A History of Operations Research Optimization in the Petroleum Industry

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Abstract

In the petroleum industry, references to a new science called Operations Research appeared in the literature in the late 1950s; however, over the last 60 years, use of Operations Research optimization techniques in the petroleum industry has been sporadic, resulting in vast untapped optimization opportunities. Some subsets of the petroleum industry have successfully used Operations Research optimization techniques for specific applications; however, when these techniques were not used by the industry, the stated reasons involved difficulty dealing with non-linearities and stochastic elements, insufficient computational power to solve realistic models, and the necessity for specialized knowledge of Operations Research optimization software and solvers. In this paper we provide a history of the use of Operations Research optimization methods in the petroleum industry by presenting a comprehensive review of papers that use these techniques. We focus on linear, non-linear, integer, and mixed-integer optimization methods and the evolution of these models in the petroleum industry over time. Finally, we provide examples of sub-optimal optimization schemes and explore reasons for the lack of Operations Research optimization use in the petroleum industry.

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Al-Khalifa, H. H. 2013. Produced Water Re-Injection System Optimization: Recipe to Improve Efficiency. Presented at the SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain, 10-13 March. SPE-164372-MS. https://doi.org/10.2118/164372-MS.

Ali, H. M., Beasley, J. F., Batchilor, A. S. J., 1977. Mathematical Models to Help Manage the Oil Resources Of Kuwait. Presented at the SPE Annual Technical Conference and Exhibition, Denver, CO, 9-12 October. SPE-6711-MS. https://doi.org/10.2118/6711-MS.

Allen, F. H., and Jones, K. R. 1961. Operations Research, A New Discipline of Interest to the Petroleum Engineer. Journal of Petroleum Technology 13 (01): 11–15. SPE-1658-G-PA. https://doi.org/10.2118/1658-G-PA.

Aronofsky, J. S. 1963. Operations Research and the Management of Large Crude Reservoirs. Presented at the 6th World Petroleum Congress, Frankfurt am Main, Germany, 19-26 June. WPC-10710. https://www.onepetro.org/conference-paper/WPC-10710.

Aronofsky, J. S. 1967. Relationship Between Data Processing and Operations Research. Presented at the 7th World Petroleum Congress, Mexico City, Mexico, 2-9 April. WPC-12561. https://www.onepetro.org/conference-paper/WPC-12561.

Arsie, A., and Belorgey, M. 1998. Multi-Layer Breakwater Optimization. Presented at the 8th International Offshore and Polar Engineering Conference, Montreal, Canada, 24-29 May. ISOPE-I-98-278. https://www.onepetro.org/conference-paper/ISOPE-I-98-278.

Attra, H. D., Wise, W. B., and Black, W. M. 1961. Application of Optimizing Techniques for Studying Field Producing Operations. Journal of Petroleum Technology 13 (01): 82–86. SPE-1338-G-PA. https://doi.org/10.2118/1338-G-PA.

Babcock, R. E., and Perry, R. H. 1968. Non-Linear Dynamic Programming of Hydraulic Fracturing Models. Presented at the 43rd Fall Meeting of the Society of Petroleum Engineers of AIME, Houston, TX, 29 September - 2 October. SPE-2159-MS. https://doi.org/10.2118/2159-MS.

Bartholomew, T. V., and Mauter, M. S. 2016. Multiobjective Optimization Model for Minimizing Cost and Environmental Impact in Shale Gas Water and Wastewater Management. ACS Sustainable Chemistry & Engineering 4 (7): 3728–35. https://doi.org/10.1021/acssuschemeng.6b00372.

Bohannon, J. M. 1970. A Linear Programming Model for Optimum Development of Multi-Reservoir Pipeline Systems. Journal of Petroleum Technology 22 (11): 1429–36. SPE-2626-PA. https://doi.org/10.2118/2626-PA.

