1. Introduction: Learning about Operations Research

IRV LUSTIG: So hi, my name's Irv Lustig from Princeton Consultants and today, I'm privileged to interview George Nemhauser, who is currently a distinguished professor at the Georgia Institute of Technology. So thank you, George, for joining us today and let's get started.

GEORGE NEMHAUSER: Oh, you're most welcome. I'm really looking forward to it.

IRV LUSTIG: All right. So tell me, when did you first learn about operations research?

GEORGE NEMHAUSER: So basically, I am a chemical engineer. And I think it was the summer between when I graduated with a Bachelor's degree in Chemical Engineering and the fall, when I was going to go off to graduate school at Northwestern for Chemical Engineering, I had a job with the research department of Allied Chemical.

And there was a guy-- I think he was my supervisor who was working there-- who told me he was taking a part-time degree at Princeton and he was studying things like linear programming and game theory and I think maybe Kuhn, Tucker conditions, And he told me about this kind of stuff and I thought, wow, this is really interesting stuff, much more interesting than what I'm doing in chemical engineering.

So when I got to Northwestern, as a first-year graduate student in Chemical Engineering, I had one elective course. And I looked and there was this new course called Operations Research and it included linear programming and game theory and stuff like that. I said, that's it. That's the course I'm going to take.

IRV LUSTIG: And so then, you were able to switch out from the Chem E program to a different program?

GEORGE NEMHAUSER: No. So I took that in my first year. I stayed with the Chemical Engineering and I got a Masters degree but I was hooked and by the most wonderful professor who had the most incredible effect upon my life. His name is Jack Mitten and Jack taught that course in Operations Research.

And pretty much by the end of the first semester the first year, I had somewhat made up my mind that I was going to switch to what was then a very small Industrial Engineering program-- really just started. Abe Charnes was there, as well, and I made up my mind to switch.

I came home for Christmas vacation and told my parents and they're not very educated people at all. And they thought, oh my god, a chemical engineer. A chemical engineer can get a job. What is somebody doing this new crazy stuff that has something to do with decisions and computers-- seems-- they were really upset about the fact that I might switch.

I talked to a couple of other people -- I was also taking a course in Electrical Engineering and Control Theory. And this professor of Control Theory, he told me, he said, if you want to switch

out of Chemical Engineering, switch to Electrical Engineering. Do something solid like Control Theory. But Industrial Engineering-- it's the lowest form of-- this professor actually told me this is the lowest form of engineering, hardly engineering. But because of Mitten, I did it anyway and it was one of the best decisions I've ever made in my life.

And it's funny because-- can I just take a second--

IRV LUSTIG: Go ahead.

GEORGE NEMHAUSER: I'm giving the graduation-- Georgia Tech has separate graduations for undergraduates, because it's big enough, and graduate students. And so I'm the commencement speaker for the graduate student graduation in December. And I'm right now drafting my 10 to 12-minute speech and I've never done anything like this before and it scares the hell out of me.

But I've started writing this and I thought, OK, what I'm going to start with is I'm supposed to give advice to these graduates, right? I'm going to start with saying, be very careful about what advice you listen to because a lot of the advice that I got turned out to be, I think, pretty bad advice. I did exactly the opposite and it's paid off very well.

IRV LUSTIG: But you were getting advice then from Jack Mitten saying, push it.

GEORGE NEMHAUSER: No, Jack was so low-key. He said, you've got to decide what you want to do. I just said, I'm with you.

IRV LUSTIG: And he ended up being your PhD advisor.

GEORGE NEMHAUSER: He was my PhD advisor.

IRV LUSTIG: And so what was your--

GEORGE NEMHAUSER: And he's a chemical engineer, too, by the way.

IRV LUSTIG: Oh, really? And then, so your PhD thesis-- what was that about?

