Guzmán S. Author and Manrique J. Author

Touristic guide for city guidance with minimum-maximum optimization multi-criteria model: Budget VS Number of cities

*Abstract* – This articles consists in developing a description of the implementation of a modelling and optimization process on the development of a software tool for trip guidance among cities with the goal to maximize the quantity of visited places and minimizing the budget spent on the trip. With the use of a mathematical model, verifying with a computational methods tool (GAMS) and generating appropriate metaheuristics (SPEA 2), this paper illustrates the basis for implementing a project of such magnitude and what it would take to make it a reality.

*Key Terms –* Multi-objective optimization, evolutionary algorithms, mathematical modelling, touristic guidance, transport.

# INTRODUCTION

T

RAVELLING represents one of the most enriching experiences for the contemporaneous human because it allows him to leaving his sedentary nature and discover new places, flavors and people. In spite of this, not everyone has the same preferences or restrictions at the moment of planning a new journey, in other words, parameters as the number of available days for travelling, cities for visiting, budget, among others, are too specific for each traveler. This means that there exist numerous ways to execute a journey, for which it is desirable that every planned journey is the best among the available alternatives.

# PROBLEM DEFINITION

From the point of view of the traveler, the best journey is that which minimizes costs. Here, a good journey is defined by the quantity of visited places and the quality of these. In other words, the problem to attack is to minimize the cost of travelling maximizing the amount and quality of the visited places. Under this premise, the variables taken into consideration re the next ones:

**Places to visit:** Each traveler has a list of the places he would like to potentially visit in his next journey.

**Places’ score:** Each place must have a score which must be comparable to other places´, in order to decide which of them is better.

**Time:** A traveler has a limited time window to accomplish his journey.

**Living cost (daily):** The traveler must afford his own living in each place he visits. For this, the cost of average living per place is going to be used.

**Transport costs:** Moving from one place to another implies some costs. For now, only terrestrial means will be considered in such parameter.

**Maximum number of days per place:** This, with the goal of giving every traveler enough time (the one he/she considers necessary) to know each place he visits, meaning, the planned number of days in each place must not surpass this number. This parameter also allows us to avoid the model to only consider one city (with the best score and lowest living costs) by forcing the change after a certain quantity of days.

**Minimum number of days:** This number decide how much of a “nomad” can a traveler be, given a minimum threshold of days that can result in constant displacements. IN the opposite way, if it has a high value, the movement between places will be harshly reduced. This can e useful for travelers that don´t mind moving frequently or minimizing their displacements (e.g. Travelers with children, motor liabilities or the elderly).

# OBJECTIVES STABLISHMENT

1. Identify the best travelling plan given a set of places (cities) and the other proposed restrictions.

2. Identify and implement a metaheuristic that allows the program to find good solutions to the problem given a certain execution time threshold.

# MODEL FORMULATION AND PLANNING

## Model conceptualization

**Parameters**:

* mind; Minimum number of days.
* maxd: Maximum number of days.
* s: Starting point.
* d: Number of days.
* CT: Transport costs matrix for going from one city to another. Currently only terrestrial means are taken into account.
* CV: Average living costs array for every city.
* n: Number of cities.
* : Priority for maximizing the number of days.
* : Priority for minimizing the Budget spent.
* S: Scores matrix for city i with an interest point l.
* R: Quantity of reviews matrix for city i with an interest point l.

**Decision variable:**

In day *i*, the traveler stays in city *j*.

**Target function**: W estate a multi-objective model using the method of pondered summation of weights between the two proposed functions: quantity of days and spent Budget (divided in transport and living costs).

(1)

Where:

Formula () assigns a score to a destiny l proportional to his aggregated rating (average) and the number of persons that have rated the destination. The formula “normalizes” scores dividing them by 5 and seeks to penalize those destinations with a huge amount of reviews by calculating the squared root of such values. Due to the fact that there can be places without a huge popularity that should be considered in the travelling plan, this penalty is taken into consideration.

In equation (1), we decided to normalized both functions F1 (quantity of places) and F2 (costs function) with the use of two factors:

1. F1: Multiply by the minimum of the scores calculated in “Puntaje” times the number of days, plus 1
2. F2: Divide by the summation of the maximum cost of transport with the maximum average living cost, times d.