Boyd, W. E. 1967. Better Investment Planning of Gas-Producing

Operations By Computer Simulation. Journal of Petroleum Technology 19 (02): 157–62. SPE-1502-PA. https://doi.org/10.2118/1502-PA.

Bratvold, R. B., and Koch, F. 2011. Game Theory in the Oil and Gas Industry. The Way Ahead 07 (01): 18–20. SPE-0111-018-TWA. https://doi.org/10.2118/0111-018-TWA.

Brown, D. L., Wattenbarger, R. A., and Startzman, R. A. 1988. Linear Programming Optimization on Microcomputers. Presented at the Petroleum Computer Conference, San Jose, CA, 27-29 June. SPE-17777-MS. https://doi.org/10.2118/17777-MS.

Cain, G. M., and Shehata, M. T. 1982. A Computerized System To Optimize Daily Oil and Gas Production in Kuwait. Journal of Petroleum Technology 34 (03): 487–94. SPE-9622-PA. https://doi.org/10.2118/9622-PA.

Cantarelli, E., Kojadinovic, N., Le, K. P. D., 2017. Invisible Lost Time Reduction and Drilling Risk Management Optimization in United Arab Emirates Onshore Field. Presented at the Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE, 13-16 November. SPE-188640-MS. https://doi.org/10.2118/188640-MS.

Carroll, J. A., and Horne, R. N. 1992. Multivariate Optimization of Production Systems. Journal of Petroleum Technology 44 (07): 782–831. SPE-22847-PA. https://doi.org/10.2118/22847-PA.

Cho, H., and Shah, S. N. 2002. Optimization of Well Length for Horizontal Drilling. Journal of Canadian Petroleum Technology 41 (05): 53–65. PETSOC-02-05-03. https://doi.org/10.2118/02-05-03.

Coats, K. H., Dempsey, J. R., and Henderson, J. H. 1970. A New Technique for Determining Reservoir Description from Field Performance Data. Society of Petroleum Engineers Journal 10 (01): 66–74. SPE-2344-PA. https://doi.org/10.2118/2344-PA.

Codas, A., and Camponogara, E. 2012. Mixed-Integer Linear Optimization for Optimal Lift-Gas Allocation with Well-Separator Routing. European Journal of Operational Research 217 (1): 222–31. https://doi.org/10.1016/j.ejor.2011.08.027.

Conway, F. M. 1963. Contributions of Linear Programing. Presented at the 6th World Petroleum Congress, Frankfurt am Main, Germany, 19-26 June. WPC-10636. https://www.onepetro.org/conference-paper/WPC-10636.

Crumpton, P. I., Habiballah, W. A., Yerburgh, P. G., 2011. Multilateral-Complex Well Optimization. Presented at the SPE Reservoir Simulation Symposium, The Woodlands, TX, 21-23 February. SPE-140882-MS. https://doi.org/10.2118/140882-MS.

Currie, J. C., Novotnak, J. F., Aasboee, B. T., 1997. Optimized Reservoir Management With Mixed Linear Programming. SPE Computer Applications 9 (04): 103–6. SPE-37963-PA. https://doi.org/10.2118/37963-PA.

Debanne, J. G. 1970. The Operations Research Systems Approach And the Manager. Journal of Canadian Petroleum Technology 9 (03). PETSOC-70-03-02. https://doi.org/10.2118/70-03-02.

Ding, Z. X., and Startzman, R. A. 1996. A Software System for Oilfield Facility Investment Minimization. SPE Computer Applications 8 (04): 111–16. SPE-28252-PA. https://doi.org/10.2118/28252-PA.

Douglass, T. R. 1986. Linear Programming Optimizes Unit Negotiations. Journal of Petroleum Technology 38 (03): 330–36. SPE-13766-PA. https://doi.org/10.2118/13766-PA.

Ejckmeier, J. R., and Eng, P. 1973. Pumping Well Optimization Techniques. Journal of Canadian Petroleum Technology 12 (02): 53–61. PETSOC-73-02-07. https://doi.org/10.2118/73-02-07.