GEORGE NEMHAUSER: Optimization in the chemical industry and mainly what I did was dynamic programming. Typically, when you think of it, it's this multi-stage stuff but most of the early work was multi-stage in time, right? Time periods are the stages. It's a natural thing.

Well, think of a chemical plant-- chemical plant multi-stage. But the key thing I knew how to do was the standard time thing, time just flows forward. In a chemical plant, you have stuff going from one piece of equipment to another, continuing, and then recycling back. So I had to figure out how to do dynamic programming where in today's terms, you have a graph which is not just a path but can have cycles and so on and so forth, thinking of the stages as the nodes of the graphs and the arcs as the transition points between the nodes.

IRV LUSTIG: Now, you mentioned earlier about--

GEORGE NEMHAUSER: And that stuff all got published in Chemical Engineering journals.

IRV LUSTIG: So you mentioned earlier that you came home and your parents were like, what do you mean you're going away from Chemical Engineering? So can you tell us some stuff about growing up and what influences you had being young and what led you down this path?

GEORGE NEMHAUSER: Not much. I was not a serious student pretty much through-- certainly through high school. I went to a great high school. I went to the Bronx High School of Science, which at the time was really a good place. I was not by any means one of the best students there. I did-- for example, I had one math teacher there who was a PhD. And he became a very interesting person in that he was caught up very much in the McCarthy hearings and eventually was fired from his job as a teacher at Bronx High School of Science.

He was the best teacher I ever had in high school-- shows you how bad that time was. He influenced me a little bit but I just was not serious enough to be a good student. In college, it was easy to get good grades but beyond that, I didn't give a damn until I found Operations Research.

2. An Evolving Career

IRV LUSTIG: Oh, wow. So you talked about your topic and your PhD being about dynamic programming in a chemical engineering framework. How would you say that start influenced your career as things evolved?

GEORGE NEMHAUSER: Well, already that was the start for me in optimization and I began to explore other avenues of optimization. And here's something interesting because I think in a note that I got from Mark, Sid Hess is being interviewed here. I should stop by and say hello to Sid Hess because Sid Hess was the person who got me started with integer programming. I had not been looking much-- I knew of its existence, I knew a little bit about teaching it, but I wasn't really exploring it.

Sid Hess came to Hopkins some time in the mid-60s and he's a chemical engineer. I'm pretty sure he's a chemical engineer and he was working for some chemical company, I think, in New Jersey. But there was a school districting problem where he lived and he volunteered to help with this redistricting process for this rather non-political districting problem. And so many of them are so politically driven. And Sid came to Hopkins to give a seminar and he talked about this districting problem.

And they actually had some funding from, I think, the Ford Foundation to do this kind of work. And so I talked with Sid and I said this is something that I might like to really work on as a serious research problem. And he agreed and actually provided some funding and I had a student then by the name of Rob Garfinkel and Rob and I started working on what is a set partitioning problem, my number one integer programming application and we attempted to develop algorithms. And from there--

IRV LUSTIG: Now, if you talk about a practical problem such as the redistricting problem and there's others that I know you've worked on, as well, back then in the 60s, our computational

facilities were nowhere near where they are today. So what were the methods that you used to actually provide practical solutions?

GEORGE NEMHAUSER: And so in fact with that political districting problem, we could deal pretty much with, by today standards, incredibly small problems. But Garfinkel, was a programmer before he started graduate school. After undergraduate, he worked as a programmer for a few years. He was an unbelievable programmer and so he did all this-- he wrote a machine language program, I think, for being able to do partitioning, which made it possible to do much bigger problems.

And what we did was an implicit enumeration, without linear programming-based implicit enumeration, almost like constraint programming but we didn't know about constraint programming. And remember, Balas had an implicit enumeration algorithm, I think, in the early 70s.

IRV LUSTIG: I see.

GEORGE NEMHAUSER: This preceded that.

IRV LUSTIG: So you mentioned the collaboration with Sid Hess. You mentioned Jack Mitten. Are there other people in OR from that time that had influences in shaping your career?

