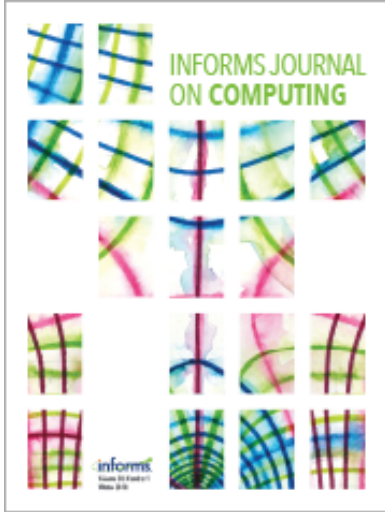




INFORMS Journal on Computing

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To cite this article:

J. Cole Smith (2019) In Memoriam: Shabbir Ahmed (1969–2019). INFORMS Journal on Computing 31(4):633–635.
<https://doi.org/10.1287/ijoc.2019.0931>

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In Memoriam

Shabbir Ahmed (1969–2019)

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Received: September 2, 2019

History: Accepted by Alice E. Smith, Editor-in-Chief.

Accepted: September 7, 2019

Published Online in Articles in Advance:
October 16, 2019

<https://doi.org/10.1287/ijoc.2019.0931>

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Keywords: computational • programming, integer • programming, stochastic

This article honors Dr. Shabbir Ahmed, one of the most beloved and deeply respected researchers in the operations research field, and summarizes some of his many contributions to the science and practice of computational optimization. In his 19 years as a professor at the Georgia Institute of Technology (Georgia Tech), he published well over 100 journal articles, proceedings, and book chapters. Far more important than the volume of his work is its depth and impact. And more important than his research: The genuine empathy and care he exhibited for his colleagues. After his passing at age 49 after a courageous fight with cancer, our profession witnessed an outpouring of emotional and heartfelt tributes to Shabbir. Those tributes are truly worth the reader's time, especially those that reflect on how someone at the very top of his profession—among his many honors, Shabbir had already achieved the rank of Anderson-Interface Chair and Professor at Georgia Tech and was the 2018 winner of the prestigious INFORMS Optimization Society Farkas Prize—was also so modest, kind, and supportive.

Shabbir built an elite career via his research in mixed-integer programming and stochastic programming. He played a critical role in the integration of these fields, a task that demanded thorough mastery of theory, analysis, and computation. In fact, his understanding of the implications of his research on computational optimization is one of the primary reasons that his research program has had such a notable and enduring impact. This brief reminiscence of his work focuses on his contributions in the computing field, with a special emphasis on work appearing in the *INFORMS Journal on Computing* (*IJOC*). As Shabbir would be quick to point out, none of these papers are *his* research papers, but rather projects he completed alongside his fellow researchers.

The original mission of *IJOC* is grounded in research that includes, but goes beyond, computational optimization, involving the creation of software and analysis of computer science principles within the field of operations research. An exemplar of this style of work appears in one of Shabbir's earliest contributions to *IJOC*. By 2004, Shabbir had already garnered a reputation of being one of the creative young minds in stochastic integer programming (SIP), having won a U.S. National Science Foundation CAREER award in 2002 on "Extensions of Stochastic Programming: Models, Algorithms, and Applications." (I can still remember a Q*bert-like figure illustrating the nonconvexity of SIP second-stage value functions in his presentations regarding this work.) Despite the popularity of this field, no general-purpose software existed for modeling and solving SIPs, creating a significant barrier to those conducting computational research in the area. His paper (Parija et al. 2004) contributes such a software package and demonstrates its effectiveness on an array of various problem classes.

More to the computational aspects of SIP, Shabbir helped contribute some key algorithmic concepts to the field in *IJOC* publications. His work in Angulo et al. (2016) examines the integer L-shaped method for two-stage SIPs and explores the integration of two mechanisms for improving computational efficacy. One mechanism mitigates the computational expense associated with repeated integer subproblem evaluations by alternating between the solution of exact and integer subproblems. The second devises a cut-generating linear program that leverages the history of solutions found by the algorithm during the course of its execution. In a more recent study, Shabbir and his colleagues derive scenario decomposition algorithms for risk-averse 0-1 stochastic programs with

objective functions based on coherent risk measures (Deng et al. 2018).

