

Marcos Goycoolea Guzmán

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Research Interest

Marcos is interested in the study and development of computational optimization methodologies. During the last years he has focused on project management, with applications in scheduling large mining operations. He is also interested in general mixed integer programming methodologies and the traveling salesman problem. Marcos is a founding partner of Alicanto Labs, a small R&D company that develops and transfers optimization tools for strategic mine planning.

- Production scheduling in mining.
- Computational methods for integer programming and combinatorial optimization.
- The Traveling Salesman Problem.

Bibliographical Information

Complete Name	Marcos Goycoolea Guzman
Date of Birth	November 27, 1975
City of Birth	St. Paul, MN. USA
Country of Citizenship	Chile / USA

Education

- PHD, INDUSTRIAL ENGINEERING December, 2006.
School of Industrial and Systems Engineering
Georgia Institute of Technology. Atlanta, GA.
- MATHEMATICAL ENGINEER October, 2001.
Department of Mathematical Engineering.
Universidad de Chile. Santiago, Chile.

Academic and Professional Experience

ASSOCIATE PROFESSOR, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE Aug. 2023 -

I am an Associate Professor at the Escuela de Administración (Business School) of Pontificia Universidad Católica de Chile, where I teach Operations Management, Operations Research and Data Analytics at the under-graduate, masters, MBA and PhD levels.

PROFESSOR, SCHOOL OF BUSINESS, UNIVERSIDAD ADOLFO IBAÑEZ (UAI) Aug. 2006 - Feb. 2023.

I taught Operations Management, Operations Research and Data Analytics at the under-graduate, masters, MBA and PhD levels. During most of my tenure at UAI I was head of the Business Analytics and

Operations Group, comprised of ten faculty members at the time I left. Starting in 2015, and for three years, I was research director of the business school.

ASSOCIATE RESEARCHER, CENTER FOR MATHEMATICAL MODELING (CMM) 2022 - Present.

I am a member of the Center for Mathematical Modeling, a research conglomerate led by researchers from the Department of Mathematical Engineering of Universidad de Chile.

DIRECTOR, ALICANTO LABS 2018 - Present.

I am a founding partner and lead of Alicanto Labs, technology startup focused on optimization for strategic mine planning. Alicanto develops advanced planning software for the mining industry that is distributed by Deswik, a major developer of mine planning software based in Australia. Deswik.GO, their strategic mine planning software, uses the Alicanto Solver to power its optimization processes for direct block scheduling and production scheduling of open pit mines. Alicanto has advised, both directly and indirectly, many of the world's largest mining companies on strategic planning decisions.

Journal Publications

1. “*A target-time-windows technique for project scheduling under uncertainty.*” Lamas, P; Goycoolea, M; Newman, A; Pagnoncelli, B. European Journal of Operational Research. Accepted (October, 2023).
2. “*Optimization Strategies for Resource-Constrained Project Scheduling Problems in Underground Mining.*” Hill, A; Brickey, A; Cipriano, I; Goycoolea, M; Newman, A. INFORMS Journal on Computing. Published Online Augusted 12, 2022.
3. “*Predicting out-of-stocks using machine learning: an application in a retail packaged foods manufacturing company.*” J.M. Rozas, G.A. Ruz, and M. Goycoolea. Electronics. Volume 10, 2787, 2021.
4. “*Underground Mine Scheduling Under Uncertainty.*” P. Nesbitt; L. Blake, P. Lamas, M. Goycoolea; B. Pagnoncelli, A. Newman; A. Brickey. European Journal of Operational Research. Volume 294, Issue 1. pp 340 – 352. 2021.
5. “*Lane’s Algorithm Revisited.*” M. Goycoolea, P. Lamas, B. Pagnoncelli and A. Piazza. Management Science. Volume 67, Issue 5, pp 3087 – 3103, 2021.
6. “*Barrick’s Turquoise Ridge Gold Mine Optimizes Underground Production Scheduling Operations.*” A. Brickey, A. Chowdu, A. Newman, M. Goycoolea and R. Godard. INFORMS Journal of Applied Analytics. Forthcoming. Volume 51. Issue 2. pp 91–165. 2021.
7. “*The Generalized Reserve Set Covering Problem with Connectivity and Buffer Requirements.*” E. Alvarez-Miranda, M. Goycoolea, I. Ljubic, and M. Sinnl. European Journal of Operational Research. Volume 289, Issue 3. pp 1013–1029. 2021.
8. “*Production scheduling for strategic open pit mine planning: A mixed integer programming approach.*” O. Rivera, D. Espinoza, M. Goycoolea, E. Moreno and G. Munoz. Operations Research. Volume 68. Issue 5. pp 1285– 1624. 2020.
9. “*A Multi-Mode Resource-Constrained Project Scheduling Reformulation for the Waterway Ship Scheduling Problem*” has been accepted for publication in *Journal of Scheduling.*” A. Hill, E. Lalla-Ruiz, S. Voss, and M. Goycoolea. Journal of Scheduling. Volume 22. Issue 2. pp 173–182. 2019.

