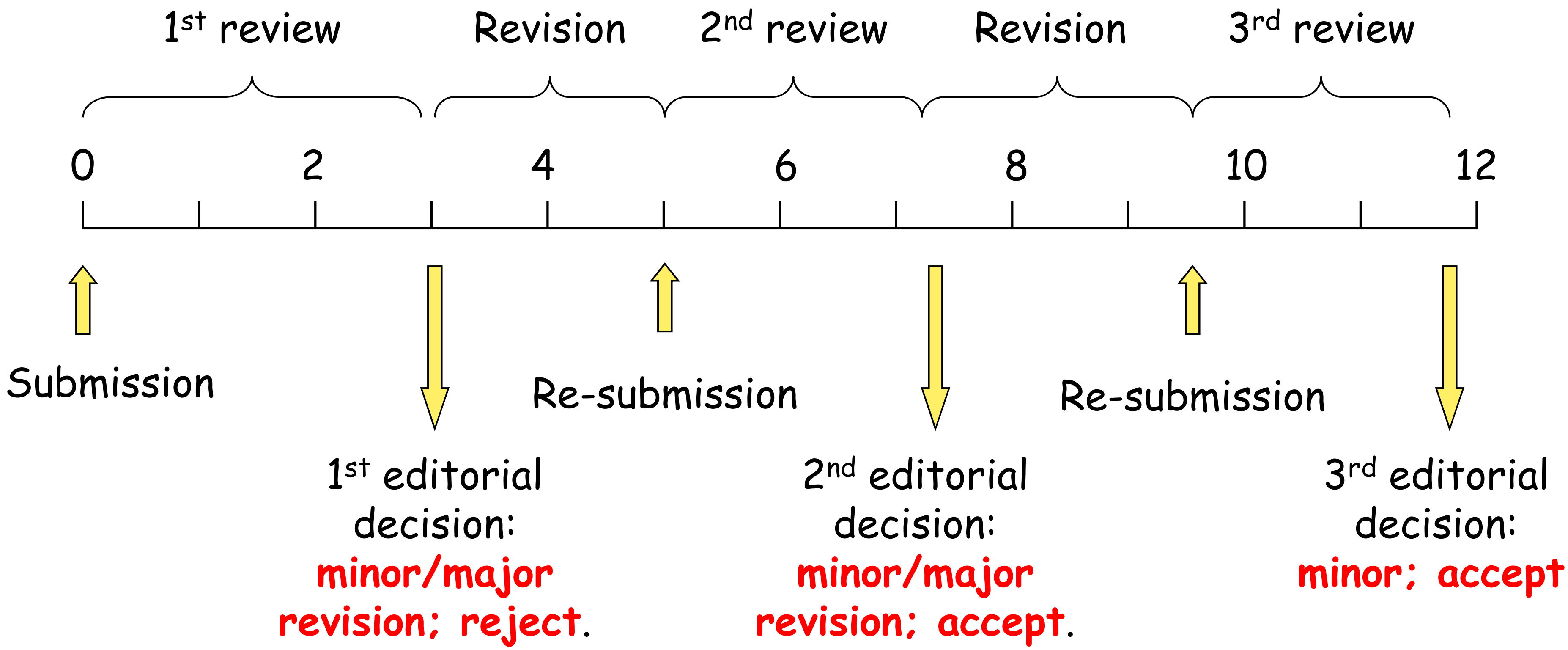
Corresponding authors

- Normally someone with a permanent position **(i.e., not a Ph.D. student)**
- Normally supervisor (with relatively longer stay than the students in an organization) or research team leader
- Someone who knows how to answer the doubts if readers have inquiries when reading the paper.

Documents to Submit

- **Cover letter to editor**
  - ✓ Brief description of the paper
  - ✓ Suggested reviewers
- **Manuscript** (see guide for authors)
  - ✓ Text (double space)
  - ✓ Figures (usually 1 per page)
  - ✓ Tables (usually 1 per page)
- Other documents as required by journal
- Supplementary e-files

The review process



Some tips to speed things up

- Special issues (normally fast-tracked review)
  - ✓ Dedicated to specific themes
  - ✓ Based on selected or invited papers from a conference
- **Present in conferences with special issues (even if they are more expensive!)**

PRES'09

12th Conference Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction

PUBLICATION POLICY

The selected papers will be published in special thematic issues:

* **Journal of Cleaner Production**
  General Editor: Prof. Don Huisingh, Center for Cleaner Products and Clean Technologies, University of Tennessee, Knoxville, USA
* **Applied Thermal Engineering**
  Editor-in-Chief: Prof. David A Reay, DRA Ltd, Tyne and Wear, UK
* **Resources, Conservation and Recycling**
  Journal Chief Editor: Prof. Ernst Worrell, Lawrence Berkeley National Laboratory, Berkeley, CA, USA
* **ENERGY - The International Journal**
  Editor-in-Chief: Prof. Noam Lior, University of Pennsylvania, Philadelphia, USA
* **Heat Transfer Engineering**
  Editor-in-Chief: Prof. Afshin J. Ghajar, School of Mechanical and Aerospace Engineering, Oklahoma State University, Stillwater, USA

After acceptance

- The article will (eventually) be published in print with full citation details (i.e., volume and page numbers)
- **Publication of an article isn't the end of the story.**
- The true test of the value of your research is the interest it generates upon publication.

Citation

- Universally accepted measure of research quality
- Citation means your work is ***included in someone else's literature review in a published work*** and is thus "scientifically useful"
- Types of citations:
  - ✓ Passing mention of your work
  - ✓ Criticism of your work
  - ✓ ***Use of your work as key input needed for success of their research***

Research conceptualization, execution and documentation

Key Phases of Research

Phase	Key Question
Research conceptualization	Is the topic **important** and is the approach **novel**?
Research execution	Is there sufficient human and capital resource to deliver the results? Is there "**comparative advantage?**"
Research documentation	Can the entire process be described **comprehensively**, **concisely** and **convincingly**?