Eren, T., and Ozbayoglu, M. E. 2010. Real Time Optimization of Drilling Parameters During Drilling Operations. Presented at the SPE Oil and Gas India Conference and Exhibition, Mumbai, India, 20-22 January. SPE-129126-MS. https://doi.org/10.2118/129126-MS.

Evans, R. 2001. Produced Water Management Strategy with the Aid of Decision Analysis. Presented at the SPE/EPA/DOE Exploration and Production Environmental Conference, San Antonio, TX, 26-28 February. SPE-66543-MS. https://doi.org/10.2118/66543-MS.

Feldman, M. B. 1988. Optimization of Gas Transmission Systems Using Linear Programming. Presented at the PSIG Annual Meeting, Toronto, Ontario, Canada, 20-21 October. PSIG-8809. https://www.onepetro.org/conference-paper/PSIG-8809.

Ferber, P., Basu, U., Venkataramanan, G., 1999. Gas Pipeline Optimization. Presented at the PSIG Annual Meeting, St. Louis, MO, 20-22 October. PSIG-9905. https://www.onepetro.org/conference-paper/PSIG-9905.

Fujii, H., and Horne, R. N. 1995. Multivariate Optimization of Networked Production Systems. SPE Production & Facilities 10 (03): 165–71. SPE-27617-PA. https://doi.org/10.2118/27617-PA.

Furui, K., Zhu, D., Hill, A. D., 2007. Optimization of Horizontal Well-Completion Design With Cased/Perforated or Slotted Liner Completions. SPE Production & Operations 22 (02): 248–53. SPE-90579-PA. https://doi.org/10.2118/90579-PA.

Garcia-Diaz, J. C., Startzman, R. A., and Hogg, G. L. 1996. A New Methodology for Minimizing Investment in the Development of Offshore Fields. SPE Production & Facilities 11 (01): 22–29. SPE-26018-PA. https://doi.org/10.2118/26018-PA.

Garin, A. N. 1968. Suitability of a Linear-Programming Model for Optimization of an Oil Refinery. Chemistry and Technology of Fuels and Oils 4 (3): 196–99. https://doi.org/10.1007/BF00718538.

Garvin, W. W., Crandall, H. W., John, J. B., 1957. Applications of Linear Programming in the Oil Industry. Management Science 3 (4):

407–30. https://doi.org/10.1287/mnsc.3.4.407.

Goodman, D. F., French, B. J., and Grekel, H. 1973. Optimization of Plant Operations. Presented at the 48th Fall Meeting of the Society of Petroleum Engineers of AIME, Las Vegas, NV, 30 September - 3 October. SPE-4576-MS. https://doi.org/10.2118/4576-MS.

Govier, L. J., and Choppen, E. F. 1959. Better Budgeting by Operational Research. Presented at the 5th World Petroleum Congress, New York, NY, 30 May - 5 June. WPC-8810. https://www.onepetro.org/conference-paper/WPC-8810.

Gu, Z., Nemhauser, G. L., and Savelsbergh, M. W. P. 1998. Lifted Cover Inequalities for 0-1 Integer Programs: Computation. INFORMS Journal on Computing 10 (4): 427–37. https://doi.org/10.1287/ijoc.10.4.427.

Ierapetritou, M. G., Floudas, C. A., Vasantharajan, S., 1999. Optimal Location of Vertical Wells: Decomposition Approach. AIChE Journal 45 (4): 844–59. https://doi.org/10.1002/aic.690450416.

Janssen, M. L. 1967. Relationship Between Data Processing and Operational Research in the Oil Industry. Presented at the 7th World Petroleum Congress, Mexico City, Mexico, 2-9 April. WPC-12560. https://www.onepetro.org/conference-paper/WPC-12560.

Jeavons, D., Chaudry, A., Jones, W., 2017. Spare Part Inventory Optimisation. Presented at the SPE Offshore Europe Conference & Exhibition, Aberdeen, UK, 5-8 September. SPE-186170-MS. https://doi.org/10.2118/186170-MS.

