The Newsletter of the RAILWAY APPLICATIONS SECTION

informs | **ras**

From the Editors' Desk:

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A recent graduate with a PhD degree said, "I think algorithms to optimize the airline schedule can be adopted for the block-to-track assignment problem." A practitioner with experience in railroading responded, "Good thinking; however, these two problems have little commonality. But there is a possibility of adopting algorithms for a sub-problem in the airline scheduling." This is a good example of how RAS has played the role of a catalyst in bringing academia and railroads together to solve the most fascinating problems in the transportation industry. The advancement of computational capabilities has provided unprecedented opportunities to use optimization and advanced analytics in the various aspects of railroad operations. If the academia-industry collaboration continues, railroads can again play a leading role in OR applications to these real-life problems.

Most Class I railroads and consulting firms serving them in advanced analytics are going through an expansion phase. With this, we are also witnessing applications of advanced analytics beyond service planning, such as crew planning, yard optimization, locomotive planning, etc. Our customer base in the railroad organizations are increasing, as is the acceptance of optimization-based applications. This is a healthy trend, and the future of OR applications in railroads appears bright.

However, this trend can only be maintained if we continue to have fresh inflows of ideas through academic involvement. RAS is fortunate to be a platform witnessing academia-industry collaboration in all of its functional areas: officers, conference session chairs, RAS competitions, etc. For example, this year we received two nominations for each of the RAS officer positions; for each position, one nomination was from industry and the other from academia.

The RAS Problem Solving Competition is another example of academic involvement. This year around 40 teams registered for the competition from all over the world. Not all of them have submitted the final report; however, they have taken interest in solving railroad problems. If each team consists of two members on average, RAS has reached 80 academicians. This was evident in a recent job interview in which the candidate excitedly described how interesting the block-to-track assignment problem is and how he was thinking of solving this problem (although he was not planning to submit the final report).

While there are several positive signs to a bright future for OR in railroads, there are obstacles as well – old and new – to derail recent advancements. The availability of data needed by algorithms is still either inadequate or difficult to get. Optimization is a process in which the quality of outputs heavily depends upon the input data quality. We do not think that waiting for a time when perfect data will be available is a viable solution. We will have to find ways to work with insufficient and imperfect data. A blend of statistical techniques, machine learning, and optimization algorithms is needed if we want to succeed in applying advanced analytics in railroads.

Keeping this in mind, the roundtable sessions in this year's conference are organized to discuss the use of big data in railroads. In addition, the data availability will be part of several talks in RAS sessions. We are looking forward to lively RAS sessions with lots of discussions. We have lined up 12 sessions and other RAS activities during the annual INFORMS conference in San Francisco. These RAS activities have become possible because of membership fees collected and generous contributions from our sponsors. We thank you, our members and sponsors, for your support.

See you in San Francisco!

Krishna and Xuesong

Updates from RAS Officers

Chair: Krishna Jha, Optym; krishna.jha@optym.com
Vice Chair: Sandra D. Eksioglu, Clemson University; seksiog@clemson.edu
Secretary: Erick Wikum, Tata Consultancy Services; erick.wikum@tcs.com
Treasurer: Viraj Karnik, Norfolk Southern; viraj.karnik@nscorp.com

Public Relations Officer: Xuesong Zhou, Arizona State University; xzhou74@asu.edu

RAS Sponsors

RAS is proud to serve its members via activities that help advance the application of operations research and analytics to railroad problems. Our events are organized by volunteers with a great sense of commitment and dedication, and we are very thankful for their time. These activities also involve a significant amount of money, so we rely on their financial support. This year we have raised $11,000 with the support of these sponsors, and we thank them for their continued time and generosity.

BNSF Railway is one of North America's leading freight transportation companies, with a rail network of 32,500 route miles in 28 states and two Canadian provinces. BNSF is one of the top transporters of the products and materials that help feed, clothe, supply and power communities throughout America and the world. BNSF moves these goods more safely and efficiently, on significantly less fuel and with fewer emissions than the all-highway alternative.

CSX Corporation, together with its subsidiaries based in Jacksonville, Fla., is one of the nation's leading transportation suppliers. The company's rail and intermodal businesses provide rail-based transportation services including traditional rail service and the transport of intermodal containers and trailers. Overall, the CSX Transportation network encompasses about 21,000 route miles of track in 23 states, the District of Columbia and the Canadian provinces of Ontario and Quebec. The CSX transportation network serves some of the largest population centers in the nation. Nearly two-thirds of Americans live within CSX's service territory.

Norfolk Southern Corporation is one of the nation's premier transportation companies. Its Norfolk Southern Railway Company subsidiary operates approximately 20,000 route miles in 22 states and the District of Columbia, serves every major container port in the eastern United States, and provides efficient connections to other rail carriers. Norfolk Southern operates the most extensive intermodal network in the eastern United States and is a major transporter of coal, automotive, and industrial products.

Oliver Wyman, the fourth largest strategic consulting firm, is the premier consultancy for railways in operations planning and improvement, regulatory matters, process improvements and strategic guidance. In addition to consulting, their award winning MultiRail planning suite software is in use by many major railways in the United States, Canada, Mexico, Europe, Asia and Africa to provide business management for the entire operating plan process.

Optym is a leading provider of advanced planning, scheduling and business intelligence solutions for the global transportation and logistics industry. The company's clients include railroads, mining companies, airlines, trucking companies and major retailers. Based in Gainesville, Florida, Optym develops its optimization, simulation and data analytics software using an innovative blend of operations research, computer science and vast industry knowledge. Optym was founded in 2000 and consists of over 130 highly skilled professionals with offices in four countries. Visit www.optym.com for more information.

Tata Consultancy Services is an IT services, consulting and business solutions organization that delivers real results to global business, ensuring a level of certainty no other firm can match. TCS offers a consulting-led, integrated portfolio of IT, BPS, infrastructure, engineering and assurance services. These services are delivered through TCS's unique Global Network Delivery Model™, recognized as the benchmark of excellence in software development. A part of the Tata group (India's largest industrial conglomerate), TCS has over 310,000 of the world's best-trained consultants in 46 countries. For more information, visit www.tcs.com.

