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Great Lakes Maritime Research Institute

A University of Wisconsin - Superior and University of Minnesota Duluth Consortium

Annual Report to Congress, the U.S. Department of Transportation and the U.S. Maritime Administration

October 2008-October 2009

The Great Lakes Maritime Research Institute is a National Maritime Enhancement Institute designated by the U.S. Department of Transportation Maritime Administration

GLMRI Program Office
1023 University Drive, 291 Marshall W. Alworth Hall, Duluth, MN 55812 • (218) 726-7446 • www.glmri.org

Supported by the U.S. Maritime Administration, Grant Number DTMA1G06005

University of Duluth research vessel *R/V Blue Heron.*

Staff (left to right)

Co-Directors	**Richard D. Stewart and James P. Riehl**
Executive Director	**Carol J. Wolosz**
Associate Researcher	**Stacey Carlson**
Program Executive Assistant	**Jeannie Hartwick**
Contract Manager	**Kathy Derick** (not pictured)

2008/09 REPORT

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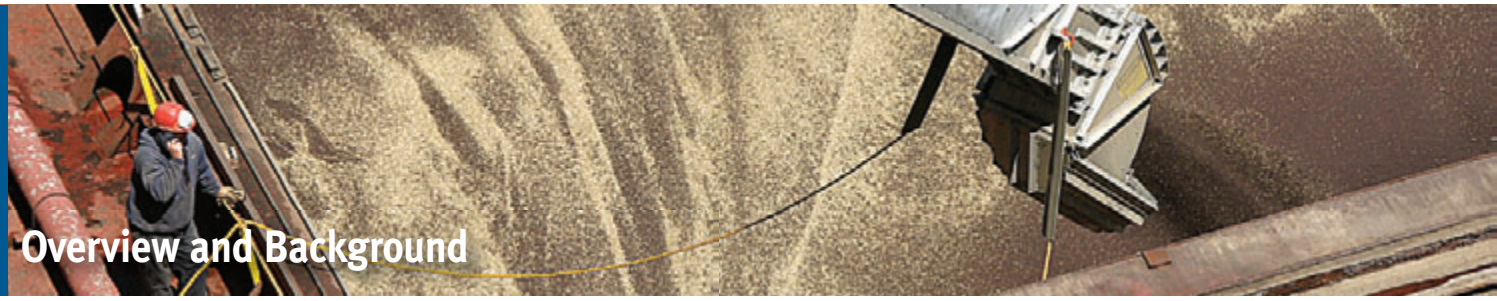


Overview and Background

The Great Lakes Maritime Research Institute (GLMRI) was established in 2004 to pursue research efforts in marine transportation, logistics, economics, engineering, environmental planning, and port management. The U.S. Maritime Administration designated GLMRI as a National Maritime Enhancement Institute on June 1, 2005. Federal funding to support GLMRI was first received in May 2005. Since that first appropriation of $750,000, GLMRI has received $1,980,000 in 2006, $990,000 in 2008, and $950,000 in 2009. This annual report summarizes the research performed under the 2008 funding from the FY '08 Federal Transportation Act. Previous annual reports are available on the GLMRI web page (www.glmri.org).

In March 2004, the University of Minnesota Duluth and the University of Wisconsin-Superior formed the GLMRI consortium to focus on Great Lakes maritime research. The two universities are located in the largest ports on the Great Lakes, the Twin Ports of Duluth, Minnesota and Superior, Wisconsin. The communities have been a transportation hub for more than 150 years. In addition to the maritime industry, the Twin Ports are serviced by four Class I railroads, and is the terminus of the longest pipeline in North America. More than 30 trucking companies are headquartered in the area. The cities are serviced by an international airport and are the corporate headquarters for the largest single engine airplane manufacturer in the U.S. The Twin Ports has a U.S. Coast Guard (USCG) Marine Safety Unit, is the home port for the USCG Cutter *Alder* and a Port of Entry with the U.S. Customs Office and The Immigration and Naturalization Service.

GLMRI represents a consortium of the University of Wisconsin-Superior Transportation and Logistics Research Center and the University of Minnesota Duluth Swenson College of Science and Engineering and Labovitz School of Business and Economics, combining the strengths of their academic and research expertise. Additionally, universities in the Great Lakes region with expertise in the research focus areas may be offered affiliation. This dynamic model provides a program with tremendous breadth as a National Maritime Enhancement Institute.

There are currently seven institutions throughout the U.S. designated as National Maritime Enhancement Institutes (NMEIs) by the Maritime Administration under Public Law 101-115. The purpose of the NMEIs is to create a research-oriented atmosphere that lends itself to providing effective input for addressing maritime issues. The institutes selected as NMEIs are capable of researching inter-disciplinary, intermodal issues, and have access to a broad spectrum of resources enabling them to address National problems within the individual program areas.

GLMRI seeks input from experts in maritime shipping and commerce and ports and governmental agencies. The consortium is committed to improving the maritime system of the Great Lakes and the United States.

Mission Statement

The Great Lakes Maritime Research Institute is dedicated to developing and improving economically and environmentally sustainable maritime commerce on the Great Lakes through applied research.

Research Focus

Initial broad research focus areas for GLMRI were mandated by Congress and have been refined with input from the Maritime Administration and various stakeholders. Each year at the GLMRI annual meetings, discussion is held with the Advisory Board as to future areas of research that can build upon completed studies and take into consideration current issues and opportunities for research within the Great Lakes maritime community.

Co-Directors' Statement

As we complete our fourth year of funded research, it is a good time to reflect on our progress and results as a university-based research institute, and confirm the course for our strategic vision. We are continuing to progress toward our goal of a permanent funding solution for maritime research. Our Advisory Board members have been a great resource as we seek solutions for a long-term funding stream that focuses on economical and environmentally-focused projects and studies for maritime transportation and commerce. Of special mention are the Saint Lawrence Seaway Development Corporation and U.S. Maritime Administration, which have been advocates in our efforts to secure funding for permanence through the U.S. Department of Transportation. This important goal of GLMRI has also been endorsed by the Great Lakes Maritime Task Force and the American Great Lakes Ports Association.

In 2009, GLMRI worked with 10 affiliated universities in the Great Lakes watershed. The research expertise of these institutions has been vital to GLMRI's success. Other universities are under consideration for affiliation as we work to expand the level and breadth of expertise in the Institute. GLMRI has continued to collaborate with Finnish and Canadian universities, and will look to expand foreign involvement in the coming year.

A key success of this year has been our engagement with our Advisory Board members and agencies. We have worked closely with the Lake Carriers' Association and their members to tie in critical topics for the GLMRI research agenda. The U.S. Army Corps of Engineers is continuing to fund GLMRI and the University of Toledo's data center for updating the master dock information for the Great Lakes. The Corps is also supporting GLMRI and the University of Minnesota Duluth's project in identifying the associated bacteria that is tied to the corrosion of the steel infrastructure in the Twin Ports and the region. GLMRI is working with a multi-agency steering group on a project to develop an annual economic impact analysis for the region and has been actively involved with the project principal investigator in providing direction and support for the project's focus.

Over the spring and summer, GLMRI had its fifth cycle for research proposal submissions, reviews and selections. In addition to reviewers from academia and industry, all of the advisory board agencies provided assistance with proposal reviews and feedback. We appreciate the agencies direct involvement and value their feedback as we strive to support research projects that address their needs.

GLMRI has continued to be an advocate for shipping in the Great Lakes by participating in many venues. Since 2007, we have been an active member of the Maritime Transportation System National Advisory Council (MTS NAC) and continue to promote Great Lakes interests for the NAC focus. We are a voting member in the Ship Operations Cooperative Program, whose mission is to address common challenges and identify new solutions for improvements in ship operations. GLMRI is also on the Advisory Board for the Maritime Primary and Secondary Education Coalition (MPSEC) in order to foster maritime education in the Nation's K-12 schools. We have been involved with the Alliance of Mayors, under the Great Lakes and St. Lawrence Cities Initiative.