**Restrictions**:

1. The costs structure for going from one place to another must be represented in real numbers. Their value will always be greater or equal than zero.
2. The structure of costs for average living by day is represented with real numbers with values greater or equal than zero.
3. The scores structure is represented with real numbers ranging from 1 to 5.

Where l is the predefined number of points of interest per city. l

1. The structure of quantity of reviews is represented with real numbers bigger tan or equal to zero.

Where l is the predefined number of points of interest per city. l

1. The summation of the priorities must be equal to 1.
2. The priorities are rational numbers between 0 and1:
3. The person cannot surpass his minimum and maximum threshold of days per city during the journey:
4. The person cannot go to two cities on the same day:

*9)*  The first day (i=0) the person must go to someplace:

## Data Adquisition

Cost of living per city was extracted from Numbeo and transport costs were extracted from Rome2Rio. Specifically, data was retrieved manually but both sources expose API’s for automatization of this process, which we left for a further iteration as Rome2Rio API requires their approval.

An important consideration is that transport between any cities a and b is the cheapest found in the Rome2Rio ’query’ from city a to city b. As this cost might not be the same on both directions, a to b might have a different cost than b to a.

# MODEL TRADUCTION

In order to solve this complex problem, we translated the previous mathematical model into the algorithm SPEA 2 (a metaheuristic) in order to get an efficient answer. Before explaining the algorithm itself, the following design decisions were taken into account:

## Allele: <Id of the city visited on day 1>-<Id of the city visited on day 2>-….<Id of the city visited on day d>

## Euclidian distance with the two target functions:

## Since SPEA 2 already calculates the whole Pareto Front, the use of parameters P1 and P2 is no longer necessary.

# VERIFICATION AND VALIDATION

For the verification process, we used the language GAMS with the development environment “gamside” that allowed the proper translation of the mathematic model in order to solve the problem with mathematical methods that, despite not being optimal in time, i sable to find answers for the basic scenarios of the previously stated model through the use of a mixed integer non-linear problem solver (MINLP) like BONMIN or COUENNE.

In order to validate the metaheuristic stated in section V, multiple input files were created for our verification program in GAMS that would represent a series of scenarios with their respective parameters theoretically calculated without the help of any external source. For each one of such scenarios, a test was done with the code in both GAMS and Java. The results of these tests are:

1. *Base Scenario 1 (Basic functioning)*
   1. P2=0
   2. Mind=1 and Maxd=1
   3. d=4
   4. n=4
   5. The rest is random

EXPECTED: Travel to each city in one day.

GAMS:

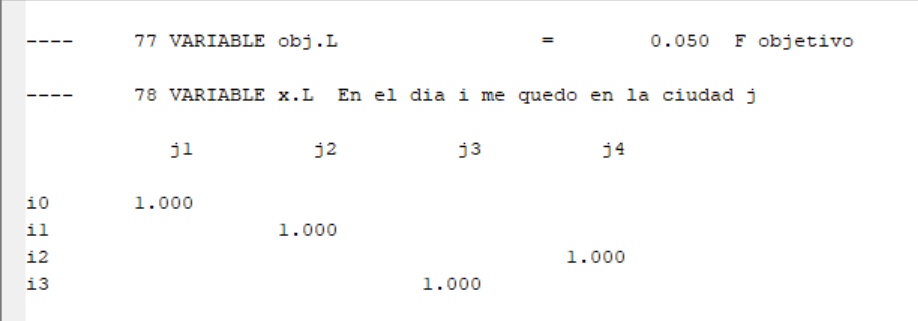


Fig 1. Resultado del escenario base 1 en GAMS

SPEA 2 (Java):

1. *Base Scenario 2 (Number of days):* 
   1. n=2
   2. mind=3
   3. maxd=5
   4. d=8
   5. s=1
   6. Puntaje(1)=10
   7. Puntaje(2)=1
   8. p1=1
   9. p2=0
   10. The rest is random

EXPECTED: 5 days in the first city, and 3 in the other one.