Announcing

2014
Distinguished Member Award
Carl Van Dyke
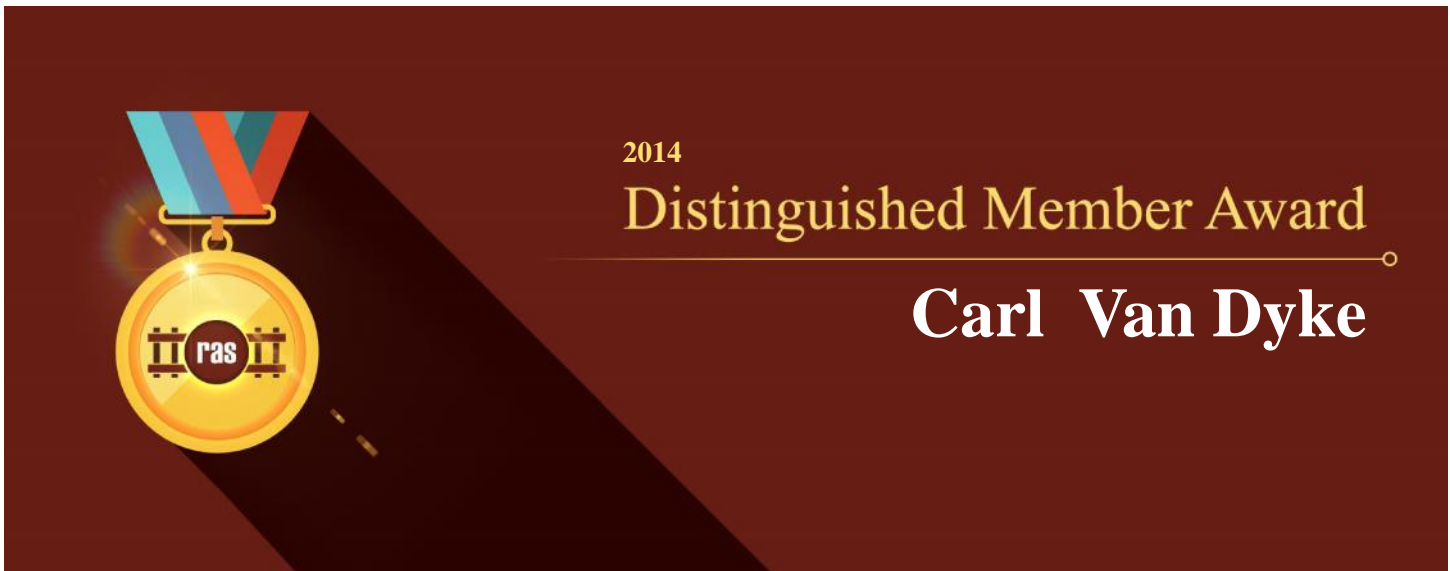
RAS is able to serve our profession through the contributions of volunteers. Although help from everyone is appreciated, some volunteers' contributions have a far reaching impact. Their work has given RAS a new direction and continues to inspire others to follow their footsteps. The RAS Distinguished Member Award, first given last year, recognizes such individuals. The award committee consists of the current officers, past award winners and past RAS Chairs/Presidents. This year, Carl Van Dyke was selected as the recipient of the RAS Distinguished Member Award for 2014.

Carl Van Dyke, president emeritus and founder of MultiModal Applied Systems (now part of Oliver Wyman) was a founding member of the Railroad Applications Special Interest Group (RASIG) that later evolved into RAS. He served RAS as Chair and as a Roundtable organizer, session chair and presenter many times. He sponsored RAS dinners, was a driving force in the Student Paper Competition, and helped organize two special RASIG-sponsored industry meetings on service design.

Carl pioneered scheduled railroading and had a significant role in moving the industry away from tonnage-base operations. Every major railway in North America, and several major railways in Europe, Asia and Africa, have directly benefitted from his work and vision. Carl also developed many of the computer models that railways now routinely use to design service and support scheduled operations, embodied in his well-known MultiRail system. These models are critical for scheduled railroading to produce the necessary high-quality service design, and to quickly adapt the design as demand trends change. His seminal work in algorithmic blocking had substantial influence on the control systems of several railways and on how many railways perform service design studies.

RAS Membership

RAS has a total of 120 members, out of which 89 are regular members and 27 are students. Compared to 2013, the count of members has remained steady. However, we have witnessed an increasing trend in the academic participation in RAS activities. We are seeing a considerable number of people participate in the RAS Problem Solving Competition and the RAS Student Paper Award. A total of 79 people who are either students or from 37 institutions in ten countries participated in the competitions. We would like to keep the RAS membership for the participants as voluntary but further reach out to students and encourage them to become RAS members.

We are soliciting for your thoughts about how to increase the registered student members. Please provide your thoughts during the RAS business meeting or send an email to the incoming RAS chair, Sandra Eksioglu(seksiog@clemson.edu).

RAS and Networks

Thanks to the efforts of Juan Morales (BNSF) and Professor Ravindra Ahuja (Optym) and kind consideration of the editor-in-chief of Networks, the winning entries of the RAS Student Paper Award and the RAS Problem Solving Competition will be considered for publication in Networks. We believe this will have a positive impact on RAS activities and will benefit its members.

RAS Problem Repository

The RAS Problem Repository was created in 2011 to facilitate a platform on which:

1. Real-life railroad application problems are presented along with dataset(s) and solutions publicly available for anyone to research, develop and test solution approaches.

2. Researchers may showcase their results, engage in questions, answers and discussions, and measure the performance of different solution approaches.

You can find the problem description and data files on our website: http://informs.org/Community/RAS/Problem-Repository.

We have added the initial version of "Rail Road Yard Operational Plan" to the repository. This problem is different than the one used in the RAS Problem Solving Competition. We encourage researchers to submit different problems to add to the repository. Please contact RAS officers to upload your problem.