Without the continued support from Congressman David Obey, Congressman James L. Oberstar and the Great Lakes congressional delegation we would not have the resources for GLMRI. This support is greatly appreciated, and certainly the success of our research institute is due in a very large part to the backing we receive from these individuals. Thank all of you for your trust in GLMRI and interest in maritime shipping and commerce.

Richard D. Stewart
Co-Director

James P. Riehl
Co-Director

Organizational Chart

GLMRI Co-Directors
Dr. James Riehl • Dr. Richard Stewart

Executive Director
Carol Wolosz

University of Wisconsin-Superior Transportation and Logistics Research Center

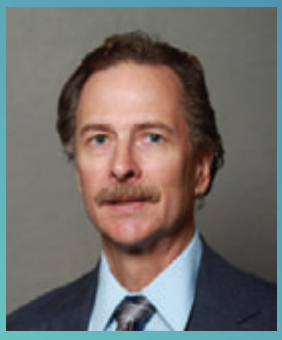
Affiliate Universities

University of Minnesota Duluth Swenson College of Science & Engineering and Labovitz School of Business & Economics

Central Harvest States grain elevator, Superior, Wisconsin.

Advisory Board

The GLMRI's Advisory Board consists of experts in maritime commerce, marine environmental issues or other segments of the Great Lakes marine transportation system. The membership was designed to bring together industry, academia, and government leaders to advise the Co-Directors on the research agenda and to provide input on topical priorities. The Advisory Board can be expanded to include additional relevant stakeholders that agree to participate.

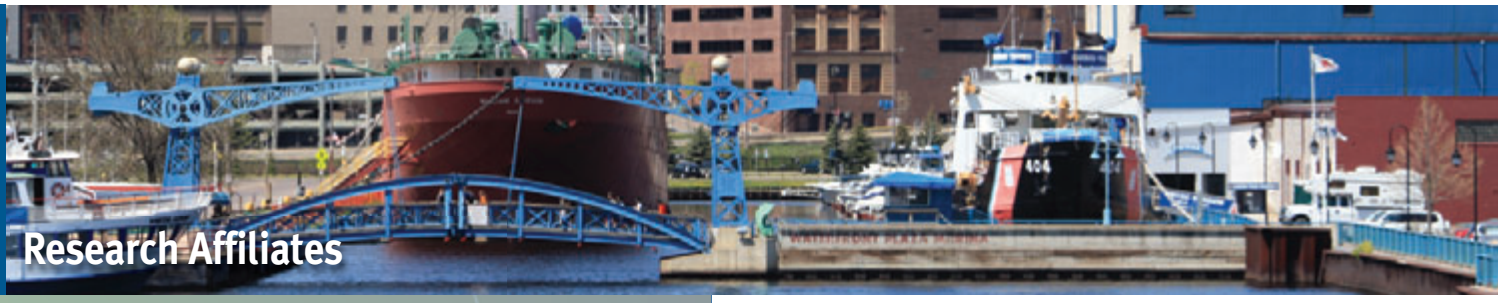


The advisory organizations, board members or their delegated representatives are below left to right:

Saint Lawrence Seaway Development Corporation **Mr. Craig Middlebrook, Deputy Administrator**	**Washington, D.C.**
U.S. DOT Maritime Administration **Mr. Floyd Miras, Acting Director, Great Lakes Gateway**	**Schaumberg, IL**
Lake Carriers' Association **Mr. James H.I. Weakley, President**	**Rocky River, OH**
U.S. Army Corps of Engineers **Lieutenant Colonel James B. Davis, District Engineer, Detroit District**	**Detroit, MI**
American Great Lakes Ports Association **Mr. Adolph Ojard, Chairman**	**Duluth, MN**
U.S. Coast Guard **Captain Lorne Thomas, Ninth District**	**Cleveland, OH**
Great Lakes Commission **Mr. David Knight, Special Events Manager**	**Ann Arbor, MI**
The Society of Naval Architects and Marine Engineers **Mr. James Sharrow, Great Lakes & Rivers Section**	**Duluth, MN**







Research Affiliates

Michigan Technological University
Houghton, MI

Great Lakes Maritime Academy
Traverse City, MI

University of Wisconsin-Green Bay
Green Bay, WI

University of Michigan
Ann Arbor, MI

Rochester Institute of Technology
Rochester, NY

University of Wisconsin-Madison
Madison, WI

University of Toledo
Toledo, OH

Purdue University North Central
Westville, IN

University of Findlay
Findlay, OH

Purdue University
West Lafayette, IN

Universities in the Great Lakes region (states bordered on the Great Lakes and in the Great Lakes watershed) with expertise in the research focus areas may be offered affiliations to partner in applicable areas. Researchers and other relevant affiliate assets from the affiliated universities are included as part of the research portfolio of GLMRI, and the affiliate may serve as project researchers based on submitted proposals in response to an annual request for proposals.

GLMRI is working with U.S. Maritime Administration personnel to advise other U.S. universities seeking status as National Maritime Enhancement Institutes to build a national platform for university maritime research. In addition to a collaboration with Finnish universities, we have initiated discussions with Canadian universities and academics.

Affiliate universities meet annually with the GLMRI Directors and the Advisory Board to provide input on future research topics and to discuss current research results and process. GLMRI maintains an open and continuous dialogue with affiliates to address evolving issues regarding maritime commerce. Research affiliates are encouraged to leverage GLMRI resources to secure independent and joint funding opportunities for Great Lakes maritime research. Matching funding is a significant consideration.

GLMRI funding for research proposals is granted only to University Research Affiliates, and only proposals from GLMRI University Research Affiliates will be accepted for funding consideration.

Universities seeking to obtain affiliate status should provide a request to the GLMRI Program Office with details on the capabilities and assets that they would bring to support the mission of GLMRI, along with an expected interest area for future research endeavors. Requests are evaluated by the Institute co-directors for affiliate status in GLMRI. University Affiliates' Agreements are reviewed annually.

The current affiliate universities are listed on the following pages.

Great Lakes Maritime Academy training vessel *T/S State of Michigan*.

UNIVERSITY OF FINDLAY
Mark Alliman, Program Manager

1000 North Main Street, Findlay, OH 45840
School of Environmental and Emergency Management

The School of Environmental and Emergency Management (SEEM) was established as a department within the University of Findlay in 1986 with the initiation of the Bachelor of Science in Hazardous Materials Management Degree.

SEEM's education and training programs include: environmental, safety and occupational health (ES&H); emergency management; public health; school safety and security; and law enforcement. SEEM's maritime security program has developed three courses approved by the U.S. Maritime Administration and is currently developing a course entitled Port & Vessel Security for Public Safety Officials for Department of Homeland Security approval.

Since its inception, SEEM has awarded degrees to more than 1,100 people from the Academic Degree Programs. Also during that time, more than 100,000 people have been trained coast-to-coast.

GREAT LAKES MARITIME ACADEMY
RADM John Tanner, USMS, Superintendent

1701 East Front Street, Traverse City, MI 49686

The Great Lakes Maritime Academy (GLMA) is a division of Northwestern Michigan College (NMC) and a partner of Ferris State University. The Academy trains men and women to serve as business professionals and Merchant Marine officers aboard Great Lakes and ocean ships.

The program is unique among other state maritime academies. GLMA is designated as a regional maritime academy and the nation's only freshwater academy. Upon graduation, mariners are qualified to sail the Great Lakes or oceans and are awarded both a Bachelor's Degree in Business Administration and an Associate's Degree in Maritime Technology. This dual degree combination offers employers the finest maritime personnel who are fully compliant with STCW 95 standards.

Successful cadets will be qualified to take the U.S. Coast Guard examination for a Third Mate Great Lakes or Oceans Unlimited Tonnage, First Class Pilot Great Lakes (Deck Program) or Third Assistant Engineer, Steam and Motor Vessels of any Horsepower (Engineering Program).