Research Conceptualization

- Key research directions must be driven by a seasoned team leader (and not by students!)
- Directions may be justified by ***thorough literature review***
  - ✓ Recent review papers
  - ✓ "Future work" sections of recent articles
  - ✓ Conference papers and informal discussions

Research Execution

- Identify your **"comparative advantage"**
- Discuss with your adviser and lab colleagues
- Limited resources at DLSU means focusing on:
  - ✓ Computational work
  - ✓ Theoretical work
  - ✓ Highly focused "small" experiments **(think quality over quantity)**

Research Documentation

- Let's talk about this in more detail, using a specific example…

Anatomy of a good journal paper

Anatomy of a good paper

- ***Documentation of your ideas, activities and results***
- Key elements:
  - ✓ Abstract
  - ✓ Introduction/Literature review/background
  - ✓ Problem statement
  - ✓ Research methodology
  - ✓ Results and discussion
  - ✓ Conclusions
  - ✓ References

An example to learn from

Clean Techn Environ Policy
DOI 10.1007/s10098-012-0555-5

ORIGINAL PAPER

A methodology for augmenting sparse pairwise comparison matrices in AHP: applications to energy systems

Raymond R. Tan · Michael Angelo B. Promentilla

Received: 28 August 2012 / Accepted: 16 November 2012
© Springer-Verlag Berlin Heidelberg 2012

Abstract Multiple-attribute decision making (MADM) techniques can be used to provide a systematic approach to selection problems in energy engineering and management. They may be used for selecting the best technologies or policies based on environmental, technical, and socio-economic criteria. Among the many available MADM techniques, the analytic hierarchy process (AHP) has become one of the most widely used due to its effective hierarchical decomposition of complex problems. However, AHP may be tedious due to the large number of pairwise comparisons needed in large problems. Furthermore, in many cases, relevant information may also be available for determining criteria weights based on past decisions that have proven satisfactory in retrospect. Thus, we propose a simple methodology for augmenting sparse pairwise comparisons in AHP through a non-linear programming model that extracts a set of consistent weights from a priori ranking of a subset of alternatives. Two case studies on the ranking of bioethanol feedstocks and of CO_2 storage sites are then shown to illustrate this technique.

Keywords Multiple-attribute decision making (MADM) · Analytic hierarchy process (AHP) · Non-linear programming (NLP) · Bioethanol feedstock · CO_2 storage

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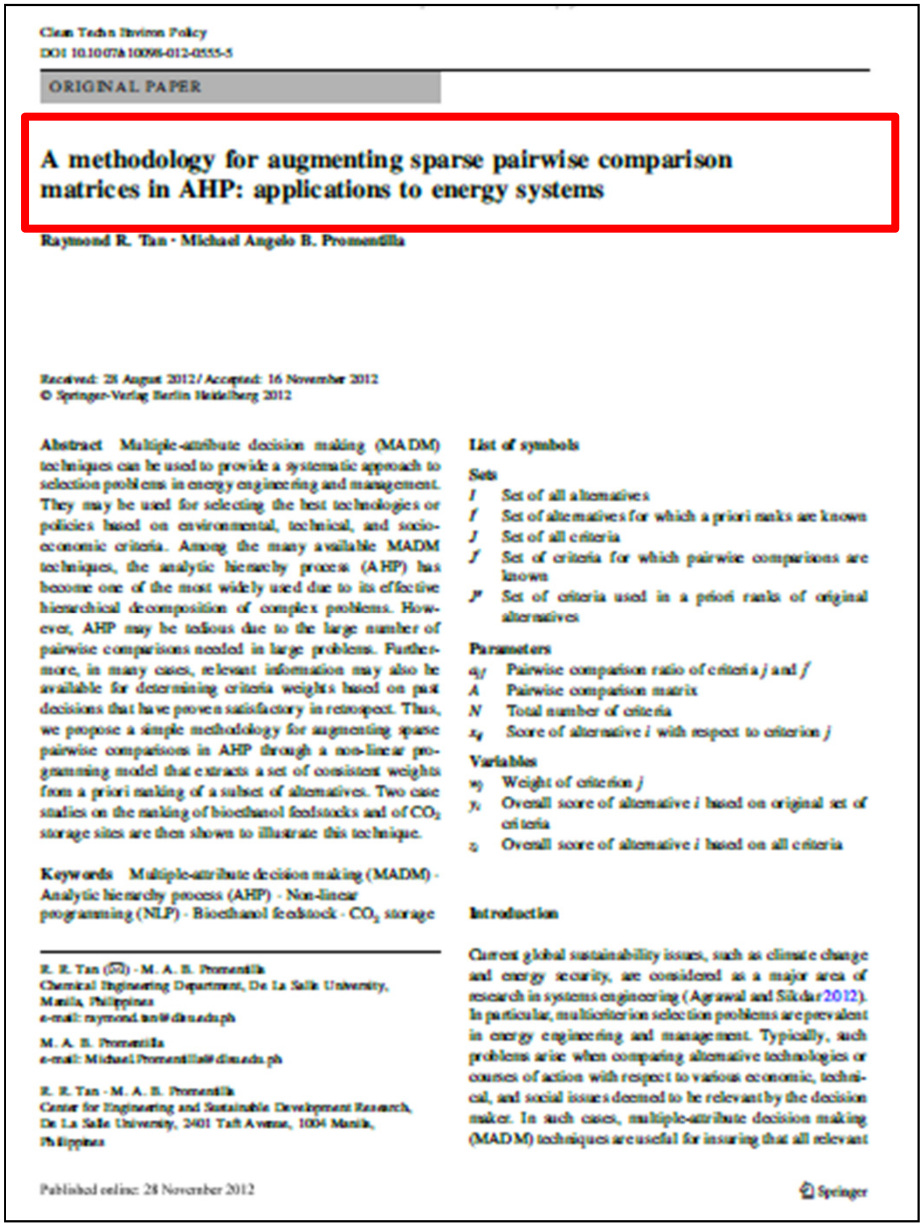
Current global sustainability issues, such as climate change and energy security, are considered as a major area of research in systems engineering (Agrawal and Sikdar 2012). In particular, multicriterion selection problems are prevalent in energy engineering and management. Typically, such problems arise when comparing alternative technologies or courses of action with respect to various economic, technical, and social issues deemed to be relevant by the decision maker. In such cases, multiple-attribute decision making (MADM) techniques are useful for insuring that all relevant

Published online: 28 November 2012

- Conceived in late 2011
- Preliminary presentation at APPChE 2012 in Singapore
- Additional case studies and refinements to extend to a full article
- Submitted for review in August 2012
- Accepted for publication in *Clean Technologies and Environmental Policy* (Springer) in December 2012