GAMS:

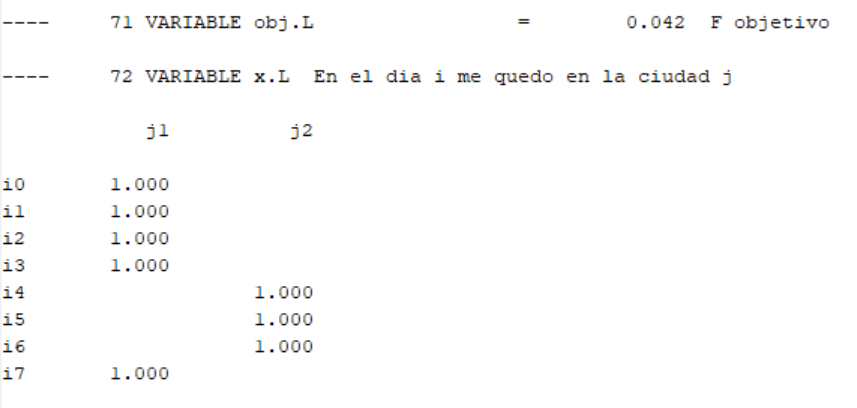


Fig 2. Resultado del escenario base 2 en GAMS

SPEA 2 (Java):

1. *Base Scenario 3 (Average living cost):*
   1. n=2
   2. mind=3
   3. maxd=5
   4. d=8
   5. s=1
   6. The values in the transport costs matrix are the same.
   7. p1=0
   8. p2=1
   9. The rest is random.

EXPECTED: 5 days in the first city, 3 in the other one.

GAMS:

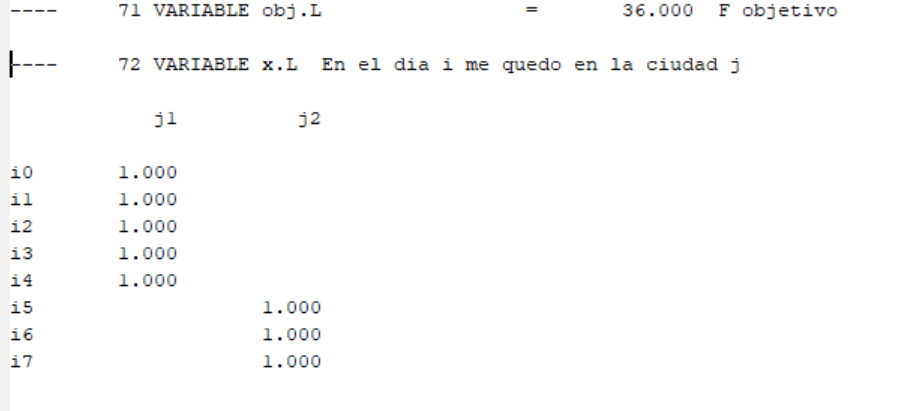


Fig 3. Resultado del escenario base 3

1. *Base Scenario 4 (Transport costs):* 
   1. n=3
   2. mind=|
   3. maxd=1
   4. d=3
   5. s=1
   6. p2=1
   7. p1=0



Fig 4. Tabla de costos del escenario base 4.

* 1. Average living cost is the same for every city.
  2. The rest is random

EXPECTED: Goes from city 1 to 2, and then from 2 to 3.

GAMS:

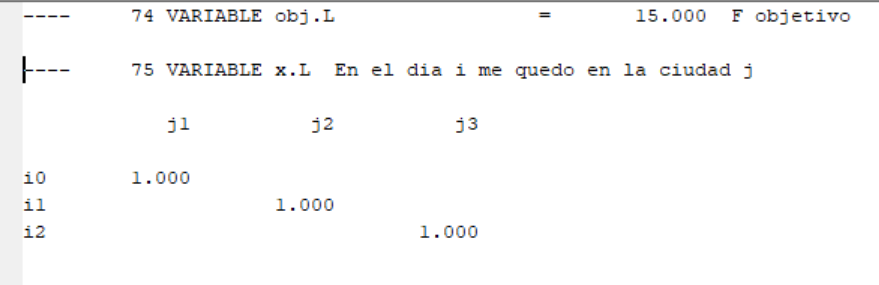


Fig 5. Resultado obtenido del escenario base 4 en GAMS

1. *Intermediate Scenario:*
   1. n=10
   2. 5 cities have high living cost and low scores (From city 1 to 5)
   3. 5 cities have low living cost and high scores (From city 6 to 10).
   4. Transport costs are the same.
   5. d=15
   6. maxd=3
   7. mind=1
   8. p1=0.5
   9. p2=0.5
   10. s: One of the cheap cities (from 6 to 10).
   11. The rest is random

EXPECTED: Go to the cheapest cities.