GEORGE NEMHAUSER: Yeah, I would say the main person aside from those-- with Sid Hess, it was just a small thing. It happened, it was great, but I didn't really associate with him that much. But the next person who had an unbelievable influence on me was Ray Fulkerson. And so I came to Cornell in the fall of 1970. I believe that Ray came-- Mark might even know-- Ray came in the fall of '72 or '73.

And I'm more or less an engineer. Ray was a mathematician and Ray was just very much a class act in everything he did. And he gave me a new perspective on what Operations Research was. And so I began at that point in my career to look more at some theoretical problems and algorithmic problems more from a theoretical point of view. And so Ray's influence from a scholarly point of view on me was very substantial and I think lasted for my whole career after that.

3. Major Career Themes

IRV LUSTIG: So prior to our interview today, I looked at your Georgia Tech website and it showed that you've authored and/or co-edited seven books. And as of 10 years ago-- I guess you have some updates to do-- you had authored and co-authored over 175 papers

GEORGE NEMHAUSER: Is that right?

IRV LUSTIG: And I'm sure it's much more than that, given that the last one on there was 2005 and I know you've still been writing. So you'll have to go back and get some updates done. But

what would you say are some of the major themes that you've had in your career? I saw works in dynamic programming, integer programming, but how do you view it at this point?

GEORGE NEMHAUSER: Well, there's no doubt in my mind that the two integer programming books, the first one with Garfinkel but the really big one with Laurence Wolsey in 1988 was really what I considered to be my main accomplishment. That book is still selling quite a few copies. It's surprising for a technical book like that, although if you went to the awards thing last night, you'd see that Conforti, Cornuejols, and Zambelli, they have a new book out there.

I think it's a very, very good book but it's less approachable as a textbook than the book with Laurence. And of course, Gerard is my PhD student from Cornell and he, research-wise, is the best PhD student I've ever had. Nobody's close. He's amazing. He's won all these awards, too.

In the late 70s, when Gerard was a PhD student, Marshall Fisher was visiting Cornell at the time. And Marshall came with a nice problem and we worked together with it and Gerard was involved, too. And this had to do with float, in terms of bank transfers and so on. And we did win a Lanchester Prize for that paper, as well. So now, Gerard has two Lanchester prizes and so there are now three people with two Lanchesters, Lex Schrijver, as well. I didn't answer your question, by the way. Excuse me.

IRV LUSTIG: Well, yeah. So we know about the work that you've done in integer programming and the books and you talked about, I guess, how Fulkerson really introduced you into integer programming and got you into it when you got to Cornell. Are there particular things that you've seen that you feel like over your career-- aside from the books-- that were results that you're particularly proud of?

GEORGE NEMHAUSER: Sure. First of all, the thing I'm most proud of all is not all the papers. It's all the PhD students. And so I'm going to venture to guess-- and I could be wrong about this because I have no proof. But I'm going to venture to guess that I have graduated more PhD students than anyone else in Operations Research. Now, that's a big claim, right?

IRV LUSTIG: That's a big claim. Well, there's a mathematical genealogy project. You can actually prove it.

GEORGE NEMHAUSER: Right. It's not up to date at all but I'm just making a guess that that's the case. Check with a few other people who might-- by the way, I'm not going to hold this for long. Dimitris Bertsimas is amazing. He now at MIT already has about 50 PhD graduates. I'm around close to 70. Dimitris is now supervising 18 PhD students.

IRV LUSTIG: At one time?

GEORGE NEMHAUSER: At one time. I don't know how he does it. It's amazing. And so the thing that I'm really most proud of at all is all these students that I have graduated and some of them who have-- not just Gerard but so many others who've really been so successful. A keynote here is being given by Alper Atamturk at Berkeley. He was one of my Georgia Tech students.