The Title



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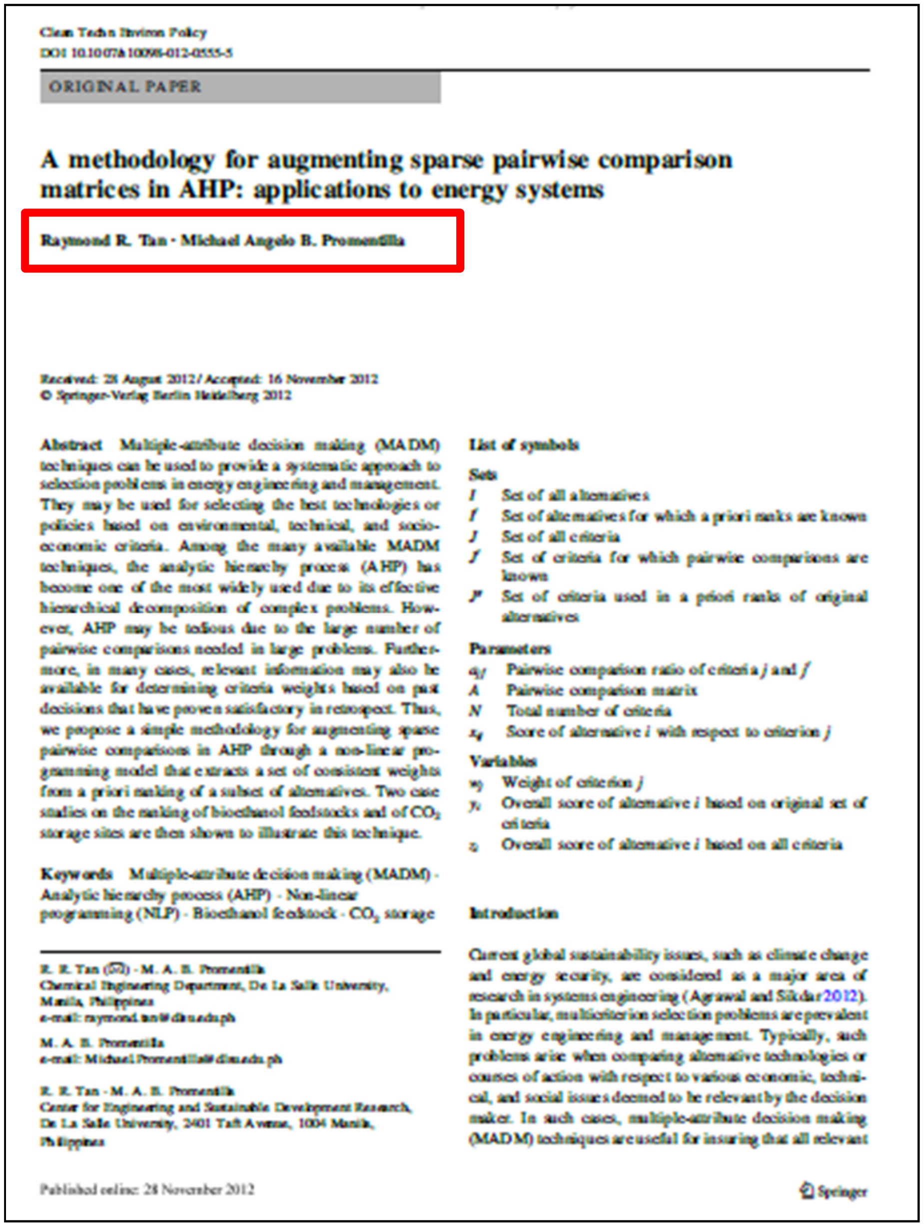
- Concise but complete
- Need not be the same as the title of your Ph.D. thesis
- Tailored to the "norms" of the journal or the discipline **(such knowledge is part of being an expert in your area)**

The Authors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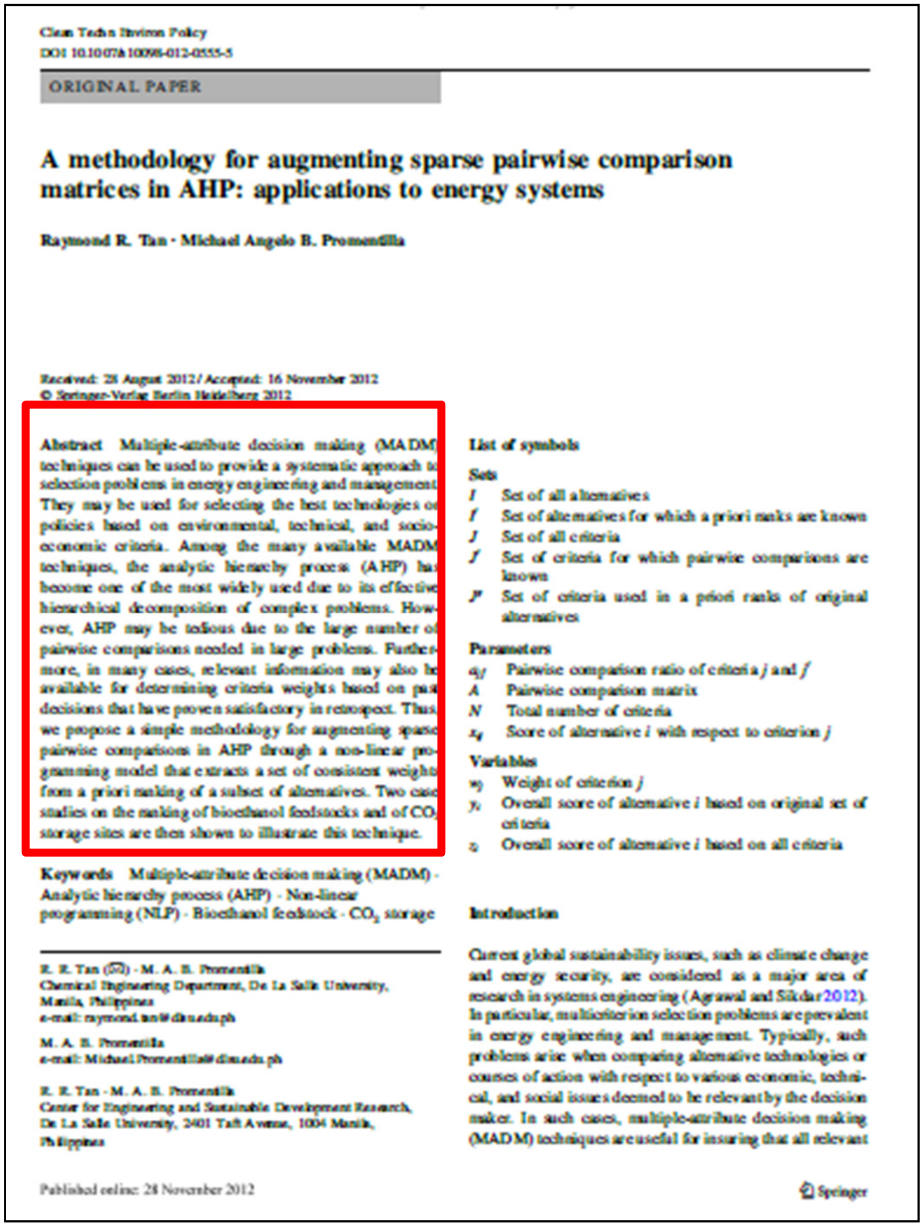
- Anyone who makes **substantial intellectual contributions** to the work should be coauthor.
- Make sure this list is complete to avoid accusations of plagiarism later.