Shabbir's work was inspired by real-life applications: the more difficult, the more interesting. Two of those works appeared in *IJOC*. The first (Ahmed et al. 2010) regards intensity-modulated radiation therapy optimization. This extensive work incorporates conditional value at risk, parameter tuning, and multiobjective optimization. With an eye toward real-world implementation, the developed algorithm was fully automated and produced multiple candidate solutions, allowing practitioners to choose a treatment plan based on their own subject-matter expertise. Next, the work of Zou et al. (2018) extends Shabbir's work in power-generation optimization. The problem they consider is to solve location-allocation problems in the context of electric power plants, but without knowing future power demands or fuel prices. A two-stage model for this problem commits all decisions in a first stage and allows for no recourse decisions; this model is tractable but artificially limits the decision maker. A multistage model in which adaptive decisions can be made over time in response to evolving data provides the desired flexibility for decision makers but is extraordinarily difficult to solve. Zou et al. (2018) develop a compromise between these approaches: a partially adaptive SIP that essentially curtails the point past which adaptive decisions can be made.

Much of Shabbir's computational research was enabled by impressively deep analytical study. His ability to translate theory and analysis into computationally effective algorithms is evident in the study of Vielma et al. (2008), which prescribes a branch-and-bound algorithm for solving mixed-integer conic quadratic programs. The enabling theory behind this research comes from strong higher-dimensional relaxations of the conic constraints. Another example from an integer programming perspective is a note on the relative strength of a proposed class of formulations for piecewise-linear models (Vielma et al. 2010), vis-à-vis formulations that had previously been proposed for such structures. In fact, Shabbir's research program with George Nemhauser and Juan Pablo Vielma on mixed-integer programming models for piecewise-linear functions would ultimately be recognized with the 2017 INFORMS Computing Society Prize, honoring the best group of papers at the interface of operations research and computer science. A third example appearing in *IJOC* (Qiu et al. 2014) studies linear programs in which some limited number of the given constraints can be violated. The contributions in that research use a combination of coefficient strengthening techniques, cutting-plane methods, and customized branching rules, yielding an exceptionally effective approach to solving the problem.

Shabbir's computational research unsurprisingly goes well beyond his papers in *IJOC*. His work (Ahmed et al. 2004) in *Mathematical Programming* is truly significant, in that it studies general two-stage SIPs with integer variables appearing in the second stage. This research was some of the output of the aforementioned CAREER grant and was part of why Shabbir was asked to present so many summary chapters, tutorials, and featured talks on two-stage SIP theory and algorithms. One of his most-cited works examines a stochastic program to solve a class of supply chain network design models (Santoso et al. 2005). Their proposed algorithm uses the sample average approximation (SAA) framework and innovates an accelerated Benders decomposition algorithm to handle the very large scale of the instances they considered. The scale of problems considered is even larger in his research collaboration on stochastic routing problems (Verweij et al. 2003). There, the authors employ SAA on stochastic programs having up to 2^{1694} scenarios, identifying solutions that are provably near-optimal.

Ultimately, Shabbir will be missed in many ways. Our field has lost a tremendous talent, along with the creative and impactful contributions to our literature that he would have provided for many years to come. We also lost a gentle, kind, and supportive leader. I will remember him in many ways (including his love for running and Judas Priest music), but mostly for the example he set for others. Shabbir was proof that top-notch researchers are truly devoted to their craft, but that they are not one-dimensional. He was, first and foremost, a gentleman fully committed to his family. He was also refreshingly generous with his time for his friends; I am especially grateful for the time he spent with me and the effort he made to help mentor some of my PhD students. I see the same ethos reflected in his current and former students, giving me some small comfort that, although Shabbir has passed on, his best qualities endure in the many people he guided and befriended.

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