GAMS:

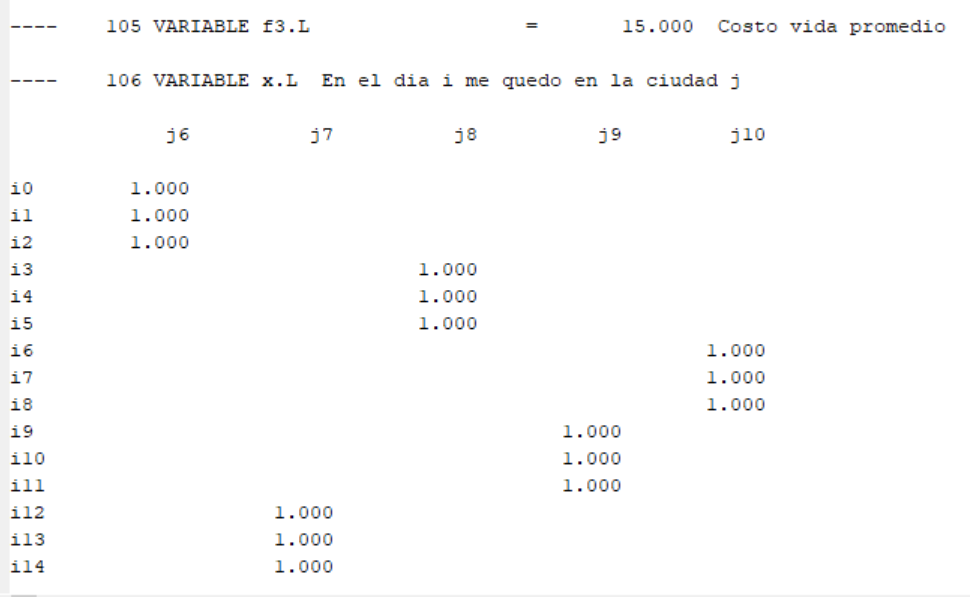


Fig 6. Resultado obtenido del escenario intermedio en GAMS

SPEA 2 (Java):

1. *Real life Scenario:* 
   1. n=16. The researched cities from Spain are in order:
      1. valencia
      2. barcelona
      3. sevilla
      4. granada
      5. málaga
      6. córdoba
      7. cádiz
      8. almería
      9. toledo
      10. salamanca
      11. madrid
      12. zaragoza
      13. pamplona
      14. bilbao
      15. segovia
      16. santander
   2. Transport costs are researched in “Rome2Rio”.
   3. Average living costs are researched in “Numbeo”.
   4. Scores and quantity of reviews are researched in Google.
   5. d=50
   6. maxd=5
   7. mind=2
   8. The rest is random

EXPECTED: Unknown

GAMS: Unknown

SPEA 2 (Java):

# RESULTS ANALYSIS

# CONCLUSIONS AND FUTURE WORK

TABLE I

Units for Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Conversion from Gaussian and  CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

aGaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

BIBLIOGRAPHY

Costos (y tiempos) aproximados entre ciudades: <https://www.rome2rio.com/es/map/Bogot%C3%A1/Santa-Marta>[[1]](#footnote-1)

Costo de vida promedio: <https://www.numbeo.com/cost-of-living/>

Puntajes y cantidad de reviews: <https://www.google.com.co/destination/map/topsights?q=Bogot%C3%A1&sa=X&site=search&output=search&dest_mid=%2Fm%2F01dzyc&dest_mid=%2Fm%2F01dzyc&tcfs>

*Basic format for books:*

1. J. K. Author, “Title of chapter in the book,” in *Title of His Published Book, x*th ed. City of Publisher, Country if not
2. USA: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx.*

*Examples:*

1. G. O. Young, “Synthetic structure of industrial plastics,” in *Plastics,* 2nd ed., vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
2. W.-K. Chen, *Linear Networks and Systems.* Belmont, CA: Wadsworth, 1993, pp. 123–135.

*Basic format for periodicals:*

1. J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. *x,* no. *x,* pp*. xxx-xxx,* Abbrev. Month, year.

*Examples:*

1. J. U. Duncombe, “Infrared navigation—Part I: An assessment   
   of feasibility,” *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959.
2. E. P. Wigner, “Theory of traveling-wave optical laser,” *Phys. Rev*.,   
   vol. 134, pp. A635–A646, Dec. 1965.
3. E. H. Miller, “A note on reflector arrays,” *IEEE Trans. Antennas Propagat*., to be published.