The Abstract



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Current global sustainability issues, such as climate change and energy security, are considered as a major area of research in systems engineering (Agrawal and Sikdar 2012). In particular, multicriterion selection problems are prevalent in energy engineering and management. Typically, such problems arise when comparing alternative technologies or courses of action with respect to various economic, technical, and social issues deemed to be relevant by the decision maker. In such cases, multiple-attribute decision making (MADM) techniques are useful for insuring that all relevant

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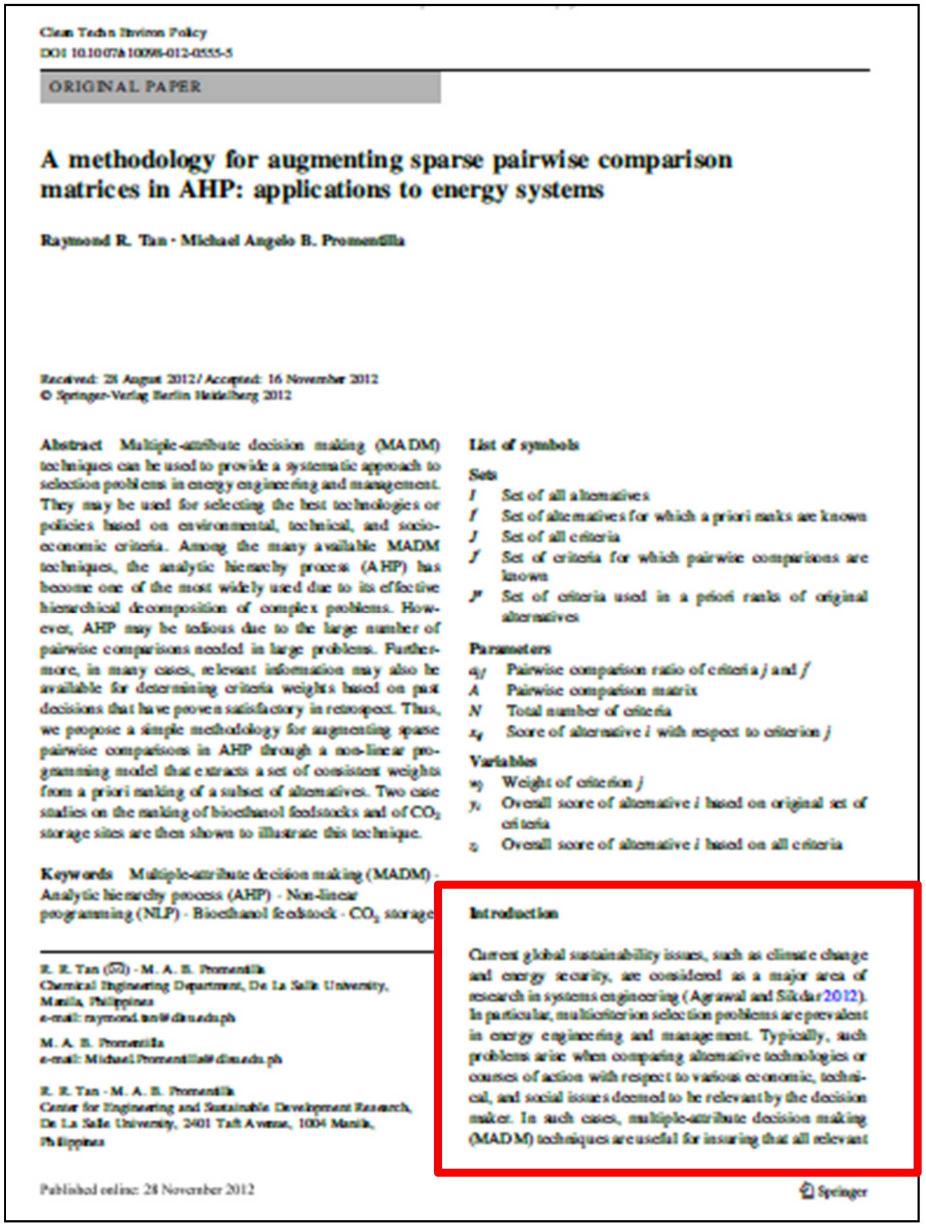
The Introduction



Clean Techn Environ Policy
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ORIGINAL PAPER

A methodology for augmenting sparse pairwise comparison matrices in AHP: applications to energy systems

Raymond R. Tan · Michael Angelo B. Promentilla

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Abstract Multiple-attribute decision making (MADM) techniques can be used to provide a systematic approach to selection problems in energy engineering and management. They may be used for selecting the best technologies or policies based on environmental, technical, and socio-economic criteria. Among the many available MADM techniques, the analytic hierarchy process (AHP) has become one of the most widely used due to its effective hierarchical decomposition of complex problems. However, AHP may be tedious due to the large number of pairwise comparisons needed in large problems. Furthermore, in many cases, relevant information may also be available for determining criteria weights based on past decisions that have proven satisfactory in retrospect. Thus, we propose a simple methodology for augmenting sparse pairwise comparisons in AHP through a non-linear programming model that extracts a set of consistent weights from a priori ranking of a subset of alternatives. Two case studies on the ranking of bioethanol feedstocks and of CO_2 storage sites are then shown to illustrate this technique.