In moving from Cornell to Georgia Tech, the thing that I worried about most in whether that transition was going to be something that I was going to be happy with was the whole issue of, could I get the same quality PhD students that I was getting at Cornell at Georgia Tech? It took a little while but it clicked after a while.

4. Applications

In terms of applied work-- but not really applied work so much but motivated by applied work-- the thing that I like is that-- and I try to tell this to my students-- I don't try to work on the problem that somebody writes a paper and says, here's the open problem, because they probably have such a heads-up on anybody doing it. That's not the thing to do. I like to find my questions from the applications.

Part of my motivation for doing applications is I'll learn about what exactly is needed in the field and then go off and maybe get funding from NSF or something like that to work on that kind of stuff. So the big one for me in that regard is "Branch-and-Price."

And so that, by the way, is my most cited. Of all my papers, the most cited one is the "Branch-and-Price" paper. It's joint with Ellis Johnson, Cindy Barnhart, and Martin Savelsbergh and maybe one other person, one of my other students, Pam Vance, maybe. Martin was my postdoc at Georgia Tech. Cindy was an assistant professor, but I regarded her as a postdoc student, too.

She's Chancellor of MIT now. She's amazing. She's an amazing woman and we just had dinner together at the National Academy of Engineering meeting a couple weeks ago. Cindy's just great. And those are the kinds-- you're working with younger people like that. And but also, let me say that working with Ellis Johnson was amazing.

When you probably ask for one person who's done more in both theory and applications together, I would vote for Ellis. Working with Ellis at Georgia Tech was a great thing and we were a good team together.

And the "Branch-and-Price" stuff came partly from all the work we were doing with the airlines. So in the late '80s and early '90s, we just did a whole lot of stuff with pretty much all the airline problems. That's how we got Cindy involved. And so I'd say that work, which led to "Branch-and-Price," probably is one of the things I'm most proud of. And fortunately in that case, in which the Operations Research people don't do a very good job, we picked a good name, right? "Branch-and-Price," that's a cool way to sell it. That helps.

IRV LUSTIG: So you talked about how a lot of your work has been motivated by applications. So can you describe some of the applications that you've been involved in?

GEORGE NEMHAUSER: Sure. Well, here's the one that's the most fun for me. Mike Trick and I have a small company that does sports scheduling.

IRV LUSTIG: Right.

GEORGE NEMHAUSER: And you know about that well because you're in that business, too.

IRV LUSTIG: That's right.

GEORGE NEMHAUSER: And so the sports scheduling work, which had a fun start to it-- so many of these things come about fortuitously, how you get involved in different applications. you don't really plan it.

But once you get involved in it, you better learn the functional area because you can't just do the application without really understanding the problem. I swear, Ellis, he sometimes would memorize these schedules and, yeah, that's good. I think we should move that one. He was amazing. He would just study this stuff. But anyway, the sports scheduling started when I had a fun job at Tech and I was Georgia Tech's faculty representative to the Atlantic Coast Conference and to the NCAA.

And I was at a meeting of the Atlantic Coast Conference and the guy who was the Associate Commissioner for Basketball Operations-- it was already becoming a big business-- said, in the past, I've done the schedule for 20 years. I'd sit down with a pen and pencil and I'd write down a schedule and everything would be fine. And now, I've got to deal with ESPN and CBS and I can't do it anymore. I don't know what to do. I do something that makes ESPN happy and then the coaches start screaming at me because they've got three or four road games in a row and blah, blah, blah.

By that time, I was doing the scheduling work with the airlines and so I said, oh, let me just see if I could help a bit with this. And I knew that Mike was doing some baseball stuff already and Mike is a Georgia Tech PhD.

I taught integer programming for several years at Cornell and I'd have a reasonable group of graduate students. I just taught integer programming from a pretty full set of notes with the book with Laurence. And I started that class with three students. And I think two assistant professors, John Vande Vate and Craig Tovey sat in, but there's only three students. And by the end of the first semester, there was only one left and that was Mike Trick. They didn't have the students then. We do now.