UNIVERSITY OF MICHIGAN
Dr. Armin Troesch, Chair

2600 Draper Drive, Ann Arbor, MI 48109
Department of Naval Architecture and Marine Engineering

Students in the Department of Naval Architecture & Marine Engineering at the University of Michigan learn how to design/analyze ships and the other complex marine systems for a demanding and often harsh environment. In addition to the more traditional disciplines of naval architecture and marine engineering, the program offers courses and research opportunities in offshore engineering and coastal engineering. Graduates can be found in the U.S. Navy and other navies of the world, the U.S. Coast Guard, offshore companies, shipyards, marine design firms, shipping companies, research laboratories, peer academic institutions, etc.

Research Affiliates

MICHIGAN TECHNOLOGICAL UNIVERSITY
William J. Sproule, Professor

1400 Townsend Drive, Houghton, MI 49931-1295
870 Dow Environmental Sciences and Engineering Building
Department of Civil and Environmental Engineering

Michigan Technological University conducts an educational outreach program on Great Lakes Maritime Transportation for K-12 students, teachers, and communities. From 2006-08, program activities have included conducting 5-day summer teacher institutes in Duluth and in the eastern Upper Peninsula, developing new classroom lessons on Great Lakes shipping, assembling and disseminating 24 Great Lakes Maritime Transportation education trunks and training workshops to maritime museums and K-12 education centers throughout the Great Lakes basin, developing a web module on Great Lakes shipping (http://techalive.mtu.edu/series.htm), presenting posters and presentations at conferences, and developing a Great Lakes Maritime Transportation education website. Partners have included: Minnesota Sea Grant, Duluth Seaway Port Authority, Great Lakes Shipwreck Historical Society & Whitefish Lighthouse, and Lake Carriers' Association.

PURDUE UNIVERSITY
Dr. Lynn A. Corson, Director

2655 Yeager Road, Suite 103, West Lafayette, IN 47907-2108
Clean Manufacturing Technology Institute Center for the Environment

The Clean Manufacturing Technology Institute (CMTI) was established at Purdue University in 1994 as the successor organization to the Environmental Management and Education Program founded there in 1984. CMTI staff provides technical assistance, outreach, training and research services to manufacturers and government entities on environmental regulatory compliance, process engineering efficiencies, pollution prevention/clean manufacturing, energy conservation and ISO 14001 Environmental Management System conformance.

CMTI is supported by grants and agreements with federal and state government agencies, trade associations and private and non-profit corporations. It has provided services to more than 3,500 manufacturers and 250 local, state and federal government entities.

PURDUE UNIVERSITY NORTH CENTRAL
Dr. Thomas F. Brady, Department Chair

1401 South U.S. Hwy 421, Westville, IN 46391
Engineering Technology

The Purdue University North Central College of Engineering and Technology provides degree programs in technical disciplines and engagement assistance in economic development for citizens in north central Indiana. The college has conducted research in the areas of coal transportation infrastructure, electricity distribution and control, and simulation of large scale systems.

How to become an affiliate

Universities seeking to obtain affiliate status should provide a request to the GLMRI Program Office with details on the capabilities and assets that they would bring to support the mission of GLMRI, along with an expected interest area for future research endeavors. Requests are evaluated by the Institute's co-directors for affiliate status in GLMRI. University affiliates are renewed annually.

GLMRI funding for research proposals is granted only to University Research Affiliates, and only proposals from GLMRI University Research Affiliates will be accepted for funding consideration.

GLMRI Program Office
1023 University Drive
291 Marshall W. Alworth Hall
Duluth, MN 55812
(218) 726-7446
www.glmri.org

ROCHESTER INSTITUTE OF TECHNOLOGY
Dr. James Winebrake, Co-Director

92 Lomb Memorial Drive, Rochester, NY 14623
Laboratory for Environmental Computing and Decision Making

Rochester's Great Lakes Research Program is housed in the RIT Laboratory for Environmental Computing and Decision Making (LECDM). The LECDM has a central focus of studying freight movement, transportation logistics, environment, and cyberinfrastructure. Its' goal is to improve freight-related transportation decision-making by advancing and integrating environmental cyberinfrastructure tools and modeling techniques into supply chain logistics analyses. The Great Lakes Research Program is aimed at understanding and improving the efficiency and environmental footprint of intermodal cargo flows in and around the Great Lakes.

UNIVERSITY OF TOLEDO
Richard Martinko, Director

2801 West Bancroft Street, Toledo, OH 43606
Intermodal Transportation Institute & University Transportation Center

The Intermodal Transportation Institute at The University of Toledo as a partnership focuses on Transportation for Economic Security and Development: Alternate Energy, Infrastructure Utilization, and Supply Chains. These are critical transportation issues that substantially impact the ability of the U.S. to compete in an increasingly competitive global marketplace. Future economic growth and development are closely linked to the capability to move goods and people rapidly and efficiently while avoiding negative environmental impacts. The University of Toledo is designated as a U.S. Department of Transportation University Transportation Center with these same focus areas.

UNIVERSITY OF WISCONSIN-GREEN BAY
Dr. Derryl Block, Interim Dean

2420 Nicolet Drive, WH303, Green Bay, WI 54311-7001
College of Professional and Graduate Studies

The University of Wisconsin-Green Bay is unique among other state universities in its emphasis on an interdisciplinary, problem-focused educational experience that prepares students to think critically and address complex issues in a multicultural and evolving world. The university enriches the quality of life for students and the community by embracing the educational value of diversity, promoting environmental sustainability, encouraging engaged citizenship, and by serving as an intellectual, cultural and economic resource. UW-Green Bay's Urban and Regional Studies Program, Center for Biodiversity, and Institute for Environmental Management and Business are just a few examples of how the university facilitates research on social and economic development and community development in the greater Green Bay region and beyond.

UNIVERSITY OF WISCONSIN-MADISON
Dr. Teresa Adams, Director

1415 Engineering Drive, Room 2205, Madison, WI 53706
National Center for Freight and Infrastructure Research and Education

The University of Wisconsin-Madison (UW-Madison) is home to the National Center for Freight and Infrastructure Research and Education (CFIRE). CFIRE is a U.S. Department of Transportation National University Transportation Center with a multimodal research, training, education and outreach focus on Sustainable Freight Transportation Infrastructure and Systems. CFIRE has an annual budget of approximately $7 million. It facilitates the Mississippi Valley Freight Coalition, a 10-state regional organization to cooperate in the planning, operation, preservation, and improvement of freight transportation infrastructure and networks in the AASHTO Mississippi Valley Conference region.

2009 Special Projects

Maritime Transportation System National Advisory Council

Ms. Carol Wolosz continued GLMRI representation on the Maritime Transportation System National Advisory Council in 2009. The Council met in July to address its focus and new priorities with the newly-appointed Secretary of Transportation, Ray LaHood. Secretary LaHood requested advice from the Council on how to better integrate the waterways into the existing intermodal freight transportation system, as well as recommendations on how to address the Congressional mandates of the Marine Highway Program.

MTSNAC was established in 2000 to advise the Secretary on matters relating to the Marine Transportation System, including waterways, ports, and their intermodal connections. It is comprised of 30 representatives from transportation-related organizations. GLMRI was appointed by the Secretary of Transportation to MTS NAC in October 2007.

At the July meeting, Ms. Wolosz provided the members and attendees copies of the GLMRI 2008 annual report, and also provided copies of *Great Lakes/Seaway Review* magazine (Oct-Dec 2008, Vol. 37 No. 2) highlighting Dr. Stewart's article titled "Agents of Change," which looks at the challenges and opportunities for Great Lakes maritime commerce.

Collaboration for National Maritime Research Agenda

GLMRI is working with U.S. Maritime Administration (U.S. DOT) personnel to advise other U.S. universities seeking status as National Maritime Enhancement Institutes to build a national platform for university maritime research. GLMRI is also working with the Committee on the Marine Transportation System's (CMTS) Action Team for Research and Development to assist and support a national focus for maritime research. Dr. Sandra Knight from the Action Team attended the Fall GLMRI meetings, and also gave a presentation to the affiliates and researchers on CMTS.