Keywords Multiple-attribute decision making (MADM) · Analytic hierarchy process (AHP) · Non-linear programming (NLP) · Bioethanol feedstock · CO_2 storage

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List of symbols

Sets

I Set of all alternatives
I' Set of alternatives for which a priori ranks are known
J Set of all criteria
J' Set of criteria for which pairwise comparisons are known
J'' Set of criteria used in a priori ranks of original alternatives

Parameters

$a_{jj'}$ Pairwise comparison ratio of criteria j and j'
A Pairwise comparison matrix
N Total number of criteria
x_{ij} Score of alternative i with respect to criterion j

Variables

w_j Weight of criterion j
y_i Overall score of alternative i based on original set of criteria
z_i Overall score of alternative i based on all criteria

Introduction

Current global sustainability issues, such as climate change and energy security, are considered as a major area of research in systems engineering (Agrawal and Sikdar 2012). In particular, multicriterion selection problems are prevalent in energy engineering and management. Typically, such problems arise when comparing alternative technologies or courses of action with respect to various economic, technical, and social issues deemed to be relevant by the decision maker. In such cases, multiple-attribute decision making (MADM) techniques are useful for insuring that all relevant

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- Start with a general introduction to relevant **background issues**
- In this case, I discuss climate change, greenhouse gases and energy issues
- Use of statistics is a good way to add depth

The Introduction (continued)

decision elements are considered rationally and systemati-cally. Various MADM approaches have been used for the assessment of alternatives for motor vehicle fuels (Ta… 2005), power generation technologies (Aviso et al. 2008), bioenergy systems (Buchholz et al. 2009), district heating systems (Ghafghazi et al. 2010), biofuels (Gnansounou 2011), renewable energy options (San Cristobal 2011), waste biomass management options (Recchia et al. 2010), and CO… storage sites (Hsu et al. 2012), among many other applica-tions. This list of examples is not meant to be comprehensive; more detailed reviews of decision analysis techniques and applications in energy systems have been done. One survey notes the increased use of such techniques in energy litera-ture since the mid-1990s (Zhou et al. 2006). Løken (2007) identified key opportunities for using MADM in systems involving multiple energy carriers. A review of footprint metrics that are used for decision analysis in determining the sustainability of energy systems has also been published recently (Cucek et al. 2012); in some cases, notable corre-lations among footprint indicators have been observed (Cucek et al. 2011). Many MADM techniques are based on determining a single aggregate index for each alternative, which then allows for direct comparison (Sikdar 2003). Normalization of scores using ratio scales was proposed (Sikdar 2009) and then improved to eliminate numerical issues such as negative or unbounded values (Sikdar et al. 2012). A comparison of different normalization, aggrega-tion, and weighting schemes for sustainability indicators was also recently published in this journal (Zhou et al. 2012).

One of the most popular MADM techniques is the analytic hierarchy process (AHP), which was originally proposed by Saaty (1980). A review by Pohekar and Ramachandran (2004) reported that AHP was more popular for energy-related problems than competing MADM approaches. AHP's modeling philosophy is based on three basic tenets, namely (1) structuring complexity, (2) mea-suring priority on a ratio scale, and (3) synthesizing by hierarchic composition. Detailed annotated bibliographies of AHP applications and overviews of its recent applica-tions can be found in Vargas (1990) and Vaidya and Kumar (2006). A recent review of methodological developments has also appeared in the literature (Ishizaka and Labib 2011). AHP structures complexity by decomposing the decision problem to a system of hierarchical structure and deriving local priorities for the elements in each level of hierarchy according to their impact on the elements (e.g., criteria or objectives) of the next higher level. The overall priority of an alternative is then computed from the addi-tive weighting of these local priorities. Pairwise compari-son reciprocal matrices are used to compute the ratio-scale priority vectors by comparing the contributions of the elements in each level of the hierarchy to each element in the adjacent upper level. An established, calibrated 9-point scale with corresponding linguistic or subjective interpre-tation is used in AHP (Saaty 1980). When the elements in a cluster or level (e.g., criteria) are compared in pairwise mode with respect to a common property or controlling element (e.g., goal element), a total of $n(n-1)/2$ questions are needed to elicit value judgments from the decision maker and fill up the pairwise comparison matrix A:

$$A = \begin{bmatrix} 1 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & 1 \end{bmatrix} \text{ where } a_{ij} = \frac{1}{a_{ji}} \quad (1)$$

In principle, the weights of the elements can be determined through different procedures, such as the eigenvector or geometric mean methods (Saaty 1980; Ishizaka and Labib 2011). However, one of the difficulties in implementing AHP is the possibility of requiring an excessive number of pairwise comparisons in eliciting value judgments for large-scale decision problems (Harker 1987; Ishizaka and Labib 2011). In such cases, the elicitation process becomes tedious and repetitive, thus prompting the development of various techniques for deriving weights from incomplete pairwise comparisons. Harker (1987) proposed a graph theoretic approach based on the geometric mean through the assumption of transitivity. Later work using Monte Carlo simulation showed the possibility of deriving robust results from incomplete data (Carmone et al. 1997). More recently, artificial intelligence (Hu and Tsai 2006) and mathematical programming (Fedrizzi and Giove 2007) approaches to handling missing pairwise comparisons have also been demonstrated. Furthermore, even in cases with complete pairwise comparisons, Chandran et al. (2005) proposed a linear programming approach which, in principle, allows weights to be derived from the final ranking of the decision elements. The pairwise comparison strategy of AHP lends itself particularly well for handling subjective aspects of decision problems, particularly for determining the weights of criteria in conjunction with other MADM methods (San Cristobal 2011).