And so the ACC-- I got the basketball scheduling going. We did some work with Mike and we developed some software for doing that. And then, it took us years to beat that couple in doing the baseball but we finally did and we've had that contract now for more than 15 years, I believe.

IRV LUSTIG: Right. So actually, that's probably an interesting story because as we are preserving this, now you have been involved in scheduling Major League Baseball for a while. Tell us what it's like to work with MLB and work on the schedule on an annual basis now.

GEORGE NEMHAUSER: This is a situation where interaction with the client's needs is absolutely critical, which is I'm sure true in pretty much all applications, except these clients-- and it could be Major League Baseball but it could also be a little conference like the MEAC.

Do you know what the MEAC is? MEAC is Middle Eastern Athletic Conference. The MEAC is an African-American school conference. It has Howard, Morgan State-- it goes all the way down south to Florida A&M. And we do their scheduling sort of almost on a pro-- it's not pro bono. They pay us a little bit but they don't have much money. And so they contacted me and I didn't want to tell them no.

And the point, whether it's MEAC or Major League Baseball, until they look at schedules, they don't really know what they want. And so this creates an incredible iterative process. You could call it "multi-objective optimization" with 100 objectives.

And so that becomes a tricky thing. But the importance of the objectives only evolve as they look at the schedules. And so it's a process that can go on and on and on. There are no convergence theorems other than everybody's tired and the deadline has arrived and that's the day of convergence.

IRV LUSTIG: Now with something like baseball-- now you've been doing it for a number of years, is it still very iterative in that way as their objectives are changing each year?

GEORGE NEMHAUSER: Baseball is, I think, less iterative because an iteration takes an incredibly long time. And so that makes baseball a little bit less-- you just can't really do it. And in the case with baseball, I'm not the main person with the client. So I don't have such direct information as I do with--

IRV LUSTIG: With the basketball. All of a sudden-- how would you like to-- I guess you've really answered this question. How would you like to be remembered? But it seems to me-- I think I can answer it for you. It sounds like it's your PhD students.

GEORGE NEMHAUSER: There you go. That's first. That's first.

5. Service to the Profession

IRV LUSTIG: I know you served in a number of leadership positions, both within INFORMS and the Math Programming Society. Can you tell us about your roles in those societies and how you've seen those different organizations evolve?

GEORGE NEMHAUSER: INFORMS has made amazing changes since I was president of ORSA. So it's grown so much. It's a much more sophisticated, professional society. I think it's done very well. It still is not integrated as much as I would like to see academics and business people. There still is a gap there and I saw it in-- the new Fellows were announced last night and it will be the Fellows lunch coming up soon. Of the, I believe, eight Fellows elected, only two from industry.

And if you look over the years, the number of people from industry who were Fellows is small. The National Academy of Engineering, on the other hand, we have an Operations Research section and we're responsible for electing new members. We get an allocation each year. They have pushed much, much harder that there be industry people chosen for the Academy. In fact,

this year, they've taken it further than they ever have before and said of your slots, half have to come from industry.

IRV LUSTIG: Wow.

GEORGE NEMHAUSER: And so with the INFORMS Fellows, the problem is twofold. One is that not so many nominations occur from people from industry. Maybe they care less, I don't know, but maybe there are fewer nominations because there are fewer successes. And so I argued very hard this year and it wasn't so easy.

GEORGE NEMHAUSER: W we need to do more, I think. I still think we need to-- if we're going to make this the organization that I would like to see it be, then I think a better integration is needed. Exactly how we do this, I'm not sure. Maybe there should be some seminars or workshops or that INFORMS should sponsor with a direct goal of connecting industry.

6. The Future

IRV LUSTIG: It's been a challenge, I know, for the-- I guess I'm close to 30 years involved with the society, both as an academic and now as a practitioner, and I've seen it as a continual challenge. And it's always come from both sides. Where do you see the field going in the future?