LinkedIn and Email List

RAS has a LinkedIn group (visit http://www.linkedin.com/groups?gid=2399643) or simply search the Rail Applications Section of INFORMS). LinkedIn provides us a forum in which people can post and discuss topics. It is also used as part of communication during our RAS competitions. The number of members in our group increased significantly from 181 in 2012 to 527 in 2014. If you are not already a member, please join the group to connect with the other members from academia, railroads and consulting.

We also have a mailing list of all past and present RAS members. You can post job opportunities or reach out to other members for a specific question or discussion item.

Got News to Share?

Published a paper? Published a book? Hiring for full timers or interns? If you have news that you would like to share with RAS members, please let us know. We can help spread the word.

Look forward to seeing you in San Francisco!

Annual National Meeting Sessions

Cluster Chair: Burack Eksioglu, Clemson University; burak@clemson.edu

This year we have 12 sessions scheduled over three days. On Sunday we kick off with the RAS Student Paper Award, followed by the RAS Problem Solving Competition. Two roundtable sessions are scheduled on Sunday afternoon. The Monday sessions are all related to modeling. We begin Monday morning with presentations on operations research (OR) models, followed by some analytics models. Monday afternoon offers presentations on modeling issues related to fleet management, timetabling and platforming. Tuesday begins with demand-responsive service design presentations, followed by talks on network performance. RAS presentations conclude on Tuesday afternoon with topics related to advanced analytics tools and optimization models for terminal operations.

RAS sessions are in Track 27 and will take place at Hilton-UnionSq7, 4thF.

Sunday, November 9

08:00 – 09:30	**SA27: Railway Applications Section (RAS) Student Paper Award** Chair: **April Kuo,** BNSF Railway **First Place:** A Mixed Integer Programming Model for Optimizing Multi-level Operations Process in Rail Yards Tie Shi, Southwest Jiaotong University, China (Coauthor: Xuesong Zhou) **Second Place:** A Balanced Train Dispatching Model toward Reducing Train Delays and Inequity of Competitors Xiaojie Luan, Beijing Jiaotong University, China (Coauthors: Francesco Corman and Lingyun Meng) **Third Place:** Maintenance in Railway Rolling Stock Rescheduling for Passenger Railways Joris Wagenaar, Erasmus University, Netherlands (Coauthor: Leo Kroon)
11:00 – 12:30	**SB27: Railway Application Society (RAS Problem Solving) Competition** Chair: **Xiaopeng Li,** Mississippi State University **Team "DTU": Richard Martin Lusby, Jørgen Thorlund Haahr,** Technical University of Denmark, Lyngby, Denmark **Team "NCKU": I I-Lin Wang, Ping-Cheng Lin, Tsai-Ti Huang,** National Cheng Kung University, Tainan City, Taiwan **Team "The Dutch Smiths": Paul Bouman, Joris Wagenaar, Lucas Veelenturf,** Rotterdam School of Management Erasmus University, Rotterdam, Netherlands
13:30 – 15:00	**SC27: Roundtable 1: What is Big Data, How Do I Get Started and Why Do I Care?** Chair: **Marc Meketon**, Oliver Wyman **Speaker 1: Ajay Singh, Hortonworks.** A discussion of Hadoop and how to set up and use it. **Speaker 2: Mahesh Kumar, Tiger Analytics.** Data science and its applications, including railway failure rate forecasting. **Speaker 3: Kanav Hasija, Innovaccer.** How Big Data is disrupting the operations research industry.
16:30 – 18:00	**SD27: Roundtable 2: How will Big Data Affect the Railways?** Chair: **Marc Meketon**, Oliver Wyman **Speaker 1: Bruce Patty, Veritec Solutions.** The "supply and demand" of Big Data. **Speaker 2: Andy John, CSX.** The various applications that CSX has started in the use of Big Data. **Speaker 3: Sham Chotai, GE.** How GE is using Big Data for railway and applications.

Monday, November 10

08:00 – 09:30

MA27: Railroad OR Models
Chair: Clark Cheng, Norfolk Southern Railway

1. Railway Crew Scheduling with Train Departure Delay (Yutian Yang)
2. Developing a Real-time Train Movement Planning System (Ravindra Ahuja)
3. Scheduling Geometry Cars in Norfolk Southern Rail Network (Andy Yoon)
4. Locomotive Shop Routing Using Approximation Dynamic Programming (Maurice Cheung)

11:00 – 12:30

MB27: Railway Analytics
Chair: Qing He, University at Buffalo (SUNY)

1. Multivariate Deterioration Model Using Railway Track Geometric Data (Zhiguo Li)
2. Risk Analysis of Petroleum Crude Oil Transportation by Rail (Xiang Liu)
3. Rail Network Simulation System for Mining Industry (Alexey Sorokin)
4. Identification of Asymmetric Wheel Profile Wear and Its Benefit Analysis (Qing He)

13:30 – 15:00

MC27: Models for Fleet Management and Scheduling
Chair: Xuesong Zhou, Arizona State University

1. An Integrated Model for Train Timetabling and Platforming in High Density Double Track Corridor (Mahendra Birhade)
2. Fleet Management in Rail Transport: Petroleum Rakes in Indian Railways (Vishal Rewari)
3. Efficient Scheduling Operations for Dedicated Freight Corridors Corporation of India Ltd. (DFCCIL) (Nomesh Bolia)
4. Design of a Railway Network Resiliency Model (Carl Van Dyke)

16:30 – 18:00

MD27: Joint Session TSL/RAS: Railway Operations Modeling and Analysis
Chair: Matthew Petering, University of Wisconsin-Milwaukee

1. Cyclic Timetabling and Platforming of Heterogeneous Traffic on a Unidirectional Railway Line (Matthew Petering)
2. Cyclic Timetabling and Platforming of Mixed Train Types on a Bidirectional Railway Line (Mojtaba Heydar)
3. Freight rail on-time performance in Scandinavia (Hans Boysen)
4. Delivering Actionable Intelligence to Point of Performance (Kandukuri Raju)

Tuesday, Nov. 11

08:00 – 09:30

TA27: Demand-Responsive Rail Service Design
Co-Chairs: Dengfeng Yang, Infor (US) Inc. and Kuilin Zhang, Michigan Technological University