Media Coverage in Great Lakes/Seaway Review

The Oct-Dec 2008 edition of the *Great Lakes/Seaway Review*, published by Harbor House Publisher Boyne City, Michigan, featured many stories on GLMRI's work, including:

- Great Lakes Shipping and Commerce by Dr. Richard Stewart
- Ballast-free Ship Design and Testing by Drs. Michael Parsons and Miltiadis Kotinis
- Shipboard Testing of B-20 by Dr. Dan Pope
- Shipbuilding Capacity Study by Dr. David Singer
- GLMRI's sponsored trip to Finland by David Knight, from the Great Lakes Commission.

Alliance of Mayors

In December 2008, Dr. Richard Stewart provided an overview on short sea shipping and issues impacting the Great Lakes at a meeting of the Alliance of Mayors under the Great Lakes and St. Lawrence Cities Initiative. The meeting was held in Superior, Wisconsin hosted by Superior's Mayor Dave Ross, with the mayors from Duluth, Minnesota and Thunder Bay, Ontario, in attendance.

The group's focus is to enhance Great Lakes and St. Lawrence Seaway transportation of commercial goods while benefitting the economy, energy, and environment.

In addition, Dr. Stewart provided a presentation at a meeting in Trois-Rivieres, Quebec, to a bi-national group of 20 Great Lakes mayors, government agencies and non-government agencies at the Great Lakes and St. Lawrence Cities Initiative meeting on "Expanding Great Lakes and St. Lawrence Marine Transportation" in June 2009.

Northern Minnesota/Northwest Wisconsin Regional Freight Study

Dr. Richard Stewart and Associate Researcher Stacey Carlson participated in the Northern Minnesota/Northwestern Wisconsin Regional Freight Plan, a joint undertaking by the Minnesota Department of Transportation and the Duluth-Superior Metropolitan Interstate

Windmill components staged for shipment, Lake Superior Warehousing, Superior, Wisconsin.

SOURCE: CRAIG MIDDLEBROOK

Council. As participants on the steering committee, Dr. Stewart and Ms. Carlson provided information on the maritime and pipeline industries.

Dr. Peter Lindquist and Dr. Mark Vonderembse at the University of Toledo played a vital role in the freight study by making the Great Lakes Maritime Information Delivery System available to the consulting team. They provided insight into their research on commodity movements and economic impacts of freight in the Upper Midwest region by providing commodity flows by mode for each region, intermodal connectivity in each region, socio-economic data for each region, and the relationship between cargo movements and economic activity.

The freight study is a multimodal transportation planning effort that includes highway (commercial vehicle operations), rail, waterway, air cargo, pipeline, and intermodal transportation. The study is intended to increase the understanding of the freight demands being placed on the regional transportation infrastructure. (http://www.dot.state.mn.us/planning/freightplan/resources.html)

Manual of Best Environmental Management Practices

Dr. Lynn Corson, Director of the Clean Manufacturing Technology Institute at Purdue University, and Mr. Steve Fisher, Executive Director for the American Great Lakes Ports Association, developed the Best Management Practices manual to assist small ports in finding ways to better manage environmental issues under their 2007/8 GLMRI-funded project. They evaluated 12 U.S. and Canadian ports with regard to key environmental management areas to identify opportunities for Great Lakes ports to move beyond compliance. The manual is accessible on the GLMRI web page (www.glmri.org/resources/).

Ship Operations Cooperative Program Membership

In October 2009, GLMRI was accepted for membership in the Ship Operations Cooperative Program (SOCP). SOCP is a government industry organization whose purpose is to address and promote commercial operations through the identification, development, and application of new methods, procedures, and technologies. Through SOCP, U.S. shipping companies and other maritime organizations can work together to solve common problems relating to vessel operations and provide opportunities to explore new technologies (http://www.socp.us/).

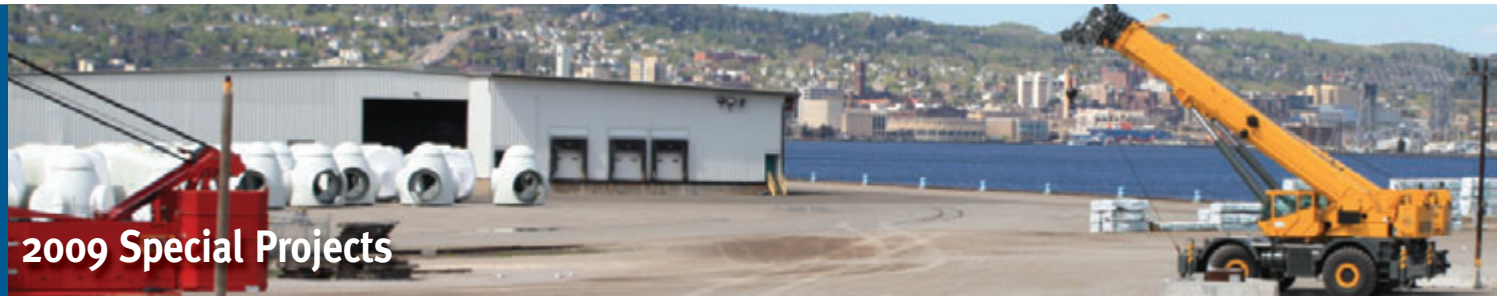
Lake Superior Technology Conference

Carol Wolosz provided a program overview at the Lake Superior Technology Conference in Ashland, Wisconsin, on August 6, 2009. The conference was produced by the Wisconsin Technology Council and the Wisconsin Innovation Network, Lake Superior Chapter, to promote economic development through technology assets in Northwest Wisconsin. The conference was attended by industry and service specialists, state and local government officials, regional academics and economic developers. The keynote speaker was Dick Leinenkugel, Secretary of Commerce for Wisconsin.

7th Annual Northeastern Wisconsin Trade Conference

The 7th Annual Northeastern Wisconsin Global Trade Conference was held in Green Bay, Wisconsin, April 6-7. The focus was to provide Wisconsin and regional business professionals with the resources to compete in the demanding global trade markets.

U.S. Rep. Tom Petri (R-6th District) and U.S. Rep. Steve Kagen (D-District 8) were key supporters of the conference. Drs. Ray Hutchison and John Stoll, along with Ms. Libby Ogard and the team of University of Wisconsin-Green Bay (UW-GB) students, provided a poster and informational display at the conference on their feasibility study to build a container terminal and the freight services in Green Bay. Ms. Wolosz also provided a GLMRI program display as a joint presentation with the UW-GB team, and met with the congressmen and their staff along with other conference attendees.



2009 Special Projects

Great Lakes GIFT workshop

Dr. James Winebrake from Rochester Institute of Technology and Dr. James Corbett from University of Delaware, along with their research team, held a summer workshop on the Great Lakes Geographic Intermodal Freight Transport (GL-GIFT) model on August 17, in Rochester, New York. Public and private stakeholders learned about the GL-GIFT model and provided feedback to the team. Participants included energy and environmental consulting firms, universities, and U.S. and Canadian transportation agencies. The workshop aimed to introduce GL-GIFT to those unfamiliar with the model, allow for hands-on exploration of the model, and request suggestions for improvement of the GL-GIFT model.

Advisory Board Meeting

On September 23, the GLMRI Advisory Board met in Superior, Wisconsin, at the Richard I. Bong Veterans Heritage Center. The meeting was attended by Mr. Craig Middlebrook (Saint Lawrence Seaway Development Corporation), LTC James Davis (U.S. Army Corps of Engineers), LCDR Robert Haggerty (U.S. Coast Guard), Mr. Floyd Miras (U.S. Maritime Administration), Mr. Adolph Ojard (American Great Lakes Ports Association) and Mr. Ken Gerasimos (Lake Carriers' Association). Other guests included Ms. Marie Strum and Mr. Mike O'Bryan from USACE and Mr. Todd Ripley from the Maritime Administration.

Each of the board members provided an update on their agency and their views and needs for research focus and impacts. Pending changes for shipping standards, opportunities for researchers and the need for good data was emphasized. This was the fifth annual meeting of the Advisory Board.