*Basic format for reports:*

1. J. K. Author, “Title of report,” Abbrev. Name of Co., City of Co., Abbrev. State, Rep. *xxx*, year.

*Examples:*

1. E. E. Reber, R. L. Michell, and C. J. Carter, “Oxygen absorption in the earth’s atmosphere,” Aerospace Corp., Los Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.
2. J. H. Davis and J. R. Cogdell, “Calibration program for the 16-foot antenna,” Elect. Eng. Res. Lab., Univ. Texas, Austin, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

*Basic format for handbooks:*

1. *Name of Manual/Handbook*, *x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, year, pp. *xxx-xxx.*

*Examples:*

1. *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.
2. *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, 1989.

*Basic format for books (when available online):*

1. Author. (year, month day). *Title.* (edition) [Type of medium]. *volume (issue).* Available: site/path/file

*Example:*

1. J. Jones. (1991, May 10). *Networks.* (2nd ed.) [Online]. Available: [http://www.atm.com](http://www.atm.com/)

*Basic format for journals (when available online):*

1. Author. (year, month). Title. *Journal.* [Type of medium]. *volume (issue),* pages. Available: site/path/file

*Example:*

1. R. J. Vidmar. (1992, Aug.). On the use of atmospheric plasmas as electromagnetic reflectors. *IEEE Trans. Plasma Sci.* [Online]. *21(3),* pp. 876–880. Available:<http://www.halcyon.com/pub/journals/21ps03-vidmar>

*Basic format for papers presented at conferences (when available online):*

1. Author. (year, month). Title. Presented at Conference title. [Type of Medium]. Available: site/path/file

*Example:*

1. PROCESS Corp., MA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at   
   INET96 Annual Meeting. [Online]. Available: <http://home.process.com/Intranets/wp2.htp>

*Basic format for reports and handbooks (when available online):*

1. Author. (year, month). Title. Comp an y . C ity, State or Country. [Type of Medium]. Available: site/path/file

*Example:*

1. S. L. Tall een. (1996 , Apr . ). The In t r an et Archi -tecture: M a nagi ng i n f o rm at i on i n t h e ne w paradigm. Amdahl Corp., CA. [Online]. Available:<http://www.amdahl.com/doc/products/bsg/intra/infra/html>

*Basic format for computer programs and electronic documents (when available online):* ISO recommends that capitalization follow the accepted practice for the language or script in which the information is given.

*Example:*

1. A. Harriman. (1993, June). Compendium of genealogical software. *Humanist.* [Online]. Available e-mail: [HUMANIST@NYVM.ORG](mailto:HUMANIST@NYVM.ORG) Message: get GENEALOGY REPORT

*Basic format for patents (when available online):*

1. Name of the invention, by inventor’s name. (year, month day). *Patent Number* [Type of medium]. Available: site/path/file

*Example:*

1. Musical toothbrush with adjustable neck and mirror, by L.M.R. Brooks. (1992, May 19). *Patent D 326 189*

[Online]. Available: NEXIS Library: LEXPAT File: DESIGN

*Basic format for conference proceedings (published):*

1. J. K. Author, “Title of paper,” in *Abbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), year, pp. *xxxxxx.*

*Example:*

1. D. B. Payne and J. R. Stern, “Wavelength-switched pas- sively coupled single-mode optical network,” in *Proc. IOOC-ECOC,* 1985,   
   pp. 585–590.

*Example for papers presented at conferences (unpublished):*

1. D. Ebehard and E. Voges, “Digital single sideband detection for interferometric sensors,” presented at the 2nd Int. Conf. Optical Fiber Sensors, Stuttgart, Germany, Jan. 2-5, 1984.

*Basic format for patents:*

1. J. K. Author, “Title of patent,” U.S. Patent *x xxx xxx*, Abbrev. Month, day, year.

*Example:*

1. G. Brandli and M. Dick, “Alternating current fed power supply,”   
   U.S. Patent 4 084 217, Nov. 4, 1978.

*Basic format**for theses (M.S.) and dissertations (Ph.D.):*

1. J. K. Author, “Title of thesis,” M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.
2. J. K. Author, “Title of dissertation,” Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

*Examples:*

1. J. O. Williams, “Narrow-band analyzer,” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.
2. N. Kawasaki, “Parametric study of thermal and chemical nonequilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

*Basic format for the most common types of unpublished references:*

1. J. K. Author, private communication, Abbrev. Month, year.
2. J. K. Author, “Title of paper,” unpublished.
3. J. K. Author, “Title of paper,” to be published.