10. “*A study of the Bienstock-Zuckerberg algorithm, Applications in Mining and Resource Constrained Project Scheduling.*”. G. Munoz, D. Espinoza, M. Goycoolea, M. Queyranne, and O. Rivera. Computational Optimization and Applications. Volume 69, Issue 2. pp 501–534. 2018.
11. “*Optimizing the open pit-to-underground mining transition.*” B. King, M. Goycoolea, and A. Newman. European Journal of Operational Research. Volume 257, Issue 1. pp 297–309. 2017.
12. “*The precedence constrained knapsack problem: Separating maximally violated inequalities.*” D. Espinoza, M. Goycoolea and E. Moreno. Discrete Applied Mathematics. Volume 194, pp 65-80. 2015.
13. “*Imposing Connectivity Constraints in Forest Planning Models.*” R. Carvajal, M. Constantino, M. Goycoolea, JP. Vielma, and A. Weintraub. Operations Research. Volume 61 Issue 4, July-August 2013, pp. 824-836.
14. “*MineLib: A library of open pit mining problems.*” D. Espinoza, M. Goycoolea, E. Moreno and A. Newman. Annals of Operations Research. Volume: 206 Issue 1 Pages: 93-114. 2013.
15. “*A new algorithm for the open-pit mine scheduling problem.*” R. Chicoisne, D. Espinoza, M. Goycoolea, E. Moreno and E. Rubio. Operations Research. Volume 60. Issue 3. Pages 517–528.
16. “*Lifting, tilting and fractional programming revisited.*” D. Espinoza, R. Fukasawa and Marcos Goycoolea. Operations Research Letters. Volume 38, Issue 6, November 2010, Pages 559-563
17. “*On the exact separation of mixed integer knapsack cuts*” R. Fukasawa and Marcos Goycoolea. Mathematical Programming. Volume 128. Issue: 1-2. Pages 19-41. 2011.
18. “*A heuristic to generate rank-1 GMI cuts.*” S. Dash and Marcos Goycoolea. Mathematical Programming Computations. Volume 2, Number 4. 2010.
19. “*Generalized domino-parity inequalities for the symmetric traveling salesman problem*” W. Cook, D. Espinoza, and Marcos Goycoolea. Mathematics of Operations Research. Volume 35, Number 2. 2010. pp. 479–493.
20. “*Two step MIR inequalities for mixed-integer programs*” S. Dash, Marcos Goycoolea, and O. Gunluk. INFORMS Journal on Computing. Volume 22, Issue 2. 2010. pp. 236–249.
21. “*Numerically safe gomory mixed-integer cuts.*” W. Cook, S. Dash, R. Fukasawa and Marcos Goycoolea. INFORMS Journal on Computing, 2009. Volume 21. Number 4. Fall, 2009. pp. 641–649.
22. “*Evaluating alternative approaches to solving the ARM problem.*” Marcos Goycoolea, J. Vielma, A. Murray, and A. Weintraub. Forest Science. Vol. 55, No 2. April, 2009. pp.149–165 (17).
23. “*Certification of an optimal TSP tour through 85,900 cities*” D. Applegate, R. Bixby, V. Chvatal, W. Cook, D. Espinoza, Marcos Goycoolea and K. Helsgaun. Operations Research Letters. Vol. 37, No. 1. January, 2009. pp 11 – 15.
24. “*Per-Seat, On-Demand Air Transportation Part II: Problem Description and an Integer Multi-Commodity Flow Model.*” Daniel Espinoza, Renan Garcia, Marcos Goycoolea, George Nemhauser, and Martin Savelsbergh. Transportation Science. Vol. 42, No.3, August 2008, pp279–291.
25. “*Per-Seat, On-Demand Air Transportation Part I: Problem Description and an Integer Multi-Commodity Flow Model.*” Daniel Espinoza, Renan Garcia, Marcos Goycoolea, George Nemhauser, and Martin Savelsbergh. Transportation Science. Vol. 42, No.3, August 2008, pp263–278.
26. “*Computing with Domino-Parity Inequalities for the TSP*”. William Cook, Daniel Espinoza, Marcos Goycoolea. Informs Journal of Computing. Volume 19, Number 3, Summer 2007, pp 356 – 365.