Annual Affiliates Meeting

For the first time, the GLMRI Affiliate Universities and Researchers meeting agenda was expanded to a day and a half for research presentations and informational sessions. The schedule included a research workshop to share ideas for funding alternatives and outreach opportunities. Dr. Sandra Knight from the Committee on the Marine Transportation System (CMTS) Action Team for Research and Development provided an overview of CMTS and its interests and focus for research. The GLMRI meeting agenda and presentations are available on www.glmri.org/news/.

Maritime Education Chests

Ms. Joan Chadde, Maritime Education Program Coordinator at Michigan Technological University continues to have a growing interest in the Maritime Education Chests. Over the past year, four chests were purchased by the Port of Green Bay, the Port of Milwaukee, an elementary school in Michigan and the Maritime Museum in Sandusky, Ohio. A total of 29 maritime chests have been distributed around the Great Lakes region.

These treasure chests are designed for upper elementary and middle school classrooms and provide a wide variety of resources for teaching about Great Lakes shipping, including sample cargo, such as iron ore (taconite) pellets, coal, salt, limestone; a 12 ft. x 14 ft. canvas floor map of the Great Lakes watershed showing major shipping ports, children's books, videos, and several curricula on Great Lakes shipping.

Information on the chests, K-12 maritime education lesson plans, photos activities and other teaching materials are available on the GLMRI web page (http://www.glmri.org/resources/).

Collaboration with the Society of Naval Architects and Marine Engineers

GLMRI has been a regular participant in the Great Lakes and Rivers Section meetings of the Society of Naval Architects and Marine Engineers (SNAME). In November 2008, Drs. Miltiadis Kotinis and Michael Parsons presented an update on their GLMRI project "Hydrodynamics of the Ballast-Free Ship Revisited" meeting held in Ann Arbor, Michigan. In February 2009, Mr. Sharrow provided an update on the Duluth-Superior Corrosion Study at the meeting held in Cleveland,

Ohio. Ms. Carol Wolosz provided an update on the GLMRI current research at the meeting in June at Green Bay, Wisconsin.

Also, SNAME members have been active in the GLMRI research agenda. Members from the Great Lakes and Rivers Section have served as proposal reviewers bringing in a technical perspective with extensive industry experience. Mr. James Sharrow, the facilitating manager of the Duluth Seaway Port Authority, sits on the GLMRI Board of Advisors.

Corrosion Study Group

In June 2009, the US Army Corps of Engineers hosted a meeting of the participants/agencies involved with the projects associated with looking at the effects, potential causes and possible remedies to address the fresh water corrosion impacting the Duluth-Superior Harbor. GLMRI has been funding Dr. Randall Hicks' research on the identification of the microbiologically influenced corrosion. This research is aiding the port engineers in finding solutions and creating tools to sustain the steel structures and infrastructure in the harbors in and around Lake Superior. The meeting also addressed other research being done by the US Navy, Wisconsin Sea Grant, Duluth Seaway Port Authority and the City of Superior, with support from AMI, a local engineering firm.

Economic Analysis Project Steering Group Meeting

The Economic Steering Group met on September 22, 2009 to discuss the progress to date on the Economic Impact study under Phase I, and to review model options with the group on the best way to proceed. The meeting was chaired by Dr. Doorn, the principal investigator on the project from the University of Minnesota Duluth's (UMD) Economics Department. Attendees included representatives from the US Army Corps of Engineers, the St. Lawrence Seaway Development Corporation, the Maritime Administration (MARAD), the Duluth Seaway Port Authority, the American Great Lakes Ports Association, GLMRI, along with the academic team from UMD and University of Toledo (UT). Dr. Peter Lindquist from UT is the co-principal investigator, and is hosting the data support for the project through the Great Lakes Maritime Data Clearinghouse. Dr. Doorn will be providing the initial analysis on the Twin Ports of Duluth, Minnesota and Superior, Wisconsin, since the local resources are accessible for developing the model and working out the data issues.

The Steering Group initially met with Dr. Doorn on January 29, 2009, via teleconference. Dr. Doorn did an initial analysis of the available models and data. He and Dr. Lindquist have been working to obtain the necessary data for inclusion in the specific models.

The Duluth-Superior port pilot analysis will be scalable to the other Great Lakes ports. The Steering Group will reconvene to review the results of this initial application of the model to extend across the Great Lakes.

GLMRI Transportation Research Board Involvement

GLMRI continued to have an increasing presence at the 88th Annual Transportation Research Board Meeting in Washington, D.C., in January 2009. Dr. Stewart serves as a member on the Ports and Channels Committee and the Marine Environmental Committee. Ports and Channels Committee is concerned with planning, financing, and management of coastal and Great Lakes ports and channels to includes port maintenance and development, technology relating to cargo handling and deep draft vessels, landside access, cruise operations, environmental issues, and other local, state, and national issues which contribute to the integration of water transportation into a multimodal transportation system. The Marine Environmental Committee considers the environmental performance of the maritime transportation system including ports, vessels, waterways and other maritime activities.

Ms. Carol Wolosz and Ms. Libby Ogard participated in the Committee on Inland Water Transportation. This committee looks at research related to the movement of freight and passengers by inland and intra- and intercoastal waterways. Ms. Wolosz also participated in the Task Force on Marine Safety and Human Factors meeting.

Dr. James Winebrake from Rochester Institute of Technology and Dr.

Ships in harbor, Superior, Wisconsin.

SOURCE: CRAIG MIDDLEBROOK

2009 Special Projects

James Corbett from the University of Delaware made several presentations on the Great Lakes Geographic Intermodal Freight Transportation (GIFT) model. Dr. Peter Lindquist and his research team from the University of Toledo participated in several of the freight data sessions.

The Center for Freight and Infrastructure Research and Education (CFIRE) at the University of Wisconsin-Madison hosted the Wisconsin Reception at the TRB. GLMRI provided sponsorship support for the venue, and also had the GLMRI display and information at this networking event.

Students Brad Peot, Elisa Stoiss-Baker and Nicole Severson from the University of Wisconsin-Superior's Transportation and Logistics major attended TRB as an educational opportunity. They also worked at the GLMRI display at the Wisconsin reception to provide informational material to the attendees.

National Urban Freight Conference and Workshop

The National Center for Freight and Infrastructure Research and Education (CFIRE) and the METRANS Transportation Center hosted the second national workshop on Freight Research at University Transportation Centers on October 20, 2009, in Long Beach, California. This national workshop and forum brought together national leaders from the freight transportation community and from educational institutions to explore opportunities for collaborative research in freight, identify colleagues and contacts for continued cooperation, define existing barriers and challenges for freight research and information dissemination, and to explore institutional arrangements that will be needed to meet the research and training needs of the future. This workshop was held in conjunction with the 3rd Annual METRANS National Urban Freight Conference with the focus to examine the impacts of goods movement and international trade in metropolitan areas.

Dr. Stewart made two presentations at the meetings. He provided a presentation for discussion on a national program for dedicated funding allocated toward university maritime research at the conference. In this presentation, he discussed the various studies on maritime research needs starting with National Academy of Science in the 1960s to the present. All of the independent and government studies have highlighted the fact that there is compelling need for a national maritime research program tied to universities along with a dedicated federal funding stream for these universities. He provided examples of the few universities currently conducting maritime research. He also highlighted some of the challenges that have prevented the recommended agenda from happening and the lack of funding in recent budgets. Dr. Stewart concluded the presentation with a model to fund the National Maritime Enhancement Institutes through the Department of Transportation.

Additionally, Dr. Stewart presented a GLMRI program overview at the workshop that preceded the conference.

CFIRE, at the University of Wisconsin-Madison, is a University Transportation Research Center under Research and Innovative Technology Administration (RITA) and is also an affiliate of GLMRI.