1. Demand-oriented trains timetables for a single railway line (Eva Barrena)
2. Comprehensive Operational Dynamic Real-time Train Re-routing for a Freight Train Network (Alborz Parcham-Kashani)
3. Capacity Evaluation along Baltimore-DC Based on Directional vs. Bidirectional Scenarios of Operation (Hamed Pouryousef)
4. Quadratic programming model for optimizing demand-responsive transit timetables (Huimin Niu)

TB27: Rail System Performance
Chair: Bo Zhou, University of Illinois at Chicago

11:00 – 12:30

1. A Column Generation Approach for Designing Dynamic Train Service Network (Xuesong Zhou)
2. Capacity of Single-Track Railway Lines with Short Sidings to Support Operation of Long Trains (Ivan Atanassov)
3. Analysis of Rail Line Capacity on Shared Corridors with Multiple Freight Train Types (Mei-Cheng Shih)
4. Integrated Network Performance in Denmark (Steven Harrod)

TC27: Advanced Analytics Tools for Smart Railroad Terminal Operations
Chair: Behnam Behdani, BNSF Railway

13:30 – 15:00

1. Mixed Integer Programming Model for Optimizing Multi-level Operations Process in Rail Yards (Xuesong Zhou)
2. New Frontiers in Yard and Terminal Analytics at CSX (Jeremiah Dirnberger)
3. Simulation Based Yard Case Studies (Krishna Jha)
4. Integrated planning of locomotive service systems in large-scale railroad networks (Siyang Xie)

TD27: Optimization for Rail Planning
Chair: Mingzhou Jin, The University of Tennessee

16:30 – 18:00

1. Classification Track Assignment in Railway Hump Yards (Mingzhou Jin)
2. Integrated Modeling of Strategic Train Operation Planning on a Shared-use Corridor (Bo Zou)
3. Strategies to Control a Shortest Path Based Railroad Blocking Network (Erick Wikum)
4. Optimization-based train dispatching systems in operation in Europe (Leonardo Lamorgese)

INFORMS 2014 ANNUAL MEETING
SAN FRANCISCO, CA

Hilton

2014 RAS Problem Solving Competition

Chair: Xiaopeng Li , Mississippi State University; xli@cee.msstate.edu

The 2014 Problem

Participants were asked to build a model to identify a plan that optimizes the humping sequence and the block-to-track assignment of a railroad classification yard. In this problem, a number of inbound trains arrive in the receiving yard at given times. Each train can be broken into a number of railcar tuples (or blocks) that may go to different destinations. These blocks are sent to tracks in the classification yard according to a planned sequence. Finally, each set of classified blocks is assembled into an outbound train in the departure yard. Designing a good assignment plan is challenging as it is subject a number of interdependent constraints due to limited resources and specific classification requirements. The total cash award for this year's competition is **$3,750: First Place: $2000; Second Place: $1,000 , Third Place: $750.** Visit the competition web site for additional details: http://www.informs.org/Community/RAS/Problem-Solving-Competition

The Response

We would like to thank all of the participating teams for their hard work. We had a total of 37 teams registered (with members from Canada, China, Denmark, Germany, India, Iran, Netherlands, the United Kingdom, the United States and Taiwan) eight of which submitted reports. Special thanks go to Xuesong Zhou (Arizona State University) for developing the solution checking program, to Krishna Jha for answering the technical questions, and to Krishna Jha and Jeremiah Dirnberger for proposing the competition problem.

Three finalist teams will make their presentations at the INFORMS Annual Meeting during the RAS Problem Solving Competition Session on Sunday, November 9, 11:00 – 12:30 in the San Francisco Union Square, Room 7. Their team reports will be made available on our website (www.informs.org/Community/RAS/) soon after. We invite you to come and support these bright minds.

Finalists

Team "DTU": Richard Martin Lusby, Jørgen Thorlund Haahr, Technical University of Denmark, Lyngby, Denmark
Team "NCKU": I-Lin Wang, Ping-Cheng Lin, Tsai-Ti Huang, National Cheng Kung University, Tainan City, Taiwan
Team "The Dutch Smiths": Paul Bouman, Joris Wagenaar, Lucas Veelenturf, Rotterdam School of Management Erasmus University, Rotterdam, Netherlands

Honorable Mention

Given the high quality of work this year, we are also recognizing the following teams with honorable mentions :

Team "Bortor": Torsten Klug, Boris Grimm, Zuse Institut, Berlin, Germany
Team "TCSexplORers": Sudhir Kumar Sinha, Shripad Salsingikar, Sumit Raut, Tata Consultancy Services, Mumbai, India
Team "Tom's": Haichuan Tang, Southwest Jiaotong University, Sichuan, China
Team "University at Buffalo Operations": Natalie Simpson, Ryan Hauser, University at Buffalo, NY, US

Recognition

We thank the sponsors, the problem owners Krishna Jha and Jeremiah Dirnberger, and the following organizing committee members for their efforts:

Xiaopeng Li (Chairman, Mississippi State University)
Behnam Behdani (BNSF Railway)
Chip Kraft (Transportation Economics & Management Systems Inc.)
Edward Lin (Norfolk Southern)
Erick Wikum (Tata Consultancy Services Limited)
Jeremiah Dirnberger (CSX Transportation)
Kamalesh Somani (CSX Transportation)
Krishna Jha (Optym)
Sandra Eksioglu (Mississippi State University)
Steven Harrod (Technical University of Denmark)
Tyler Dick (RailTEC, University of Illinois at Urbana-Champaign)
Xuesong Zhou (Arizona State University)
Yu Wang (CSX Transportation)
Yudi Pranoto (Norfolk Southern)

Special thanks go to Xuesong Zhou (Arizona State University) for developing the solution checking program, and to Krishna Jha (Optym) for answering the technical questions.