GEORGE NEMHAUSER: Well, I don't know. Immediate future--

IRV LUSTIG: Well, you can think of short-term future. You can think of five, 10, 15, et cetera.

GEORGE NEMHAUSER: I'll just think of short-term because five, 10, 15 years, I'll be out of here one way or another. And so now, of course, the issues are the big data issue, which we're seeing everybody talk about, and what we do with it and the kind of computing that we can do.

Computing power has just grown so enormously and so I think those problems are plenty to deal with over the next few years, along with, I think, our ability to deal with uncertainty is still not very well developed. I think in terms of optimization, our ability to deal with deterministic models-- there's still some huge problems we can't solve but we've done very, very well. We continue to make great progress with deterministic models.

But I think on the stochastic side, I don't see the same progress, in the sense that I don't see it adopted by industry in the same way. And to me that's the measure. The one technology that has really been enormously successful that we can say came out of Operations Research is linear and integer programming and some nonlinear programming the evidence is that there's commercial software.

But when you look at anything else that we associate directly with our field-- so sure, we use statistics and all that but I'm not going to say that came directly out of OR. I don't see that commercial software at the same level, which tells me that means that industry has not adopted it. And why? I still think it's awkward to use that stuff and the results are not there.

IRV LUSTIG: It's interesting you mention about uncertainty. When I interviewed George Dantzig 14 years ago, that was always his thing. What started George in-- from his beginning of his career, he always cared about uncertainty. And in his interview, he said, that's the one thing that I really wish people would get is understand that we really have to incorporate uncertainty into our decision making.

GEORGE NEMHAUSER: And stochastic programming has some impact now. I still think it's probably pretty light, in terms of real applications.

IRV LUSTIG: Right. And I think the challenge has been how we get business people to think and understand uncertainty and represent uncertainty and talk about uncertainty is a challenge. And even in this talk I just came from, the plenary was about how we deal with big data and computability and statistics all at once. And he says, it's a rich thing just to talk about risk. How do we think about these things? And I think it's been an ongoing challenge and I would agree with you there.

GEORGE NEMHAUSER: And new ideas have emerged, like robust optimization. But some of that can be awfully conservative. I argue with Dimitris.

IRV LUSTIG: Right. I've had debates with him, as well.

GEORGE NEMHAUSER: The one thing that's gotten really, really hot now is machine learning. Everybody talks about machine learning, machine learning, and machine learning, the way people talk about it now, clearly has become something, I think, that's viewed more generally as, say, more important than optimization. Now, that's ridiculous. I'm not putting down machine learning at all. And of course, optimization is a tool that's used in machine learning.

The machine learning algorithms are driven by optimization but the overall impact of optimization is so much greater than it is in machine learning. But the Computer Science people seem to know much better than the OR people how to market what they do. And I don't know why we haven't learned better. What are we missing? I'm not really sure but it's there.

IRV LUSTIG: Well, I think there's a continual effort that INFORMS has been doing in terms of analytics and pushing different levels of analytics. There is slow movement. You see now Gartner talking about companies saying, realize that the next place to go is go from predictive up to prescriptive analytics, which really is optimization.

GEORGE NEMHAUSER: And so by the way, I find-- last night, people say, OK, we're into this. Before, we had Operations Research and Management Science, whatever they are, and now we have Analytics. And I don't understand that statement at all. Didn't we always have Analytics?

IRV LUSTIG: Yeah. We just found a word for it.

GEORGE NEMHAUSER: We found a word for it. Yeah. Maybe unfortunately in 1940, whatever it was, had we called it "Analytics" rather than "Operations Research," we might have been a little bit better off now.

IRV LUSTIG: This is true.

GEORGE NEMHAUSER: Because people understand that word, "Analytics."

7. Criticism of Operations Research

IRV LUSTIG: Yes. So what do you feel is the most valid criticism of Operations Research in your view and how would you respond to it?