World Maritime Day

World Maritime Day was celebrated in the Twin Ports of Duluth-Superior on October 16, 2009, with climate change as the focus of the event. The public was invited to respond to the question, "How do you think a changing climate will impact the Great Lakes?" and the first 125 respondents received a free ticket to a special screening of the IMAX film, Mysteries of the Great Lakes. Along with the film, the event included a live news broadcast and free tours of the U.S. Coast Guard cutter *Alder*. Ms. Stacey Carlson attended planning meetings and provided support to the event organizers, the Duluth Seaway Port Authority, Minnesota Sea Grant, the U.S. Coast Guard, the Duluth Entertainment and Convention Center/Duluth Omnimax Theatre and Northland's NewsCenter. In total, over 200+ students and adults attended the event.

Ms. Stacey Carlson with students at the 2009 River Quest Program.

Deck Cadet Erika Schultz, Ms. Judi Rokos and Engine Cadet Katrina Walheim from the Great Lakes Maritime Academy at the Women on the Water Conference in Castine, Maine.

Great Lakes contingent participates in Women on the Water Conference

In October, MARAD hosted the 3rd Annual Women on the Water Conference at the Maine Maritime Academy in Castine, Maine. This event brings together the midshipmen and cadets attending the U.S. maritime academies with members of the maritime industry, government and academia. Ms. Carol Wolosz, GLMRI Executive Director, and Ms. Judi Rokos, Director of Administration, Deck Cadet Erika Schultz and Engine Cadet Katrina Walheim from the Great Lakes Maritime Academy, attended from the Great Lakes region. Early female graduates from the academies presented the challenges and opportunities that they experienced in their maritime careers.

2009 St. Louis River Quest

Ms. Stacey Carlson participated in the 17th annual St. Louis River Quest in Duluth, Minnesota, on May 12-14, 2009. River Quest is an educational program for local sixth-graders to help them understand and better appreciate the Duluth-Superior harbor and St. Louis River by teaching them about making good environmental decisions, being safe on the water, and understanding shipping activities.

The presentation this year focused on navigating around the Duluth-Superior harbor and a large 9'x12' canvas painted of the harbor was used to show the many docks in the harbor, the two entries, and the physical make-up of the harbor. The sixth-graders were grouped as "shipmates" and navigated the harbor with a small-scale ship and a length of yarn. The students were asked to determine how long a ship was in port by identifying which docks it traveled to, how long it took to load or unload its cargo, and how long it took to navigate throughout the harbor. (http://www.duluthport.com/rqfs.html)

K-12 Maritime Conference Participation, Focus on Great Lakes Regional Programs

In May, Ms. Carol Wolosz participated in the Great Lakes Primary and Secondary Maritime Education Conference in Erie, Pennsylvania. The conference focused on expanding K-12 maritime education in the Great Lakes Region.

Congresswoman Kathy Dahlkemper, Congressional District 3, Pennsylvania, was a key presenter at the conference, and also was provided information and an overview of GLMRI. The conference was co-sponsored by the Ship Operations Cooperative Program (SOCP) and the Maritime Primary and Secondary Education Coalition (MPSEC).

GLMRI is an active partner and advisory board member of MPSEC, whose mission is to promote maritime education in primary and secondary schools across the nation. (http://www.mpsecoalition.com/)

K-12 Teachers Workshop Planning for June 2010

Ms. Joan Chadde from Michigan Technological University is setting up a new venue in Toledo, Ohio for the K-12 Teachers Workshop June 21-25, 2010. The project for 2010 has gained support from GLMRI affiliates at the University of Wisconsin-Madison's Center for Freight and Infrastructure Research and Education (C-FIRE) and University of Toledo's Intermodal Transportation Institute for additional sponsorship.

Also, the Maritime Primary and Secondary Education Coalition will be participating in the program and assisting in the publicity for the program. Renee Marazon from the Toledo Maritime Academy will be helping with the local arrangements. Dave Knight, GLMRI Advisory Board member representing the Great Lakes Commission, will be one of the many presenters on the 2010 agenda, along with area businesses and agencies. Information will be posted on the GLMRI web site as the details are available.

GLMRI Research Projects for 2009

In this report, project summaries are provided on the research efforts selected for GLMRI in 2008. The Request for Proposals was released in March 2008. The program office received a total of 16 proposals from nine of the 12 universities, requesting over $1.1 million. External reviewers were selected based on the content/topic of the proposal. Each proposal was reviewed by multiple reviewers from academia, the maritime industry and governmental agencies. As in the past, proposals were prioritized, and a funding plan was developed within the constraints of the available resources. Many of the proposers were offered a lesser amount than their requests, and were asked to provide an update work plan and budget to allow for the reduced funding.

Additionally, efforts at the University of Minnesota Duluth continued on the bio-diesel research for the Research Vessel *Blue Heron*, and a "seed" project was initiated to develop an Economic Analysis for the Great Lakes with research funding from UMD and UW-S.

GLMRI Focus Areas for 2010

For the FY 2010 research projects, the following GLMRI focus areas were included as the key areas to target research efforts. This list was provided to potential researchers for their preparation in developing proposals.

- Evaluate short sea shipping market opportunities on the Great Lakes.
- Evaluate export and import markets for foreign trade between ports on the Great Lakes and foreign ports such as those located in Europe and Africa.
- Evaluate the environmental benefits of waterborne transportation in the Great Lakes region and assist in developing sustainable solutions to the environmental effects of maritime transportation and port operations.
- Analyze the methods and effects of taxes and fees imposed on Great Lakes shipping.
- Evaluate the state of shipbuilding and repair bases on the Great Lakes and the impact to the industry and national security.
- Analyze the origin-to-destination flow of freight in the Great Lakes.
- Analyze the economic viability of establishing transshipment facilities and intermodal for ocean-going and intra-lake cargoes on the Great Lakes, which may include the evaluation of 12-month operations of the locks and shipping lanes.
- Evaluate new vessel designs for domestic and international shipping on the Great Lakes.
- Develop new products and technologies to enhance port security and port operations.
- Provide education and outreach activities to the public on Great Lakes maritime shipping, port security and intermodal operations.
- Identify ways to improve the integration of the Great Lakes Marine Transportation System (MTS)/Marine Highway into the national transportation system.
- Examine the potential of expanded seasonal operations on the Great Lakes MTS/Marine Highway.
- Identify ways to include intelligent transportation applications into the Great Lakes MTS.
- Analyze the effects and impacts of aging infrastructure and port corrosion on the Great Lakes MTS.
- Establish and maintain a model Great Lakes MTS database, and develop tools for economic and environmental modeling and analysis.
- Identify market opportunities for, and impediments to, the use of United States-flag vessels in trade with Canada on the Great Lakes.

GLMRI Research Selections for 2010

GLMRI released its fifth Request for Proposals on April 2, 2009. Fifteen proposals were received in June, and the review process ensued over June and July. Each proposal was reviewed by a panel of academics, representatives from the maritime industry and governmental agencies. The following projects were selected to be funded from the joint funding source for the 2010 research year.

- WebGIFT: Expanding Access to the Great Lakes Geospatial Intermodal Freight Transportation (GL-GIFT) Model (Rochester Institute of Technology - Dr. J. Scott Hawker)
- Evaluation of Integrated Electric Plants for Great Lakes Self-Unloaders (University of Michigan - Dr. David Singer)
- Refinement of the Ballast-Free Ship Concept (University of Michigan - Dr. Michael Parsons)
- Modal Comparison of Great Lakes Freight Transportation Effects on the General Public (University of Minnesota Duluth - Dr. Christopher McIntosh)
- Economic Impact of the Great Lakes and St. Lawrence Seaway System (GLSLS), Phase II (University of Minnesota Duluth - Dr. David Doorn)
- Developing a Risk Assessment Tool to Predict the Accelerated Corrosive Loss of Port Transportation Infrastructure (University of Minnesota Duluth - Dr. Randall Hicks)
- Year 4: Building Sustainable Solutions to the Issue of Ballast Water Treatment: Testing Relationships between Propagule Pressure and Colonization Success of Invasive Species (University of Minnesota Duluth - Dr. Donn Branstrator, along with the University of Wisconsin-Superior's Lake Superior Research Institute and Great Ships Initiative)
- The Great Lakes Maritime Information Delivery System: A Resource for the Regional Analysis of Intermodal Freight Flows in the Great Lakes Region (Phase V) (University of Toledo - Dr. Peter Lindquist)
- Great Lakes Maritime Education Program for K-12 Teachers, Students and Communities (Michigan Technological University - Ms. Joan Chadde)

Additionally, UMD and UW-S will look to fund efforts within the university research programs. UW-S will provide partial funding toward the continuation of the Great Lakes Marine Container Service Feasibility Study: Connecting Green Bay to Global Container Service providers serving ports on the St. Lawrence Seaway (University of Wisconsin-Green Bay - Drs. Ray Hutchison and John Stoll).