Jin, F., Xi, W., and Shunyuan, Z. 2017. Optimization and Application of Cluster Horizontal Well Drilling Technologies and Foamy Oil Flow in ML Block, Venezuela. Presented at the Offshore Technology Conference Brasil, Rio de Janeiro, Brazil, 24-26 October. OTC-28065-MS. https://doi.org/10.4043/28065-MS.

Kahle, R. V. 1965. Use of Mathematical Programming Techniques in Production Planning. Presented at the Symposium on Petroleum Economics and Evaluation, Dallas, TX, 8-9 February. SPE-1105-MS. https://doi.org/10.2118/1105-MS.

Karlsson, H., and Brassfield, T. 1985. Performance Drilling Optimization. Presented at the SPE/IADC Drilling Conference, New Orleans, LA, 6-8 March. SPE-13474-MS. https://doi.org/10.2118/13474-MS.

Kazemi, Y., and Szmerekovsky, J. 2015. Modeling Downstream Petroleum Supply Chain: The Importance of Multi-Mode Transportation to Strategic Planning. Transportation Research Part E: Logistics and Transportation Review 83 (November): 111–25. https://doi.org/10.1016/j.tre.2015.09.004.

Kirby, M. W. 2000. Operations Research Trajectories: The Anglo-American Experience from the 1940s to the 1990s. Operations Research 48 (5): 661–70. https://doi.org/10.1287

/opre.48.5.661.12402.

Kirby, M. W. 2007. Paradigm Change in Operations Research: Thirty Years of Debate. Operations Research 55 (1): 1–13. https://doi.org/10.1287/opre.1060.0310.

Kleyweg, D., Tiemann, W. D., and Dalziel, S. G. 1983. Gaslift Optimization - Claymore Field. Presented at the SPE Offshore Europe Conference & Exhibition, Aberdeen, UK, 6-9 September. SPE-11885-MS. https://doi.org/10.2118/11885-MS.

Lalehrokh, F., and Bouma, J. 2014. Well Spacing Optimization in Eagle Ford. Presented at the SPE/CSUR Unconventional Resources Conference - Canada, Calgary, Alberta, Canada, 30 September - 2 October. SPE-171640-MS. https://doi.org/10.2118/171640-MS.

Lee, A. S., and Aronofsky, J. S. 1958. A Linear Programming Model for Scheduling Crude Oil Production. Journal of Petroleum Technology 10 (07): 51–54. SPE-862-G. https://doi.org/10.2118/862-G.

Lo, K. K., Starley, G. P., and Holden, C. W. 1995. Application of Linear Programming to Reservoir Development Evaluations. SPE Reservoir Engineering 10 (01): 52–58. SPE-26637-PA. https://doi.org/10.2118/26637-PA.

Lummus, J. L. 1970. Drilling Optimization. Journal of Petroleum Technology 22 (11): 1379–88. SPE-2744-PA. https://doi.org/10.2118/2744-PA.

McCloskey, J. F. 1987a. OR Forum—The Beginnings of Operations Research: 1934–1941. Operations Research 35 (1): 143–52. https://doi.org/10.1287/opre.35.1.143.

McCloskey, J. F. 1987b. OR Forum—British Operational Research in World War II. Operations Research 35 (3): 453–70. https://doi.org/10.1287/opre.35.3.453.

McCloskey, J. F. 1987c. U.S. Operations Research in World War II. Operations Research 35 (6): 910–25. https://doi.org/10.1287/opre.35.6.910.

Meisingset, H., Hove, J., and Olsen, G. 2004. Optimization of Pipeline Routes. Presented at the 14th International Offshore and Polar Engineering Conference, Toulon, France, 23-28 May. ISOPE-I-04-199. https://www.onepetro.org/conference-paper/ISOPE-I-04-199.