In this study, we propose a simple methodology for determining weights in AHP decision problems from a sparse pairwise comparison matrix. The proposed approach supplements the limited number of pairwise comparisons with prior information in overall ranks of a subset of the alternatives based on a subset of the given criteria. A non-linear programming (NLP) model is then formulated which determines the set of weights to satisfy both the pairwise comparisons and the partial rankings from historical data. The model begins with the default assumption that the given criteria are equally weighted, and then finds the minimum deviation from the default assumption which suffices to satisfy the added conditions imposed by the new

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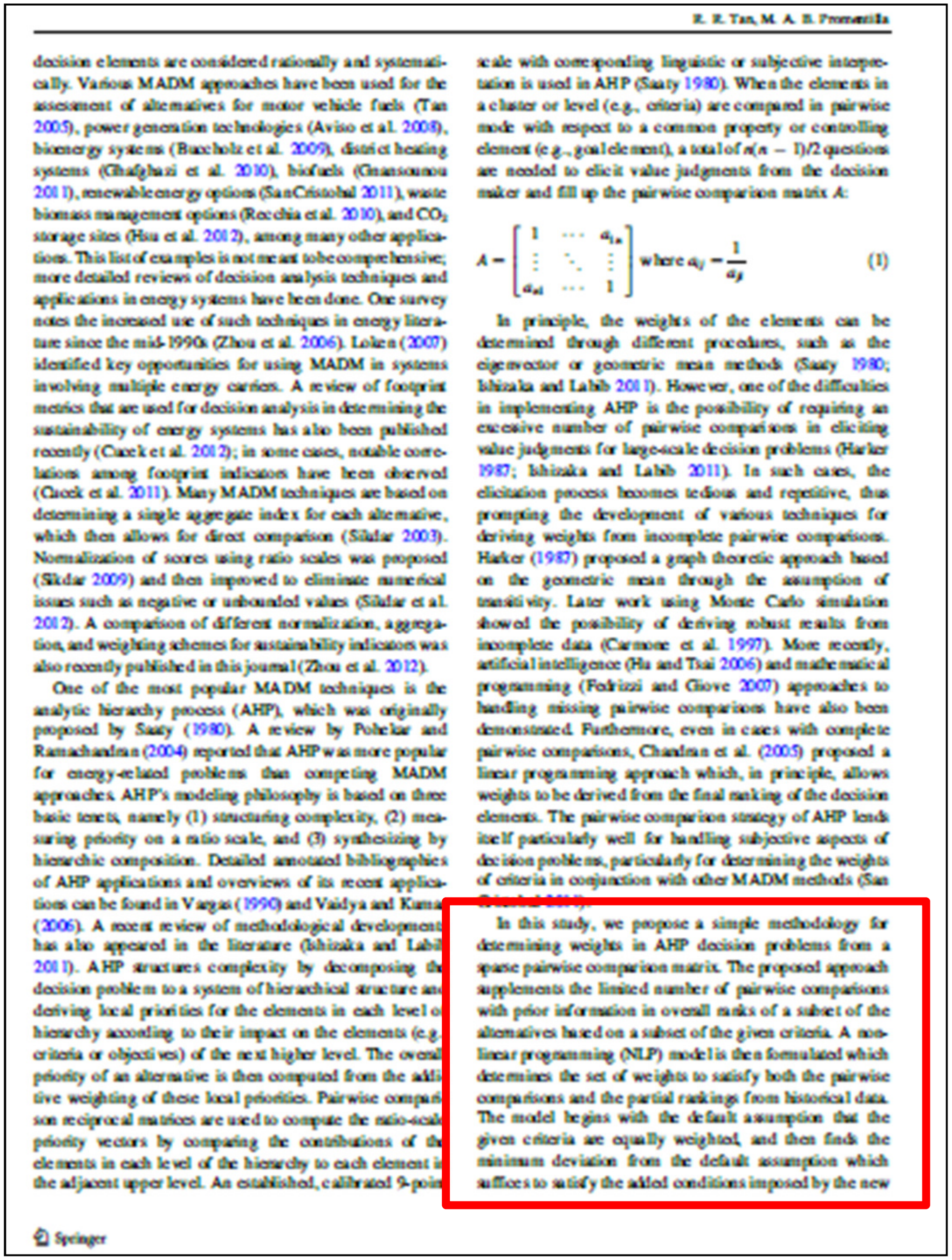

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The Introduction (continued)

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Main Body

information. The proposed methodology is then demonstrated using two case studies in low-carbon energy systems. The first example is on bioethanol feedstock selection, while the second example is on site selection for CO_2 storage. Finally, conclusions and prospects for future work are given.

Problem statement

The problem may be stated formally as follows. We consider a set of alternatives I^r for which a priori ranks based on a set of criteria J^r are known. Note that the preliminary rankings need not be based on AHP. The decision problem arises when new alternatives and new criteria are added; the expanded set of alternatives is I, while the expanded set of criteria is J. Furthermore, some pairwise comparison data are given for a subset of the criteria, J^p. The objective is to use the information embedded in the a priori ranks of alternatives in set I^r, as well as the pairwise comparisons of criteria in set J^p, to determine the weights of all the criteria in set J, so as to allow the ranking of the expanded set of alternatives I. It is necessary that the sets J^r and J^p are overlapping, i.e., at least one of the criteria used in the a priori rankings must be involved in the pairwise comparisons with the new criteria. Note that this final ranking sequence must be consistent with both the a priori ranks and the pairwise comparisons. The corresponding decision hierarchy for the generic problem is illustrated in Fig. 1.

Methodology

The overall methodology consists of two main steps. First, an optimization model is solved to determine the criterion weights; then, these weights are used to compute the overall scores of the alternatives so that they can be ranked. For the optimization model in the first step, the objective is to determine the set of weights with the minimum deviation from a naive assumption of equally weighted criteria:

$$\text{Min} \sum_{j \in J} \left(\frac{1}{n} - w_j \right)^2 \tag{2}$$

where n is the total number of criteria in the problem and w_j is the weight of each criterion j. Note that this approach assumes that each criterion is initially given a weight of $1/n$ unless additional information is given. This assumption is typically used in the absence of detailed preference information (Zhou et al. 2012).

The weights are normalized to sum up to unity:

$$\sum_{j \in J} w_j = 1 \tag{3}$$

The approach developed here then updates the weights based on two sources of information. First, the original set of alternatives with a priori ranks serve as examples from which consistent weights may be derived through a process of logical induction. Second, explicit but incomplete pairwise comparisons of criteria weights are also taken into consideration. These weights must result in the same ranking of alternatives as the a priori ranks. Thus, the overall scores of the original set of alternatives based on the original set of criteria are computed as

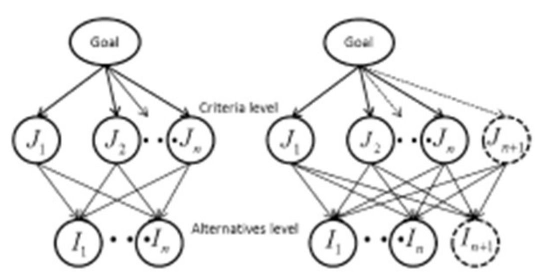
$$y_i = \sum_{j \in J^r} w_j x_{ij} \quad \forall i \in I^r \tag{4}$$

where y_i is the overall score of alternative i based on the original set of criteria and x_{ij} is the score of alternative i with respect to criterion j. For any two alternatives for which a priori ranks are given, the overall scores must conform to

$$y_i \geq y_{i'} \quad \forall i, \forall i' \in I^r \tag{5}$$

where alternative i outranks alternative i'. Furthermore, weights for which pairwise comparisons are known are subject to