2014 RAS Student Paper Awards

Chair: April Kuo, **BNSF Railway**, April.Kuo@BNSF.com

Rail Applications Section (RAS), a section of the Institute for Operations Research and Management Science (INFORMS), sponsored a student research paper contest on analytics and decision making in railway applications, with a total cash award of $1,750:

First Place: $1,000, Second Place: $500, Third Place: $250.

To qualify, the paper must have been written by a student or students enrolled in an academic institution during the 2013-2014 academic year. The paper must advance the application or theory of OR/MS for improvement of freight or passenger railway transportation, and it must represent original research that has not been published elsewhere by the time it is submitted. More details on the eligibility criteria, the application procedure and deadlines are available at RAS's website: https://www.informs.org/Community/RAS/Student-Paper-Award.

Eight students from around the world with a wide variety of topics registered for the competition. The quality of the submitted papers was in general very outstanding. Authors of the First, Second and Third Place award winning papers will present their papers at the Student Paper Award Session of the INFORMS Annual Meeting in San Francisco, CA. We encourage all RAS members to attend this session and motivate our young researchers to continue to make great strides in building new models for railroad planning, scheduling and analytical problems. We provide below the abstracts of these papers. Extended abstracts of the awarded papers are available on the RAS website.

I had the honor of leading an elite paper reviewing committee made up of twelve members from different academic and industry backgrounds. In order to avoid any conflict of interest, members of the committee with any type or affinity with any of the authors or co-authors did not review the corresponding paper(s). The First Place paper will be considered for publication in Networks. The paper needs to go through the journal's normal refereeing procedure; however, the paper will receive an expedited referring and publication .

A Mixed Integer Programming Model for Optimizing Multi-level Operations Process in Rail Yards

by Tie Shi, **Southwest Jiaotong University, China (visiting student at Arizona State University)**

Coauthor: Xuesong Zhou

Abstract: This paper presents a time-expanded multi-layer network flow model to describe the connection between different layers of yard operations. A mixed integer programming model is developed to optimize the overall performance by jointly considering interconnected components. We adopt cumulative flow count representation to model the spatial capacity in terms of the number of railcars in classification yards. A novel lot-sizing modeling framework and valid inequality formulations are introduced to model the assembling jobs.

A Balanced Train Dispatching Model toward Reducing Train Delays and Inequity of Competitors

by Xiaojie Luan, **Beijing Jiaotong University, China**

Coauthors: Francesco Corman and Lingyun Meng

Abstract: We study the problem of dispatching trains during operations. We consider the innovative aspect of control decisions to deliver equitable solutions when multiple Train Operating Companies are competing in the network. Various optimization models are defined that minimize average train delays and delay inequity among competitors. Comprehensive numerical experiments, performed on an artificial and a realistic dataset from the Dutch network, show the efficiency and effectiveness of the proposed models.

Maintenance in Railway Rolling Stock Rescheduling for Passenger Railways

by Joris Wagenaar, **Erasmus University, Rotterdam, Netherlands**

Coauthor: Leo G. Kroon

Abstract: This paper addresses the Rolling Stock Rescheduling Problem (RSRP) while taking maintenance appointments into account. The EUT model adds additional types for every rolling stock unit that requires maintenance. The SA model keeps track of a shadow account for all the units that require maintenance. Within the JC model, paths are created such that units are on time for their appointments. The results show that the models are able to efficiently take maintenance appointments into account.

Operations Research at Railways in Japan

Norio TOMII, Chiba Institute of Technology; tomii@cs.it-chiba.ac.jp

In urban areas of Japan, a lot of people commute by railways. As a matter of fact, the market share of railways in three big cities is about one half. In Tokyo, the capitol area, the number of passengers a day is 38 million on average. In order to transport such a huge number of passengers, trains are operated very densely. In many lines in Tokyo area, trains are running every two to three minutes on a double track line. Even on the high-speed rail (Shinkansen), trains are operated every three to four minutes.

Railways in Japan are known for their safety and punctuality. For example, there have been no accidents involving passenger fatalities since the high-speed rail began its operation in 1964, and the average delay of a train of Tokaido Shinkansen in 2012 was only 0.6 minutes.

Railways in urban areas of Japan offer a very convenient transportation service as well. One example is the direct operation between subway lines and suburban lines. This means that trains from suburban areas go directly into subway lines and commuters can reach their workplaces without transferring.

But it is true that we have some problems. We are going to solve those problems using an OR approach.

One such problem is that small delays often happen during peak hours. Because trains are running densely, even a small delay propagates to other trains. In particular, in railway lines where the direct operation is carried out, a small delay in a suburban area propagates to subway lines, and the delay expands to the suburban lines in the opposite side. It is not an exaggeration that such a delay propagates to the whole railway network in Tokyo. The delay is small (usually several minutes), but passengers complain a lot because they trust in railways.

In order to get a clue to this problem, we devised to visualize train operation records in a train graph that we named the Chromatic graph. Examples are shown below. In the Chromatic graph, train delays are depicted by the color of the train lines. The color progressively changes from indigo to blue, green, yellow, orange and red as the delay increases. Actual dwell times, which are very important to keep punctuality, can be also illustrated by circles on the graph.

Before

After
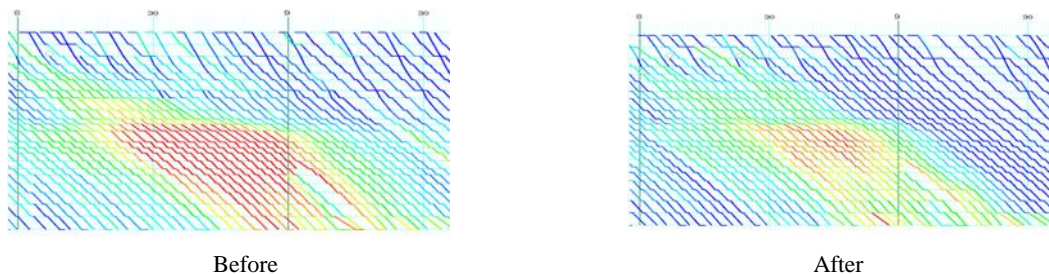
This line (Tozai Line in Tokyo area) was once notorious for its unpunctuality (left). From this Chromatic graph, you can intuitively grasp where delays emerge and how they are propagating. The company (Tokyo Metro Co. Ltd.) improved the timetable, facilities (tracks, signaling systems etc.) as well as train operation and they succeeded to significantly reduce the delays (right). In the above examples, we show the "before" and the "after" of these efforts. Other railway companies are now also very keen to reduce small delays during peak hours and, thanks to their efforts, delays are now decreasing.