Dredging in the Duluth-Superior harbor.

SOURCE: MARINE TECH, LLC

PROJECT REPORT

Year 3: Building Sustainable Solutions to the Issue of Ballast Water Treatment: Testing Relationships Between Propagule Pressure and Colonization Success of Invasive Species

PRINCIPAL INVESTIGATOR **Donn Branstrator, Ph.D.**

Biology Department **University of Minnesota Duluth**

Dr. Donn Branstrator leads a team of undergraduate and graduate students that study zooplankton ecology and evolution at the University of Minnesota Duluth. He teaches courses in ecology and plankton biology, and won a Young Teacher Award in 2006. Donn received his Ph.D. in Biology from the University of Michigan in 1993.

This multi-year project addresses the issue of ballast water treatment by examining the efficacy of the standards that will be applied concerning permissible levels of biological pollution. Burgeoning human transportation and trade networks are disrupting the natural range boundaries of flora and fauna on a global scale. Ballast water ferried by ships and used to correct imbalance in cargo is believed to be the leading dispersal agent of coastal non-native aquatic biota in North America (Ruiz et al. 2000). In an effort to prevent additional species introductions via this vector, the U.S. Congress passed and reauthorized legislation in the 1990s that requires vessels to manage their ballast water in one of two ways. Ships are required either to carryout Ballast Water Exchange (BWE) by flushing ballast tanks in the open ocean or to perform Ballast Water Treatment (BWT) by proactive decontamination. Because it is widely recognized that no BWT technology can be expected to perform with 100% effectiveness all of the time, accepted standards will allow a certain level of biological pollution (viable non-native organisms) to escape in the post-treated water. The post-treatment standards required of BWT technologies will be guided by standards agreed upon by the International Maritime Organization (IMO); however, few experimental data are available from which to quantify levels of invasion risk associated with specific levels of propagule pressure (MacIsaac et al. 2002). Our project begins to fill this gap and should provide valuable experimental-based information that can guide the IMO regarding post-treatment standards for BWT technologies.

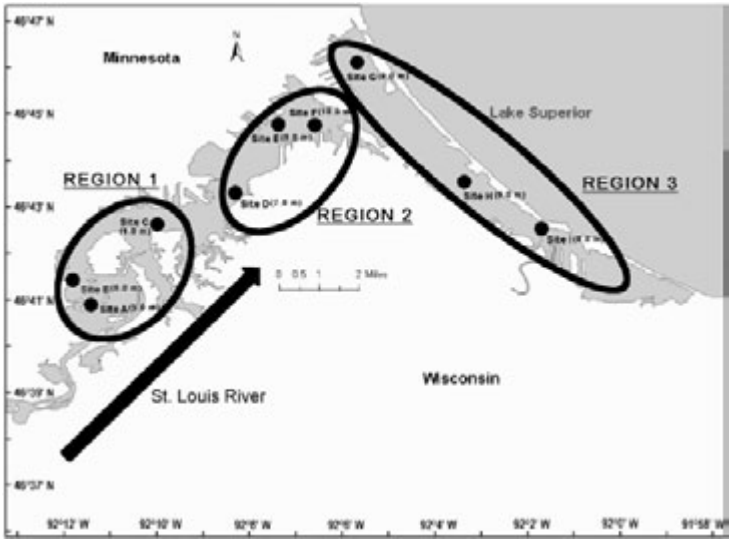


Figure 1. Schematic of the nine sampling sites A-I (maximum depth) in the Duluth-Superior Harbor and St. Louis Estuary. Circles define sets of sites (Regions 1, 2 or 3) used in the analyses. The large arrow indicates direction of water flow.

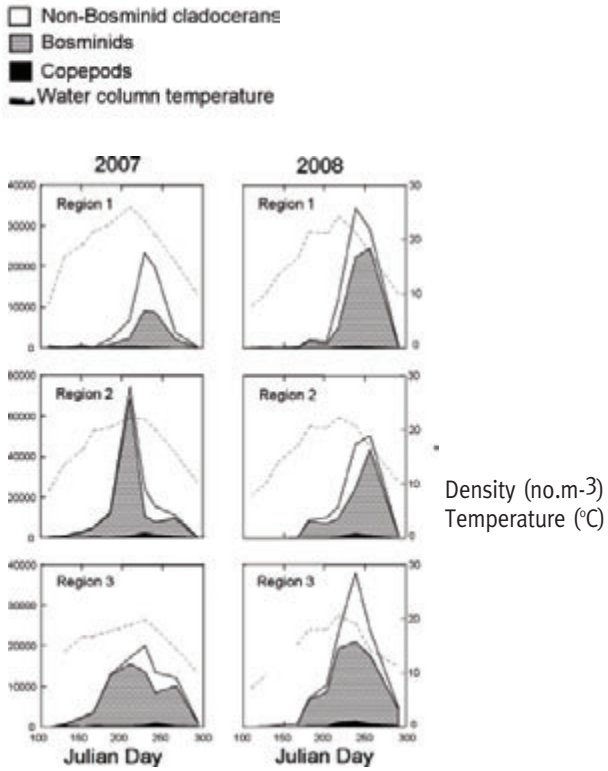


Figure 2. Average water column densities (no. m-3) of crustacean zooplankton as a function of date (Julian Day, where day 100 = April 10 and day 300 = October 27) shown by region (see Figure 1 for region locations). The average integrated water column temperatures by region are also shown. In 2007 and 2008, missing values for temperature in Region 3 reflect instrumentation problems.

The main objective of the first and second years of research was to characterize the density and diversity of crustacean zooplankton at nine sites in the Duluth-Superior Harbor and St. Louis Estuary (see Figure 1). Details of the sampling protocol and some methods were given in an earlier report.

Crustacean zooplankton samples were analyzed for taxonomic composition and abundance in the laboratory with dissecting and compound microscopes. Zooplankton densities (no. m-3) were averaged by site within a region. Taxon richness by region was computed as the number of all unique taxa per region, regardless of their density or site(s) where they were detected within a region. Water temperature was averaged across depths by site, and across sites by region.

An earlier report displayed preliminary results for the 2007 sampling year. Here we show the summarized results for 2007 and 2008. Figure 2 shows the seasonal trends in crustacean zooplankton densities by year and by region. On most dates, the majority of zooplankton scored belonged to a single cladoceran family, the Bosminidae. In order to depict this biased composition, for graphical presentation we partitioned the total assemblage of crustacean zooplankton into three groups: non-bosminid cladocerans, bosminids, and copepods. Densities of the total assemblage ranged widely on a seasonal basis from <1,000 to >70,000 individuals m^{-3}. Densities in all three regions generally increased between days 150-200 and consistently peaked between days 200-250. The timing of the buildup in zooplankton densities closely reflected increasing ambient water temperatures, and often lagged temperature by about one month. The parallel patterns in zooplankton densities and temperature are broadly consistent with the hypothesis that water temperature is a major environmental factor controlling zooplankton growth potential in this ecosystem.

Taxon richness patterns by region and year are shown in Figure 3. In 2007, richness ranged between 5-10 taxa per region. In 2008, richness ranged more widely from 5-15 taxa per region and there was a trend that year toward increasing richness with time in each region. However, in neither 2007 nor 2008, was there evidence for a disparity in richness by region.