*Examples:*

1. A. Harrison, private communication, May 1995.
2. B. Smith, “An approach to graphs of linear forms,” unpublished.
3. A. Brahms, “Representation error for real numbers in binary computer arithmetic,” IEEE Computer Group Repository, Paper R-67-85.

*Basic format for standards:*

1. *Title of Standard*, Standard number, date.

*Examples:*

1. IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.
2. Letter Symbols for Quantities, ANSI Standard Y10.5-1968.

**First A. Author** (M’76–SM’81–F’87) and the other authors may include biographies at the end of regular papers. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author’s educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year the degree was earned. The author’s major field of study should be lower-cased.

The second paragraph uses the pronoun of the person (he or she) and not the author’s last name. It lists military and work experience, including summer and fellowship jobs. Job titles are capitalized. The current job must have a location; previous positions may be listed without one. Information concerning previous publications may be included. Try not to list more than three books or published articles. The format for listing publishers of a book within the biography is: title of book (city, state: publisher name, year) similar to a reference. Current and previous research interests end the paragraph.

The third paragraph begins with the author’s title and last name (e.g., Dr. Smith, Prof. Jones, Mr. Kajor, Ms. Hunter). List any memberships in professional societies other than the IEEE. Finally, list any awards and work for IEEE committees and publications. If a photograph is provided, the biography will be indented around it. The photograph is placed at the top left of the biography, and should be of good quality, professional-looking, and black and white (see above example). Personal hobbies will be deleted from the biography. Following are two examples of an author’s biography.

**Second B. Author** was born in Greenwich Village, New York City, in 1977. He received the B.S. and M.S. degrees in aerospace engineering from the University of Virginia, Charlottesville, in 2001 and the Ph.D. degree in mechanical engineering from Drexel University, Philadelphia, PA, in 2008.

From 2001 to 2004, he was a Research Assistant with the Princeton Plasma Physics Laboratory. Since 2009, he has been an Assistant Professor with the Mechanical Engineering Department, Texas A&M University, College Station. He is the author of three books, more than 150 articles, and more than 70 inventions. His research interests include high-pressure and high-density nonthermal plasma discharge processes and applications, microscale plasma discharges, discharges in liquids, spectroscopic diagnostics, plasma propulsion, and innovation plasma applications. He is an Associate Editor of the journal *Earth*, *Moon*, *Planets*, and holds two patents.

Mr. Author was a recipient of the International Association of Geomagnetism and Aeronomy Young Scientist Award for Excellence in 2008, the IEEE Electromagnetic Compatibility Society Best Symposium Paper Award in 2011, and the American Geophysical Union Outstanding Student Paper Award in Fall 2005.

**Third C. Author, Jr. (M’87)** received the B.S. degree in mechanical engineering from National Chung Cheng University, Chiayi, Taiwan, in 2004 and the M.S. degree in mechanical engineering from National Tsing Hua University, Hsinchu, Taiwan, in 2006. He is currently pursuing the Ph.D. degree in mechanical engineering at Texas A&M University, College Station.

From 2008 to 2009, he was a Research Assistant with the Institute of Physics, Academia Sinica, Tapei, Taiwan. His research interest includes the development of surface processing and biological/medical treatment techniques using nonthermal atmospheric pressure plasmas, fundamental study of plasma sources, and fabrication of micro- or nanostructured surfaces.

Mr. Author’s awards and honors include the Frew Fellowship (Australian Academy of Science), the I. I. Rabi Prize (APS), the European Frequency and Time Forum Award, the Carl Zeiss Research Award, the William F. Meggers Award and the Adolph Lomb Medal (OSA).

1. Costos de transporte: Se mandó la propuesta para solicitar acceso al API de Rome2Río que contiene costos de desplazamiento entre ciudades sobre diferentes medios de transporte. Sin embargo, la solicitud no ha sido respondida por lo que es necesario extraer los datos manualmente . [↑](#footnote-ref-1)