Another problem exists in rescheduling trains when an accident occurs. Sometimes accidents or troubles occur and trains are delayed. In such a case, dispatchers try to restore the train traffic by modifying the timetable so that passengers do not suffer from further inconvenience. They cancel trains, change tracks of trains, change departing orders of trains and so on. At present, in many railway companies, rescheduling is done by human experts. But because this is a very demanding work, they long for assistance from computers. As you know, to develop a train rescheduling algorithm based on an OR approach is a very hot topic in the OR community now. We have been working on this topic for a long time and using various OR techniques such a as simulation, PERT, meta heuristics, constraint programming, MLIP and so on. As a result, in some railway companies a rescheduling algorithm that automatically proposes an optimal rescheduling plan by changing tracks, changing departing orders, etc. is already practically used.

We believe the most important thing in developing rescheduling algorithms is to consider the passengers' point of view. For example, passengers' inconvenience caused by increased travel time, congestion etc. should be included in the criteria of optimization. At the moment, however, this is still difficult. We will continue our travel to search for the Holy Grail.

Bringing Rail Network Simulation to Western Australia

Ravindra K. Ahuja, **Optym;** ravi@optym.com

Steel is an integral component in the growth and development of communities. With an increasing global population and China's economic boom, the demand for steel is growing rapidly. Western Australia is rich with iron ore mines and has over US $5 trillion of untapped reserves. Some of the world's largest mining companies, including Rio Tinto, BHP Billiton and FMG, are operating in this region and working hard to provide enough iron ore to meet this rising global need. As a result, these companies have reached annual revenues in the tens of billions of dollars and have experienced growths in volume of up to 5-10 percent each year.

These constantly increasing volumes, however, have created several challenges for mining companies. In order to keep up, they have to constantly increase the capacity of their infrastructures. These companies run complex supply chains with rail networks connecting pits (iron ore mines) to ports. With the price of iron ore hovering around $80 per ton, each iron ore train carries about $2.5 million worth of iron ore. If a mining company can carry an extra train per day over its network, this will increase its annual revenue by about $1 billion. We can therefore clearly see the value that companies gain by running extra trains.

Mining companies are capacity-constrained with respect to rail network capacity. Each company is looking for ways to increase the capacity of its rail network in the most cost efficient manner. Since each capacity expansion costs tens to hundreds of millions of dollars, a company must first justify such an investment to the board. The company needs to perform an ROI (return on investment) analysis; that is, determine the cost of investment, estimate the resulting capacity increase and compute the payback period (when the investment will be paid back through the benefits it creates). To perform such an analysis, a company needs to determine how much it will gain in rail network capacity by making a given investment. This is where Optym comes in.

For over ten years, mining companies have been using a simulation system developed using Arena software. It is a holistic simulation system that models mines, rail network and ports and enables companies to do various studies related to changes in these network components. However, this system does not model movements on the rail network in sufficient detail for the latest round of planned infrastructural changes. So companies need a much more detailed simulation system that focuses on train movements on line-of-road and through yards. One leading mining company in the region hired us to develop a rail network simulation system, which we call GeoSYM.

The company wanted to explore several options for increasing its capacity. Some of these included: .

- Running longer trains, with each train carrying more cars

- Running heavier trains, with each car carrying more iron ore

- Changing the braking system from air brakes to electronic brakes (which will enable a train to stop more quickly, thereby reducing the safe distance between trains and allowing more trains to run)

- Adding more signals (thus reducing the distance between two trains and allowing more trains to run)

- Moving to a communications-based signaling system (virtual block, moving block), which will further reduce the distance between trains

and allow more trains to run

♦ Adding crossovers in critical areas of the network to allow more meet and pass opportunities

♦ Achieving higher maintenance completion rates for better track health to reduce temporary speed restrictions and allow trains to move faster through the network

Note that several of these changes are related to reducing the distance between two consecutive trains. To see how reducing the distance between two trains will increase the rail network capacity, refer to the following diagram:

(A)

(B)
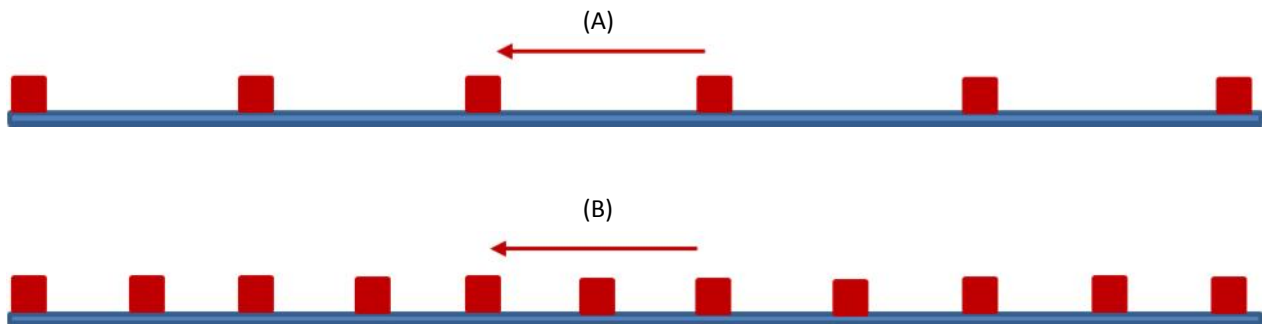
The above illustration shows that if we can halve the distance between two consecutive trains while maintaining them at the same speed, then we can double the number of trains moving through the system and thus double the network capacity. Therefore, reducing the distance between trains is critical to increasing the capacity of the network.