GEORGE NEMHAUSER: I just wonder if it should be taken as a criticism. A big part of criticism of academia-- oh, we do things-- that's just really mathematics and has nothing to do with what Operations Research is. Operations Research is really an applied science, engineering. But when you look into it, really, a lot of the people who are doing very theoretical work, like my colleague, Arkadi Nemirovski, in nonlinear programming, it may take a little more time for that work to get into practice.

And so I don't accept all the criticism that oh, there's too much theory. The theory is all useless and stuff like that. But the key thing is trying to get people to understand that if you work on applied problems, you get motivation for the important theoretical problems, sometimes somewhat more so than if you do by reading the conclusion sections of people's papers.

IRV LUSTIG: Right. So we were talking about earlier-- I know you did mention the work that you've done with the airlines. We've talked about sports scheduling. How are you finding the next applications to work on?

GEORGE NEMHAUSER: So for the past decade, I, together in part with Martin Savelsbergh and also with Shabbir Ahmed, have been working closely with Exxon Mobil research, both their upstream and downstream groups. One's in New Jersey. One's in Houston.

And they're a good company to work with because I find that we're most successful when the organization we work with-- this is on research-- when the organization we work with has its own PhD people who understand their problems. They're working on the more short-term problems that need to be solved in the next year or two. And they say, oh, also, we have the luxury of having some funding to look at what we should be doing five years from now or three years from now.

And so those interactions have been very positive and we've had great fun working with Exxon Mobil on maritime inventory routing. This is the routing of the big, big ships, which are so expensive.

IRV LUSTIG: The big tankers.

GEORGE NEMHAUSER: The big tankers all around the world, Middle East to US, China, and all this kind of stuff. And so that's been long-term research and Exxon Mobil takes a pretty long view. And so we've looked at some stochastic modeling with that because there is, of course, a lot of uncertainty in that business. But they allow us a pretty long-term view to look at stuff. And

we're just doing the task order now for next year's work and you've got to guess it was machine learning is what they want us to start looking at, right?

IRV LUSTIG: And then, you bring that back into the work that your students end up doing?

GEORGE NEMHAUSER: Exactly. Well, this is contract work with-- it's not consulting work. It's contract work with Georgia Tech, as opposed to baseball, for example, which is not Georgia Tech. It's more consulting, private company work. And that, I find, is the difference. I find mostly working with companies that have their own research staff, there, you can really do research with industry. But if you're working with somebody like a sports conference--

IRV LUSTIG: They need their schedule.

GEORGE NEMHAUSER: They don't have any interest--

IRV LUSTIG: That's right.

GEORGE NEMHAUSER: In fact, Mike and I would have always loved to have tried for an Edelman with the baseball stuff because we think the impact of that work has really been very significant, in terms of what they actually do and the revenue, in terms of new contracts. But they don't like that idea.

IRV LUSTIG: You have to have the client endorsement.

GEORGE NEMHAUSER: Exactly.

IRV LUSTIG: What do you feel in the field remains to be done that hasn't been-- well, we talked, I guess, uncertainty really is-- you're answering my questions before I ask them.

GEORGE NEMHAUSER: So George was right.

IRV LUSTIG: George was right.

GEORGE NEMHAUSER: George was always right.

8. Motivating Students

IRV LUSTIG: Today, when you have a student come in-- and let's say they haven't picked OR as a field. What would you do to sway them to join the OR department versus, say, your old field of Chemical Engineering?

GEORGE NEMHAUSER: Good question, good question. First place, you got to tell students-- now you're into my graduation speech. You've got to tell students, you've got to find something you love to do because it's all about passion. If you've got passion for something and it's something that you can be good at-- I always had passion for sports and when I was 10, I thought

I would like to play center field for the Yankees and replace Joe DiMaggio. But a couple of years later, I realized I couldn't even do it for my high school because I was so untalented.