Mikolajková, M., Saxén, H., and Pettersson, F. 2018. Mixed Integer Linear Programming Optimization of Gas Supply to a Local Market. Industrial & Engineering Chemistry Research 57 (17): 5951–65. https://doi.org/10.1021/acs.iecr.7b04197.

Mishnaevsky, L. L. 1999. Optimization of Shape of Drilling Tools. Presented at the 9th ISRM Congress, Paris, France, 25- August. ISRM-9 CONGRESS-1999-243. https://www.onepetro.org/conference-paper/ISRM-9CONGRESS-1999-243.

Mockridge, J. I., and Akhtar, N. 1986. Offshore Topside Facilities Optimization. Journal of Canadian Petroleum Technology 25 (04): 45–51. PETSOC-86-04-05. https://doi.org/10.2118/86-04-05.

Murray, J. E., and Edgar, T. F. 1978. Optimal Scheduling of Production and Compression in Gas Fields. Journal of Petroleum Technology 30 (01): 109–16. SPE-6033-PA. https://doi.org/10.2118/6033-PA.

Nystad, A. N. 1985. Reservoir Economic Optimization. Presented at the SPE Hydrocarbon Economics and Evaluation Symposium, Dallas, TX, 14-15 March. SPE-13775-MS. https://doi.org/10.2118/13775-MS.

Pigliapoco, M., Drago, M., Baldoni, A., 2007. Langeled - Intervention Work Optimisation. Presented at the 7th International Offshore and Polar Engineering Conference, Lisbon, Portugal, 1-6 July. ISOPE-I-07-065. https://doi.org/10.13140/2.1.4347.8407.

Portillo, O. E., Al-Jahwari, M. H., Nasrumminallah, M., 2011. Drilling Optimization In Deep Horizontal Wells. Presented at the International Petroleum Technology Conference, Bangkok, Thailand, 7-9 February. IPTC-15281-MS. https://doi.org/10.2523/IPTC-15281-MS.

Raleigh, J. T., and Flock, D. L. 1965. Operations Research in Petroleum Production. Journal of Canadian Petroleum Technology 4 (01): 1–4. PETSOC-65-01-01. https://doi.org/10.2118/65-01-01.

Ramsey, T., and Helander, D. 1971. Formation Evaluation by Linear Programming In the Presence of Errors and Uncertainty. Presented at the 46th Proceedings of Fall Meeting of the Society of Petroleum Engineers of AIME, New Orleans, LA, 3-6 October. SPE-3568-MS. https://doi.org/10.2523/3568-MS.

Rardin, R. L. 2017. Optimization in Operations Research, 2nd ed. Hoboken, NJ: Pearson Higher Education, Inc.

Ribeiro, E. M., Farias, M. A., and Dreyer, S. R. B. 1995. Equipment Cost Optimization. Presented at the SPE Offshore Technology Conference, Houston, TX, 1-4 May. SPE-7761-MS. https://doi.org/10.4043/7761-MS.

Ríos-Mercado, R. Z., and Borraz-Sánchez, C. 2015. Optimization Problems in Natural Gas Transportation Systems: A State-of-the-Art Review. Applied Energy 147 (June): 536–55. https://doi.org/10.1016/j.apenergy.2015.03.017.

Roebuck, I. F., Henderson, G. E., Douglas, JJr., 1968. The Compositional Reservoir Simulator; Case IV The Two-Dimensional Model. Presented at the 43rd Fall Meeting of the Society of Petroleum Engineers of AIME, Houston, TX, 29 September - 2 October. SPE-2235-MS. https://doi.org/10.2523/2235-MS.

Rosenwald, G. W., and Green, D. W. 1974. A Method for Determining the Optimum Location of Wells in a Reservoir Using Mixed-Integer Programming. Society of Petroleum Engineers Journal 14 (01): 44–54. SPE-3981-PA. https://doi.org/10.2118

/3981-PA.