27. “*Harvest scheduling subject to maximum area restrictions : exploring exact approaches.*” Marcos Goycoolea, Alan T. Murray, Francisco Barahona, Rafael Esptein, Andres Weintraub. Operations Research. Volume 53, Number 3, 2005. pp 490–500.
28. “*A Study of the Domino Parity and k-Parity Constraints for the TSP.*” William Cook, Daniel Espinoza, Marcos Goycoolea. Proceedings of the 11th Conference on Integer Programming and Combinatorial Optimization (IPCO 2005). Lecture Notes in Computer Science. Volume 3509, 2005. pp 452 – 467. Springer Berlin / Heidelberg.
29. “*Incorporating average and maximum area restrictions in harvest scheduling models.*” A.T. Murray, M. Goycoolea, and A. Weintraub. Canadian Journal of Forest Research, 34, 2004, 456-464.

Other publications

1. “*Mine schedule optimization and mine operational realities: bridging the gap.*” Brickey, A; Chowdu; Goycoolea, M. Proceedings of 39th APCOM. Wroclaw, Poland. June, 2019.
2. “*A two-stage stochastic model for open pit mine planning under geological uncertainty.*” Moreno, E; Emery, X; Goycoolea, M; Morales, N; Nelis, G. Proceedings of 38th APCOM. 2017. pp 13-27 to 13-33.
3. “*New integer programming models for tactical and strategic underground production scheduling.*” B. King, M. Goycoolea, A. Newman. Mining Engineering. Volume 69, Issue 3. March, 2017. pp 37–42.
4. “*Comparing New and Traditional Methodologies for Production Scheduling in Open Pit Mining.*” M. Goycoolea, D. Espinoza, E. Moreno, O. Rivera. Proceedings of APCOM. Fairbanks, Alaska. May, 2015. pp 352-359.
5. “*Linear Programming Approximations for Modeling Instant-Mixing Stockpiles.*” E. Moreno, F. Ferreira, M. Goycoolea, D. Espinoza, A. Newman, M. Rezakhah. Proceedings of APCOM. Fairbanks, Alaska. May, 2015. pp 582-587.
6. “*Direct optimization of an open cut scheduling policy.*” M. Goycoolea, E. Moreno, and O. Rivera. Proceedings of APCOM. November, 2013. Porto Alegre, Brasil.
7. “*Open pit mine scheduling under uncertainty: a robust approach.*” D. Espinoza, M. Goycoolea, E. Moreno, G. Munoz and M. Queyranne. Proceedings of APCOM. November, 2013. Porto Alegre, Brasil.
8. “*Large-scale multi-period precedence constrained knapsack problems: A mining application.*” E. Moreno, D. Espinoza, and Marcos Goycoolea. Electronic Notes in Discrete Mathematics. Volume 36, 2010. p407-414. Proceedings of ISCO. March, 2010. Tunisia.
9. “*A scalable approach to optimal block sequencing.*” J. Amaya, D. Espinoza, Marcos Goycoolea, E. Moreno, T. Prevost and E. Rubio. Proceedings of APCOM. October, 2009. Vancouver.
10. “*On the Exact Separation of Mixed Integer Knapsack Cuts*” R. Fukasawa and Marcos Goycoolea. Proceedings of the 12th Conference on Integer Programming and Combinatorial Optimization (IPCO 2007). Lecture Notes in Computer Science. Volume 4513, 2007. pp 225 – 239. Springer Berlin / Heidelberg.
11. “*Comparing Alternative Formulations for the ARM.*” J. Vielma, Marcos Goycoolea, A. Murray and A. Weintraub. Forthcoming. Proceedings of the 12th Symposium for Systems Analysis in Forest Resources 2006 (SSAFR’06).

12. “An adjacency-modeling problem based on constructing harvesting areas.” R. Epstein, M. Goycoolea, A.T. Murray and A. Weintraub, In Systems Analysis in Forest Resources, edited by G.J. Arthaud and T.M. Barrett, 2003, 279-289 (Dordrecht: Kluwer Scientific).

Research Grants

“An integer programming approach to production scheduling, with applications in mining, astronomy and other problems.”. 2023 - 2026. One of three principal investigators and director. FONDECYT 1231092. USD \$106,000 (CLP \$89,300,000).

“Sistema integral de planificación minera sujeto a incertidumbre geometalúrgica.” (Comprehensive system for mine planning subject to geometalurgical uncertainty. 2022 - 2023. One of three principal researchers and director (Together with Eduardo Moreno and Nicolas Loira). FONDEF ID21—10184. USD \$300,000.