Fig. 1 Decision hierarchy with new and old criteria/alternatives



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Conclusions

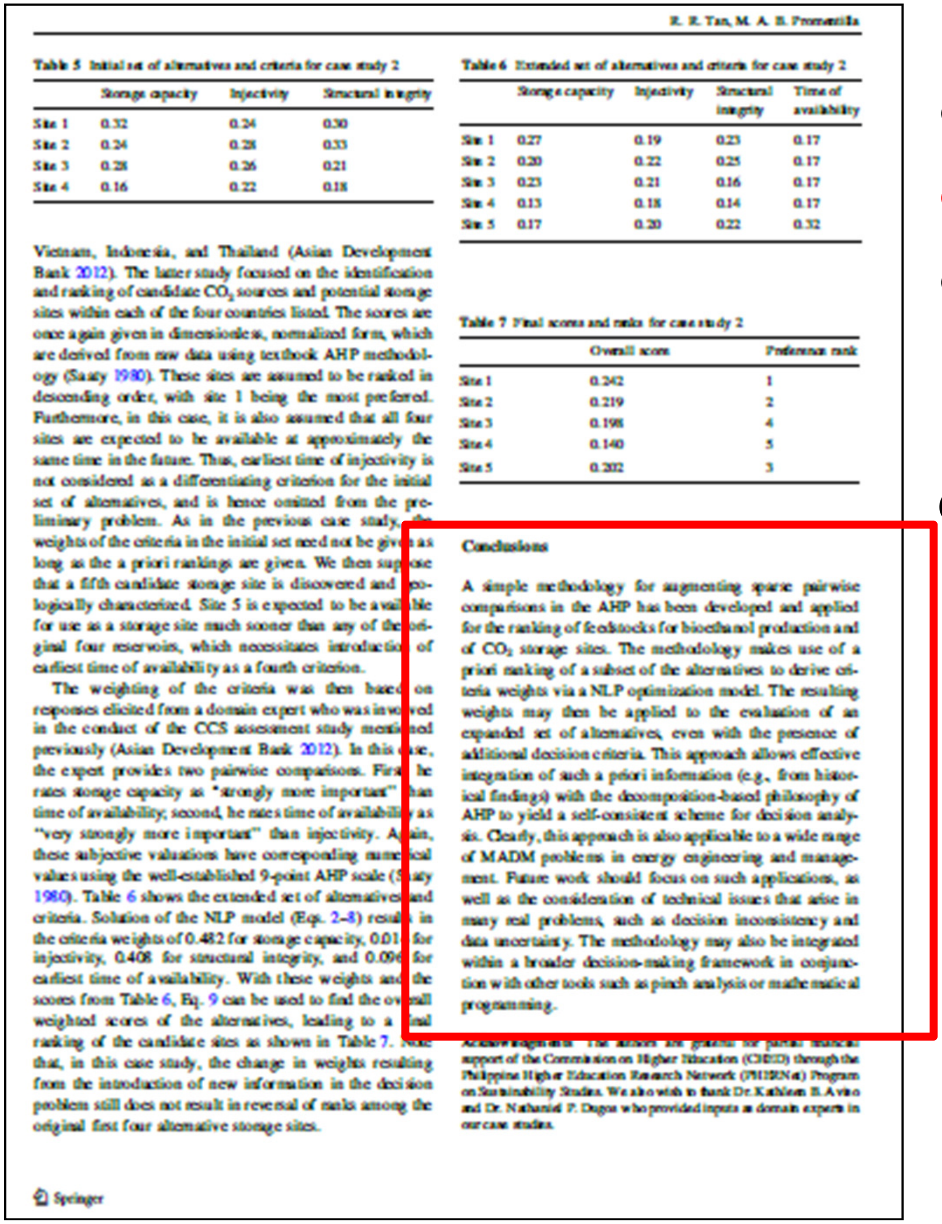

Table 5 Initial set of alternatives and criteria for case study 2

	Storage capacity	Injectivity	Structural integrity
Site 1	0.32	0.24	0.30
Site 2	0.24	0.28	0.33
Site 3	0.28	0.26	0.21
Site 4	0.16	0.22	0.18

Vietnam, Indonesia, and Thailand (Asian Development Bank 2012). The latter study focused on the identification and ranking of candidate CO_2 sources and potential storage sites within each of the four countries listed. The scores are once again given in dimensionless, normalized form, which are derived from raw data using textbook AHP methodology (Saaty 1980). These sites are assumed to be ranked in descending order, with site 1 being the most preferred. Furthermore, in this case, it is also assumed that all four sites are expected to be available at approximately the same time in the future. Thus, earliest time of injectivity is not considered as a differentiating criterion for the initial set of alternatives, and is hence omitted from the preliminary problem. As in the previous case study, the weights of the criteria in the initial set need not be given as long as the a priori rankings are given. We then suppose that a fifth candidate storage site is discovered and geologically characterized. Site 5 is expected to be available for use as a storage site much sooner than any of the original four reservoirs, which necessitates introduction of earliest time of availability as a fourth criterion.

The weighting of the criteria was then based on responses elicited from a domain expert who was involved in the conduct of the CCS assessment study mentioned previously (Asian Development Bank 2012). In this case, the expert provides two pairwise comparisons. First, he rates storage capacity as "strongly more important" than time of availability; second, he rates time of availability as "very strongly more important" than injectivity. Again, these subjective valuations have corresponding numerical values using the well-established 9-point AHP scale (Saaty 1980). Table 6 shows the extended set of alternatives and criteria. Solution of the NLP model (Eqs. 2–8) results in the criteria weights of 0.482 for storage capacity, 0.01[illegible] for injectivity, 0.408 for structural integrity, and 0.09[illegible] for earliest time of availability. With these weights and the scores from Table 6, Eq. 9 can be used to find the overall weighted scores of the alternatives, leading to a final ranking of the candidate sites as shown in Table 7. Note that, in this case study, the change in weights resulting from the introduction of new information in the decision problem still does not result in reversal of ranks among the original first four alternative storage sites.