Although this project may sound rather easy, it is immensely complex from a technical point of view. The complexity of the problem has to do with maintenance, meet-pass planning and speed restrictions. The company operates a very heavy haul network, and heavy trains cause a lot of wear and tear on the tracks. As a result, tracks must undergo various types of maintenance, which in turn negatively impacts network capacity. As more trains move over the network, the need for maintenance increases and capacity subsequently decreases. Furthermore, part of the rail network is single track and the rest is double track. Maintenance processes turn part of the double track network into a single track network. Speed restrictions cause trains to accelerate and decelerate at regular intervals. Meet-pass planning on a combined single and double track network with varying speeds per track is a computationally challenging problem.

In this project, we developed a detailed simulation system to model the movement of trains in the entire network. The system simulates movements through yards and line-of-road and incorporates all factors that impact train movements and network capacity. We validated the simulation model by comparing its key performance indicators (KPIs) with those in the real world and found the accuracy of modeling to be within two to three percent. Meet-pass planning on an underlying time-space network was an integral part of the simulation engine. We can simulate one year of rail operations within one hour of computer time. We also packaged the simulation engine into an interactive decision support system through which the user can review and modify inputs and analyze outputs.

We have performed numerous studies using GeoSYM and are continuing to perform more. These studies are guiding the company in all of its important decisions about rail infrastructure investments (the sum of which is in the hundreds of millions of dollars). We are evaluating the benefit of various operational and infrastructural improvements, including the addition of signals, crossovers, and maintenance crew members and equipment. Here are some of our results:

♦ We identified several problematic areas that were contributing most to the network's inefficiency. The system demonstrated that adding a crossover in one of these areas improved rail capacity and increased revenue by up to $200 million.

♦ We evaluated several potential locations for new signals and demonstrated that adding a signal at one particular location would further increase rail capacity and increase revenue by up to $100 million .

♦ We demonstrated the benefits of changing the current signaling system to a virtual block and moving block signaling system .

♦ We demonstrated improvements (if the trains were run on schedule) that reduce interactions between trains and track maintenance crews.

Energy-Saving Metros in China

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Railway transportation plays a key role in the daily life of Chinese people nowadays, above all in large cities such as Beijing, Shanghai, etc. In these cities, the rapid increase of floating population and the limited space block the development of ground transportation, leading to serious traffic congestion almost every day. Then the metro transportation has been put into operations or been under construction in a lot of medium- and large-scale cities due to its punctuality, large transportation capacity, high-efficiency, etc. At the end of 2014, a total of almost 3000 km metro lines will be put into operation in China; moreover, in 2015 more than 40 cities will own or construct metro lines, and the total length will be over 4000km.

In comparison to other traffic modes such as airplane, bus and car, metro transportation is an energy-saving transportation mode. However, even with this characteristic, the energy consumption in Chinese metro traffic systems is still fairly huge, especially in the process of traction operations. Take Beijing metro as an example. In 2013, the energy consumption in traction operations was 648,227,451 KWH, which is almost equal to the total electricity consumed by 340,000 families in one year. Although no limit is imposed on the usage of electricity in metro transportation, the large energy-consumption still leads to urgency of the investigation of the energy-saving technique in the real-life applications.

In practice, energy consumption mainly occurs in three stages: (1) traction operations for overcoming air resistance, wheel resistance, track resistance, etc., (2) extra energy consumption by equipment such as motor, voltage transformer, etc., and (3) energy consumption in the braking process. For different operations, the consumed energy should be different. Thus, through optimizing the combination of different operations, it can be expected that the energy-consumption in the operational process will be reduced. With this concern, the currently used method for energy-saving operations is to pre-determine optimal operational curves for each train on the considered railway lines, which are usually obtained by a variety of operational research methods such as optimal control methods, dynamic programming, heuristics, etc. In reality, the driver is usually required to follow this energy-saving operation curve on each inter-station to achieve energy-saving consequences.

In the metro systems, electric energy can be regenerated when a train is braking. Theoretically, the regenerated energy can be utilized by the successive trains within the same rail section if the successive trains are in the state of acceleration. With this concern, we also develop a cooperative scheduling method to generate the energy-saving schedule for the metro systems. In this method, we maximize the overlapping time among successive trains so that the regenerated electric energy can be absorbed by the following trains. These methods can also be generalized to the network-based metro system with multiple trains.

Even with these theoretical researches, more efforts should be made to put these methods into real-life operations, owing to the existence of potential difficulties in the complicated operational environment. On one hand, it is not easy for a train driver to control a train strictly according to the pre-trip energy-saving curve on the metro line. On the other hand, an energy-saving schedule can also be disturbed by the influence of the uncertain events in the operation process. However, some of the aforementioned methods have been successfully embedded into the train control simulation systems. In the simulation platform, it is shown that these methods can further decrease the energy consumption in comparison to the previously adapted control methods. In the future, with the rapid development of auto driving techniques, these methods can be expected to efficiently apply to real-life operations.

RAS Contest Funding Solicitation

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RAS, a 15-year-old section, consists of over 120 members from around the world, including rail practitioners, academicians, students and consultants. Over the years RAS has provided an excellent platform in knowledge sharing among railroads and in increasing interest in rail industry to academicians and students. We believe RAS has had great success and is making a big contribution in rail analytics. Among various initiatives, RAS organizes the Student Paper Contest and the Problem Solving Competition every year. The Student Paper Contest has continued for more than 10 years, whereas the Problem Solving Competition started in 2010. Both of these events have been very successful in raising great interest among academicians and students worldwide. RAS is a member-sponsored professional society that is heavily dependent on sponsors to continue successful initiatives such as the Problem Solving Competition and Student Paper Contest.

The Student Paper Contest is focused on rail applications to promote awareness of rail topics, encourage new rail research and develop a pool of intellectual talent interested in rail applications. In this contest, a contestant submits a paper of his or her previously chosen and independently generated research methodology. The outcome of the competition's research can potentially be useful not only in developing real-world applications, but could also result in publications as book chapters and/or referred journals. All submissions are reviewed by a highly competent judging panel and winners get cash prizes and citations during the annual meeting.