“Alicanto Scheduler: Optimización en gestión de proyectos para planificación minera subterránea.” (Alicanto Scheduler: Optimization for project management in underground mine planning. 2019 - 2021. One of three principal researchers and sub-director (Together with Eduardo Moreno and Nicolas Loira). FONDEF ID19—10164. USD \$350,000.

“Packaging and validation of Alicanto Scheduler, a new optimization technology for mine planning.” 2019-2020. Validation and Packaging of Innovations. CORFO Innova Chile. One of three principal researchers and sub-director. USD \$380,000.

“Facilitating the use of advanced optimization tools in Chile and UAI.” 2018-2019. MISTI MIT-Chile Seed Fund. One of four principal investigators. USD \$25,080.

“Tecnologías de optimización en gestión de proyectos para la resolución de problemas de planificación minera estratégica” (Project management technologies for solving strategic mine planning problems). 2017-2018. Subdirector. CONICYT FONDEF IT16M100006. USD \$300,000.

“Large scale optimization and uncertainty: Challenges in strategic mine planning. An interdisciplinary approach.”. 2016 - 2018. Director, and one of five principal researchers. CONICYT Pia Anillo 1407. USD \$750,000.

“Production scheduling: a mathematical programming approach and applications to natural resource management.”. 2015 - 2019. One of three principal investigators and director. FONDECYT (Regular) 2015. USD \$180,000.

“Synergies for Ameliorations and Mastering of Branch-and-Price-and-Cut based Algorithms”. INRIA Associate Teams Program 2014. One of five principal investigators. EUR \$10,000 per year.

“Advanced Decomposition Techniques for Non-Linear Optimization.” 2013 - 2014. MISTI MIT-Chile Seed Fund. One of three principal investigators. USD \$25,050.

“Proximal cutting planes for mixed integer programming and applications to the traveling salesman problem and mixed integer second order cone programming.” 2011 - 2014. One of two principal investigators and director. FONDECYT (Regular) 2011. USD \$120,000.

“Mathematical Modeling for Industrial and Management Science Applications: An Interdisciplinary Approach.” 2010 - 2013. One of five principal investigators and sub-director. ANILLO ACT-88. USD\$900,000.

“Methodologies for Mixed Integer Linear Programming Models.” 2007 - 2010. Principal investigator and director. FONDECYT (Iniciación) 11075028. USD \$70,000.

“Sistemas complejos, computación evolutiva y aplicaciones a la planificación minera.” 2007 - 2010. One

of five principal investigators. FONDEF D06I1031. USD \$500,000.

Other Research Grants and Collaborations

Marcos has received funding and worked in direct collaboration with numerous mining companies, including CODELCO, Barrick Gold, Newmont Gold, GoldCorp, Newmont-GoldCorp, Teck Resources, the VALE Institute of Technology, and Deswik, among others. He has also collaborated with consulting firms, such as GeoInnova, NCL and others.

Distinctions

BEST PAPER IN ENERGY AND NATURAL RESOURCES November, 2023.

Awarded by the Energy and Natural Resources Section of the INFORMS Society for the paper “Optimization Strategies for Resource-Constrained Project Scheduling Problems in Underground Mining.”

KEYNOTE SPEAKER IN APCOM (RAPID CITY, NORTH DAKOTA) June, 2023.

Recent developments and trends in Strategic Mine Planning.

HENRY KRUMB LECTURER October, 2019.

Awarded by the Society of Mining Engineers for his lecture “Lane’s Algorithm Revisited: A New Look at Lane’s Cutoff Grade Optimization Algorithm.” Award given to eight participants for outstanding lectures in the conference (among over 5,000 attendees).

PLENARY SPEAKER IN THE INFORMS OPTIMIZATION SOCIETY MEETING March, 2018.

Large-scale Open Pit Mine Production-Scheduling.

WINNER OF THE 2017 CORFO TECHNOLOGY TRANSFER AWARD December, 2017.

Awarded by CORFO (Chilean Ministry of Economics) for the project “OMP: A Project Scheduling Approach to Mine Planning.”

HENRY KRUMB LECTURER October, 2017.

Awarded by the Society of Mining Engineers for his lecture “OMP: A Project Scheduling Approach to Mine Planning.” Award given to eight participants for outstanding lectures in the conference (among over 5,000 attendees).

BEST PAPER IN ENERGY AND NATURAL RESOURCES November, 2015.

Awarded by the Energy and Natural Resources Section of the INFORMS Society for the paper “Imposing Connectivity Constraints in Forest Planning Models.”

BEST PAPER IN ENERGY AND NATURAL RESOURCES November, 2007.