Table 6 Extended set of alternatives and criteria for case study 2

	Storage capacity	Injectivity	Structural integrity	Time of availability
Site 1	0.27	0.19	0.23	0.17
Site 2	0.20	0.22	0.25	0.17
Site 3	0.23	0.21	0.16	0.17
Site 4	0.13	0.18	0.14	0.17
Site 5	0.17	0.20	0.22	0.32

Table 7 Final scores and ranks for case study 2

	Overall score	Preference rank
Site 1	0.242	1
Site 2	0.219	2
Site 3	0.198	4
Site 4	0.140	5
Site 5	0.202	3

Conclusions

A simple methodology for augmenting sparse pairwise comparisons in the AHP has been developed and applied for the ranking of feedstocks for bioethanol production and of CO_2 storage sites. The methodology makes use of a priori ranking of a subset of the alternatives to derive criteria weights via a NLP optimization model. The resulting weights may then be applied to the evaluation of an expanded set of alternatives, even with the presence of additional decision criteria. This approach allows effective integration of such a priori information (e.g., from historical findings) with the decomposition-based philosophy of AHP to yield a self-consistent scheme for decision analysis. Clearly, this approach is also applicable to a wide range of MADM problems in energy engineering and management. Future work should focus on such applications, as well as the consideration of technical issues that arise in many real problems, such as decision inconsistency and data uncertainty. The methodology may also be integrated within a broader decision-making framework in conjunction with other tools such as pinch analysis or mathematical programming.

Acknowledgments The authors are grateful for partial financial support of the Commission on Higher Education (CHED) through the Philippine Higher Education Research Network (PHERNet) Program on Sustainability Studies. We also wish to thank Dr. Kathleen B. Aviso and Dr. Nathaniel P. Dugos who provided inputs as domain experts in our case studies.

- Give a recap of the article
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- Always end with "future work"
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  - ✓ **Guide other researchers, but don't give away too many secrets.**

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Variables
w_j Weight of cr
y_i Overall score criteria
z_i Overall score

Introduction

Current global sus and energy secur research in system In particular, mult in energy engine problems arise wh courses of action cal, and social iss maker. In such c (MADM) techniq

- A list of 3 – 6 key terms
- During evaluation stage, acts as a guide in identification of referees
- **Facilitates search to enhance the visibility of your work to the right audience (so you get cited more!)**

Other Parts: Acknowledgement

Table 5 Initial set of alternatives and criteria for case study 2

	Storage capacity	Injectivity	Structural integrity
Site 1	0.32	0.24	0.30
Site 2	0.24	0.28	0.33
Site 3	0.28	0.26	0.21
Site 4	0.16	0.22	0.18

Vietnam, Indonesia, and Thailand (Asian Development Bank 2012). The latter study focused on the identification and ranking of candidate CO_2 sources and potential storage sites within each of the four countries listed. The scores are once again given in dimensionless, normalized form, which are derived from raw data using textbook AHP methodology (Saaty 1980). These sites are assumed to be ranked in descending order, with site 1 being the most preferred. Furthermore, in this case, it is also assumed that all four sites are expected to be available at approximately the same time in the future. Thus, earliest time of injectivity is not considered as a differentiating criterion for the initial set of alternatives, and is hence omitted from the preliminary problem. As in the previous case study, the weights of the criteria in the initial set need not be given as long as the a priori rankings are given. We then suppose that a fifth candidate storage site is discovered and geologically characterized. Site 5 is expected to be available for use as a storage site much sooner than any of the original four reservoirs, which necessitates introduction of earliest time of availability as a fourth criterion.

The weighting of the criteria was then based on responses elicited from a domain expert who was involved in the conduct of the CCS assessment study mentioned previously (Asian Development Bank 2012). In this case, the expert provides two pairwise comparisons. First, he rates storage capacity as "strongly more important" than time of availability; second, he rates time of availability as "very strongly more important" than injectivity. Again, these subjective valuations have corresponding numerical values using the well-established 9-point AHP scale (Saaty 1980). Table 6 shows the extended set of alternatives and criteria. Solution of the NLP model (Eqs. 2–8) results in the criteria weights of 0.482 for storage capacity, 0.014 for injectivity, 0.408 for structural integrity, and 0.096 for earliest time of availability. With these weights and the scores from Table 6, Eq. 9 can be used to find the overall weighted scores of the alternatives, leading to a final ranking of the candidate sites as shown in Table 7. Note that, in this case study, the change in weights resulting from the introduction of new information in the decision problem still does not result in reversal of ranks among the original first four alternative storage sites.

Table 6 Extended set of alternatives and criteria for case study 2

	Storage capacity	Injectivity	Structural integrity	Time of availability
Site 1	0.27	0.19	0.23	0.17
Site 2	0.20	0.22	0.25	0.17
Site 3	0.23	0.21	0.16	0.17
Site 4	0.13	0.18	0.14	0.17
Site 5	0.17	0.20	0.22	0.32

Table 7 Final scores and ranks for case study 2

	Overall score	Preference rank
Site 1	0.242	1
Site 2	0.219	2
Site 3	0.198	4
Site 4	0.140	5
Site 5	0.202	3

Conclusions

A simple methodology for augmenting sparse pairwise comparisons in the AHP has been developed and applied for the ranking of feedstocks for bioethanol production and of CO_2 storage sites. The methodology makes use of a priori ranking of a subset of the alternatives to derive criteria weights via a NLP optimization model. The resulting weights may then be applied to the evaluation of an expanded set of alternatives, even with the presence of additional decision criteria. This approach allows effective integration of such a priori information (e.g., from historical findings) with the decomposition-based philosophy of AHP to yield a self-consistent scheme for decision analysis. Clearly, this approach is also applicable to a wide range of MADM problems in energy engineering and management. Future work should focus on such applications, as well as the consideration of technical issues that arise in many real problems, such as decision inconsistency and data uncertainty. The methodology may also be integrated within a broader decision-making framework in conjunction with other tools such as pinch analysis or mathematical programming.

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- **This is also a good place to thank people who are not coauthors.**

Final words

Concluding Thoughts

- Research is an **essential activity** in today's knowledge-based global economy
- Publication is an **integral part** of the research process
- Peer review is a fundamental **quality assurance** step that ensures that new ideas stand up to expert scrutiny
- Various means of publication (conferences, journals, books) provide a **"developmental ladder"** for new research findings to mature.

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Thank You
Questions and Comments are Welcome

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