The Problem Solving Competition was started to further promote awareness of interesting and intriguing rail problems. This initiative has been well received and has been very successful with representation from over a dozen countries. In this competition, the organizing committee (consisting of academicians and practitioners) provides an open research problem of high interest for the railroads and seeks submissions to perform research and submit reports with methodologies and results. Using a scientific methodology, the judging panel selects three finalists in addition to a few honorable mentions. More details about the competition, the submissions and winners are available on RAS website (http://www.informs.org/Community/RAS/Problem-SolvingCompetition).

We are looking for organizations to consider sponsoring these competitions with contributions in the range of $500 to $5,000. A sponsoring organization will be recognized as a sponsor of the competitions in all promotions, on RAS website, in RAS newsletter, and in RAS sessions at the INFORMS Annual Meeting. Of course, as INFORMS and RAS are nonprofit organizations, the contribution is tax deductible. RAS committee will manage and administer all contest details.

Believe it or not...

It is considered a misdemeanor offense to throw pickle juice at a trolley in Rhode Island.

In Wisconsin it was once illegal to kiss on a train.

It is against the law for a railroad to remove itself from a town of more than five hundred people in South Carolina.

In Rhode Island, it is illegal to operate a passenger car between a locomotive and a load of dirt.

In West Virginia, it was once illegal to sleep on a train.
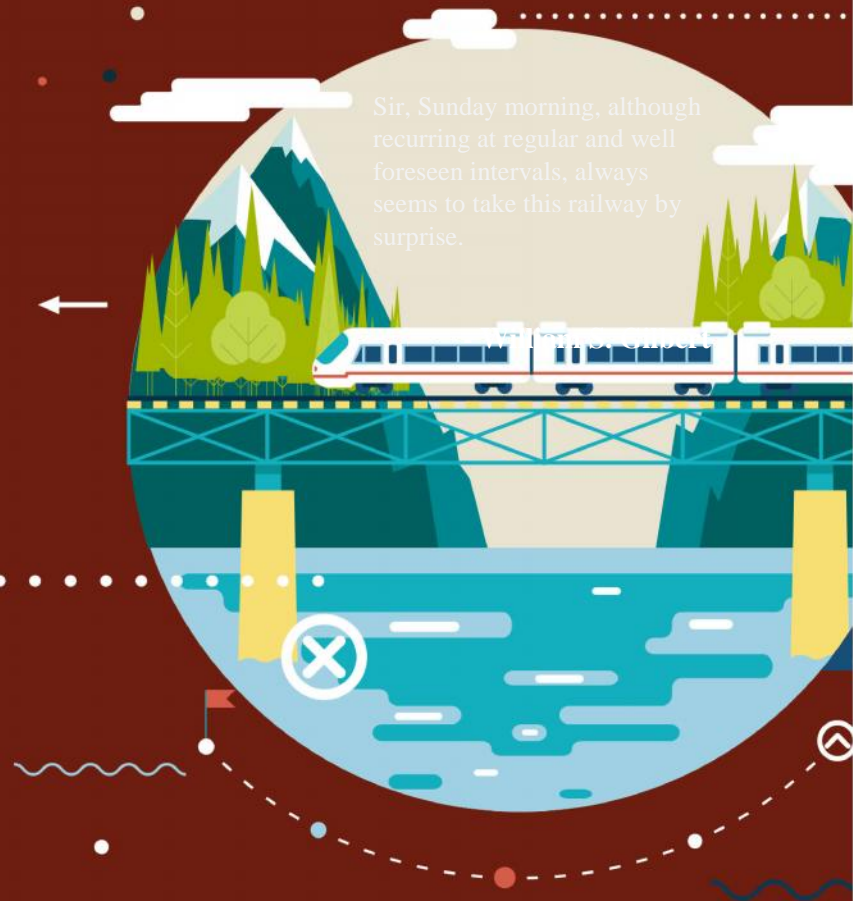
Sir, Sunday morning, although recurring at regular and well foreseen intervals, always seems to take this railway by surprise.
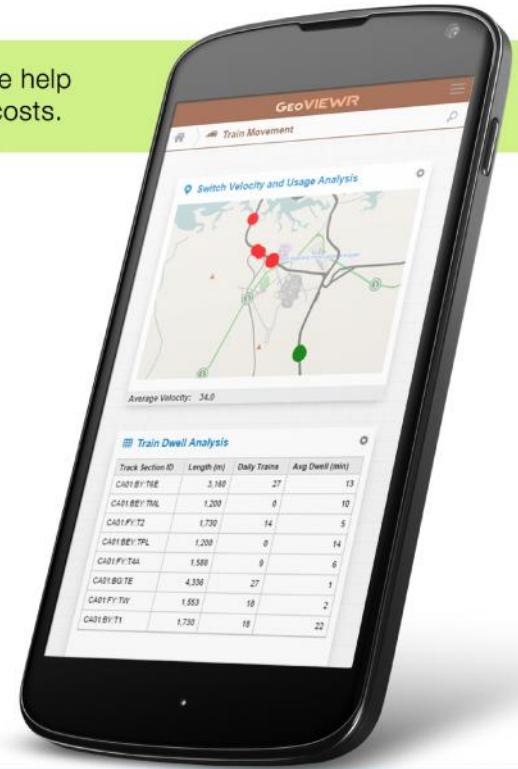
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RAS Business Meeting and Dinner at INFORMS

The RAS business meeting will be held on Sunday, November 9, from 6:15 to 7:15 pm at the Hilton Continental 2,BRLevel. The RAS Dinner will follow at 7:30 pm at Urban Tavern, located at 333 O'Farrell Street in San Francisco (www.urbantavernsf.com). The dinner is free for all RAS members and their spouses. Space is limited, so watch for a separate announcement to reserve your seats. Thanks go out to our sponsors — BNSF Railway, CSX Transportation, Norfolk Southern Corporation, Oliver Wyman, Optym and Tata Consultancy services — for their continued support of these events and of the Rail Application Section of INFORMS. We would like to invite all RAS members for the dinner on Sunday (November 9) at the INFORMS Annual Meeting.