And so the combination of passion and something you can be good at, that's what makes it. So I don't try to-- I try to encourage students to say, hey, you may like this. Come take a course. But then, you've got to decide what you want to do, right? And so I think the teaching part, at least for undergraduates, is really quite important.

We've started now-- Cornell used to do this but for us, because we have so many students, it's even bigger. And so we used to teach our undergraduate junior-level courses-- the first course in optimization, first course in stochastics. We used to teach them in sections of 75 to 100 and we could have four sections each semester of that size.

IRV LUSTIG: Wow.

GEORGE NEMHAUSER: Just such a big number of students-- and so many of those sections were taught by graduate students. And so the last thing I've decided to do is because we have so many bright people on our faculty, like Santanu Day, who can teach the integer programming course, which I've taught for years, I said I'm going to go back and really try to do undergraduate. And so now, I teach over 200 students in the first optimization course, where I do two hours of lecture and then there are recitations, which is a model.

But it's a very big class. And there, what I try to do is get the students excited by applications. And so if I say "sports scheduling," half of the students, they wake up. If I say "extreme point," they go to sleep. So you know how to do it, right?

IRV LUSTIG: Right. And what other applications do you find excite the students beyond the sports scheduling ones?

GEORGE NEMHAUSER: Most of these students will be excited by almost any application. It could be a financial application. It could be a supply chain, the Exxon stuff.

IRV LUSTIG: Really?

GEORGE NEMHAUSER: And so I think it's important-- and it sometimes doesn't happen-- and it's very important for the undergraduates that they be taught by people who do have some experience so you can motivate them by real problems.

Well, of course, when you get to the PhD course in integer programming, those 15 students are paying attention every second. They're watching whether you've got your epsilons and deltas right and so it's a whole different story. And maybe I like the model we're doing now with some of the younger people teaching that stuff because they're better at it than I am.

IRV LUSTIG: No, that's really interesting is that I think we-- you talked earlier about how the applications have motivated your work and the different types of things that you've done over your career. And that, in some sense, is a little bit of coming full circle now that teaching

undergraduates and getting them to understand the motivation comes from that. So I guess I would like to conclude here. We've gone through this list of different things. It was amazing how you answered my questions before I even asked them.

GEORGE NEMHAUSER: Your questions were so good.

IRV LUSTIG: Yes, there we go. So are there any concluding remarks you'd like to give, from a perspective of this will be something that will live on forever to inspire the next generation of students to join the field and do good work?

GEORGE NEMHAUSER: I think I'm a bit talked out here.

IRV LUSTIG: A preview of your commencement speech.

GEORGE NEMHAUSER: Yeah. I think the field is healthy. I really do. I think we went through a period and it probably was during most of the time at least that I was at Cornell, where the division between academia, theory, and industry was getting more and more separated. And there was the question of whether this field would even survive as an engineering field because it could not survive as a mathematics field unto itself. That's completely obvious.

But I think enhanced computational power that began to happen in the '80s and in PCs and all this kind of stuff began to make these analytic tools a little bit more accessible to people and things began to come together. And I believe they now will come together more and more and our field will have greater and greater impact.

Where it will wind up, I'm not sure. Some people think, well, maybe it should be like we should have an OR department that's part of a College of Computing. Maybe that would make more sense. I'm not sure about that. Certainly, OR being part of mathematics faculty is not a good idea.

Part of business faculty-- I think it's diminishing in the business schools, which worries me, at least OR. Maybe the simple analytics and stuff like that is hot in the business schools but the more rich and complex OR is not quite there. So where OR will wind up academically, I'm not 100% sure. I think it's an important issue. But I think as an applied science, it's well and healthy and will continue to be so.

IRV LUSTIG: All right. So thank you, George. I think that was a very enjoyable conversation and I appreciate spending the time with you today.

GEORGE NEMHAUSER: Yeah, well, thank you, Irv, It was good talking to you and Mark here. And thanks for doing the hard technical work. I appreciate it.