Saldungaray, P. M., and Palisch, T. T. 2012. Hydraulic Fracture Optimization in Unconventional Reservoirs. Presented at the SPE Middle East Unconventional Gas Conference and Exhibition, Abu Dhabi, UAE, 23-25 January. SPE-151128-MS. https://doi.org /10.2118/151128-MS.

Sawh, V., and Solomon, H. 2016. Drilling Optimization Platform for Well Cost Optimization. Presented at the SPE Trinidad and Tobago Section Energy Resources Conference, Port-of-Spain, Trinidad and Tobago, 13-15 June. SPE-180809-MS. https://doi.org/10.2118 /180809-MS.

See, B. A., and Horne, R. N. 1983. Optimal Reservoir Production Scheduling By Using Reservoir Simulation. Society of Petroleum Engineers Journal 23 (05): 717–26. SPE-11133-PA. https://doi.org /10.2118/11133-PA.

Sodhi, M. S., and Tang, C. S. 2010. Introduction: A Long View of Research and Practice in Operations Research and Management Science. In A Long View of Research and Practice in Operations Research and Management Science, ed. M.S. Sodhi and C.S. Tang, Chap. Introducti, 148:1–8. International Series in Operations Research & Management Science. Boston, MA: Springer US. https://doi.org/10.1007/978-1-4419-6810-4_1.

Soliman, M. Y., Byrd, A., Walters, H., 2003. Integrated Approach for Fracture Optimization. Presented at the Canadian International Petroleum Conference, 10-12 June. SPE-2003-182. https://doi.org /10.2118/2003-182.

Tan, S. H., and Barton, P. I. 2017. Optimal Shale Oil and Gas Investments in the United States. Energy 141 (December): 398–422. https://doi.org/10.1016/j.energy.2017.09.092.

Verma, C., Rodriguez, F., Qasin, Q. M., 2017. Drilling Optimisation of Extended Reach Multilateral Wells to Maximise Reservoir Contact in Carbonate. Presented at the SPE/IATMI Asia Pacific Oil & Gas Conference and Exhibition, Jakarta, Indonesia, 17-19 October. SPE-186982-MS. https://doi.org/10.2118/186982-MS.

Wagenhofer, T., and Hatzignatiou, D. G. 1996. Optimization of Horizontal Well Placement. Presented at the SPE Western Regional Meeting, Anchorage, AK, 22-24 May. SPE-35714-MS. https://doi.org /10.2118/35714-MS.

Wang, B., Liang, Y., Zheng, J., 2018. An MILP Model for the Reformation of Natural Gas Pipeline Networks with Hydrogen Injection. International Journal of Hydrogen Energy 43 (33): 16141–53. https://doi.org/10.1016/j.ijhydene.2018.06.161.

Wong, P., and Larson, R. 1968. Optimization of Natural-Gas Pipeline Systems via Dynamic Programming. IEEE Transactions on Automatic Control 13 (5): 475–81. https://doi.org/10.1109 /TAC.1968.1098990.

Wright, S., Ditzel, C., and Somani, M. 1998. Compressor Station

Optimization. Presented at the PSIG Annual Meeting, Denver, CO, 28-30 October. PSIG-9805. https://www.onepetro.org/conference-paper/PSIG-9805.

Wu, N., Li, Z., and Qu, T. 2017. Energy Efficiency Optimization in Scheduling Crude Oil Operations of Refinery Based on Linear Programming. Journal of Cleaner Production 166 (November): 49–57. https://doi.org/10.1016/j.jclepro.2017.07.222.

Yadav, S. R., and Malik, A. K. 2014. Operations Research,. New Delhi, India: Oxford University Press. https://app.knovel.com/hotlink/toc/id:kpOR000006/operations-research/operations-research.

Ye, Y., Liang, S., and Zhu, Y. 2017. A Mixed-Integer Linear Programming-Based Scheduling Model for Refined-Oil Shipping. Computers & Chemical Engineering 99 (April): 106–16. https://doi.org/10.1016/j.compchemeng.2017.01.031.