Awarded by the Energy and Natural Resources Section of the INFORMS Society for the paper “Harvest scheduling subject to maximum area restrictions : exploring exact approaches.”

GOIZUETA FOUNDATION FELLOW, GEORGIA INSTITUTE OF TECHNOLOGY Fall, 2005 - July, 2006.

PRESIDENTIAL FELLOW, GEORGIA INSTITUTE OF TECHNOLOGY Fall, 2001 - May, 2006.

Students

- July, 2023. Fabian Badilla. *Técnicas de optimización discreta para la compresión de redes neuronales*. Thesis Supervisor (with Gonzalo Muñoz). Masters in Mathematical Engineering. Universidad de Chile.
- December, 2022. Juan Manuel Rozas. Thesis Supervisor (with Gonzalo Ruz). PhD in Complex Systems. Universidad Adolfo Ibañez.
- June, 2021. Patricio Lamas. *Mine Project Scheduling: Deterministic and Stochastic Models*, Thesis Supervisor (with Bernardo Pagnoncelli). PhD in Industrial Engineering and Operations. Universidad Adolfo Ibañez.
- February, 2021. Orlando Rivera. *Applications of Integer Programming and Decomposition to Scheduling Problems: the Strategic Mine Planning Problem and the Bin Packing Problem with Time Lags*. Thesis Supervisor (with Ruslan Sadykov). Joint Degree. PhD in Industrial Engineering and Operations. Universidad Adolfo Ibañez. PhD in Mathematics. University of Bordeaux, France.
- March, 2015. Orlando Rivera. *Modelos de planificación de la producción para la minería de rajo*. Thesis Supervisor. Master in Engineering Sciences. Universidad Adolfo Ibañez.
- July, 2012. Gonzalo Muñoz. *Modelos de optimización lineal entera y aplicaciones a la minería*. Thesis Co-Supervisor. Mathematical Engineer. Universidad de Chile.
- November, 2009. Alvaro Gajardo. *Gestión de la información del punto de venta por parte del personal outsourcing de Kimberly-Clark*. Thesis supervisor. Industrial Engineering. Universidad Adolfo Ibañez.
- September, 2009. Renaud Chicoisne. *Bounds in large open-pit mine scheduling problems*. Thesis supervisor, Master 2 Recherche, Recherche Operationnelle et Productique. POLYTECH Clermont-Ferrand
- August, 2009. Rodolfo Carvajal. *Imposing connectivity constraints in forest planning models*. Supervisor of two-year directed research project. Universidad Adolfo Ibañez.
- June, 2008. Thomas Prevost. *Local search in open pit mines scheduling*. Supervisor of two-year directed research project. Universidad Adolfo Ibañez.

Other academic activities

ASSOCIATE EDITOR. Mathematical Programming Computations (2016 - 2019).

PEER-REVIEWING OF ACADEMIC JOURNALS. Reviewer of different journals, including *Operations Research*, *Management Science*, *Mathematical Programming*, *European Journal of Operational Research*, *Lecture Notes in Computer Science*, *Forest Science*, *Canadian Journal of Forest Science*, *Annals of Operations Research*, *Computers and Operations Research*, *Omega*, *Proceedings of APCOM*, among others.

ORGANIZATION AND SUPPORT OF INTERNATIONAL CONFERENCES / WORKSHOPS. Chair of 2018 DEPLAMIN Mine Planning Workshop in Santa Cruz, Chile. Member of the program committee for CLAIO 2016 (XVIII Conferencia Latino Iberoamericana de Investigación Operativa), member of the organizing committee of IPCO 2013 (Valparaiso, Chile),, chair of the Valparaiso Integer Programming Workshop 2012 (Valparaiso, Chile), member of the organizing committee for SSAFR 2011 (Marbella, Chile), member of the program committee for IPCO 2010 (Lausanne, Switzerland).

GRANT EVALUATIONS. Marcos has participated in the “Engineering 2” grant evaluation panel of FONDECYT / CONICYT (2011-2015). Was in charge of evaluating and coordinating the evaluation of post-doctoral, young-researcher and regular grants in Industrial Engineering and Operations Research.

ADMINISTRATIVE DUTIES. Head of the Business School Operations Group (2020 - Present). Research Director of the business school (2015 - 2018). Subdirector and member of the program committee (2007-2010) and interim director (2011) of the Universidad Adolfo Ibañez Management PhD Program. Member of the program committee of the Universidad Adolfo Ibañez Industrial Engineering and Operations Research PhD Program (2017). Head of the Operations group at the Universidad Adolfo Ibañez business school (2010 - 2015), and member of the intellectual contribution committee of the Universidad Adolfo Ibañez business school (2009 - present).