These data offer valuable baseline information for planning the timing of our propagule pressure experiments to be carried out under Objective 3 in the coming year. In those experiments, the background zooplankton communities against which invasive propagules will be challenged will be developed from natural assemblages in the harbor. The information in Figures 2 and 3 will be used to guide the timing of experimental set ups to ensure particular starting densities and levels of taxon richness in the background assemblages. ■

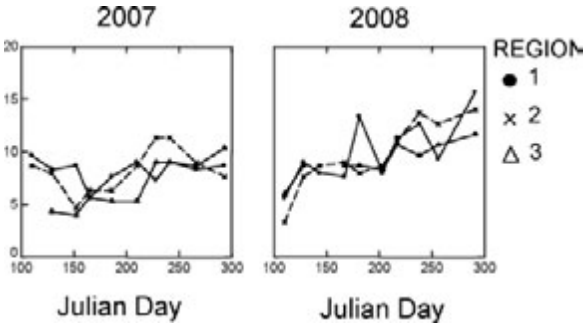


Figure 3. Taxon richness (number of unique taxa present) of crustacean zooplankton as a function of date (Julian Day, where day 100 = April 10 and day 300 = October 27) shown by region (see Figure 1 for region locations).

PROJECT REPORT

Erie Pier Re-Use Facility Phase II: An Optimized Cost-Effective Strategy for Increased Transport and Handling of Dredged Materials

PRINCIPAL INVESTIGATOR	**Hongyi Chen, Ph.D.**
Assistant Professor **Mechanical and Industrial Engineering Department**	**University of Minnesota Duluth**
CO-PRINCIPAL INVESTIGATOR	**Rodger L. Brannan, Ph.D.**
Associate Professor, Accounting Department **Labovitz School Business and Economics**	**University of Minnesota Duluth**

Dr. Hongyi Chen is an assistant professor in Mechanical and Industrial Engineering Department at the University of Minnesota Duluth. She completed her Ph.D. in Systems Science: Engineering Management at Portland State University. Her research interests include multi-criteria decision making, system optimization, lean enterprise management, and strategic management of technologies and innovations.

Rodger L. Brannon BA, MIM, MBA, Ph.D., CPA (Inactive) is an associate professor of accounting in the Labovitz School of Business and Economics at the University of Minnesota Duluth. He received his Ph.D. in business administration (accounting and public administration) from the University of Nebraska-Lincoln. He also holds a Master's of Business Administration from the University of Puget Sound and a Master's in International Management from the American Graduate School of International Management (Thunderbird). His current research interests include government and not-for-profit, accounting and business history, and cost and strategy.

Growing constraints on options for placing dredged materials at the Erie Pier Confined Disposal Facility (CDF) urged action on a plan to recycle the material at the pier. Potential recycle operations and customers to utilize the dredged materials were studied in the Erie Pier Phase I project in 2008. Of two products included in the dredged materials (designated coarse and fines), the fines cause the most concern for recycling because of relatively limited usage. Given the Duluth-Superior Metropolitan Interstate Council's Management Plan goal to prolong the life of Erie Pier indefinitely, Phase I of this research studied the possible depletion of dredged materials from Erie Pier, most of which are fines, accumulated at the pier. Phase II research supports this plan to reconfigure the facility into a re-use facility at the least cost, and to develop an optimized transportation plan to move the dredged materials from the pier to several potential customers.

Transportation modes evaluated are rail plus truck, truck only, and the RailMate™ system. Potential customers include four large-scale long-term projects and seven short-term recurring projects that are able to utilize the fines material. Long term projects include soil enrichment for the Duluth Wetlands Habitat at 21st Ave. W., and construction fill at the CN Railroad Ore Docks, Hibbard Power Plant, and at Sky Harbor Airport. Short term recurring customers include Keetac (Keewatin Taconite), UTAC (United Taconite), Wisconsin Waste Management in Superior, Waste Management in Canyon and Elk River, and farmers in the Wrenshall and Floodwood areas. A series of scenarios were created to help Erie Pier decide which customers to serve and what transportation mode(s) to use under different situations. For each scenario, an optimal year-by-year plan was developed to specify how much and in what mode the dredged materials should be shipped to each chosen customer in each year. The overall objective in all the

Rail Mate™ Photo courtesy of American Surface Lines, LLC.

scenarios analyzed is to achieve the least present value of total transportation cost.

A pre-screening analysis for the three transportation modes first eliminated the rail plus truck option since it provides an obviously inferior solution to the RailMate™ option. As compared to the RailMate™, the rail plus truck option involves: 1) Higher $/ton unit transportation cost on rail and on road; 2) Three times the loading and unloading cost; 3) Hidden cost of dealing with truck companies and rail carriers for individual contracts and taking care of the intermodal scheduling; 4) High cost ($6-18 million) and long time (up to five years) to apply for a transfer yard permit.

The RailMate™ system is an innovative way of transporting commodities by combining the advantages of truck and rail transportation. The American Surface Lines, LLC has designed bogies that can easily convert an end-dump trailer into a rail car in eight minutes. It eliminates the high costs involved in the loading and unloading between trucks and rail cars of intermodal transportation. Since only 132 feet of flat surface is needed to transfer a trailer, the conversion can be done not only at designated rail stations but also at rail track locations that are closer to customers. With this innovative solution, the American Surface Lines, LLC is willing to haul the dredged materials at a unit cost of $17/ton to customers located within 30 miles of the rail track regardless of the total delivery distance.

Two trucking companies were surveyed and price quotes were obtained. Lakehead Trucking offers one truck option with a cost of $2.25/cubic yard mile. Each truck load is 18 cubic yards. Quotes from Udeen trucking is $90/hour to use their quad trucks with a capacity of 14 cubic yards per load and $100/hour to use the end dump truck with a capacity of 20 cubic yard per load.

Since the removal of fines material turned out to be more of a problem than the removal of coarse material, the analysis focused on the distribution of the fines materials to possible customers. It is estimated that 1,250,000 cubic yards of fines are currently sitting at the pier and an additional 50,000 cubic yards could be added annually. It is also assumed that there are three bulldozers and three loaders available at the pier to perform the loading task. Due to supply and capacity issues, the maximum amount of materials that can be removed from the pier is assumed to be 100,000 cubic yards per year.

Four major steps were involved in the model building and scenario analysis stage. They are listed as follows:

Step 1: For each customer, the optimal number of trucks to use each day and the daily schedule for pick-up and delivery were determined. Individual spreadsheets were created for each customer to use each of the three different trucking options obtained from the two truck companies. This was later linked to the optimization model at the second step. Factors considered include the loading capability at Erie Pier and the distances between the trucking company, the pier, and the customer.

Step 2: An optimization model using integer linear programming was built to help decide which customers Erie Pier should serve, and in which transportation mode the dredged materials should be delivered. Note that with the prescreening analysis performed earlier, only the truck option and the RailMate™ option were included in the model. A constraint was set in the model to ensure that only one transportation mode could be selected for each chosen customer. This helped reduce the contracts that Erie Pier would need to deal with when delivering fines to a customer.

Step 3: Since the customers with recurring short-term projects did not specify how long they would like to receive the fines, the number of recurring years for each short-term customer was treated as an additional variable. To determine the optimal number of years that those projects should recur, the model built in step 2 was run hundreds of times in order to identify the least cost scenario.

Step 4: With the customers, transportation mode, and the recurring years for short-term projects determined, a year-by-year delivery plan for the dredged materials at Erie Pier was developed. This was achieved by a second-stage integer linear programming model. The objective was to minimize the total present value of the transportation cost while meeting customers' needs. A 4% inflation plus interest rate was assumed in the calculation.

To create a series of scenarios as back up plans in case certain assumptions employed in the model become invalid, steps 2 to 4 were repeated by resolving models with certain constraints added or relaxed.

The overall optimal solution suggests the use of RailMate™ to serve two long-term customers (construction fill at the CN Railroad Ore Dock and the Hibbard Power Plant), and two short-term recurring customers (land fill for Waste Management at Canyon and mine reclamation at UTAC). The associated costs are listed in Table 1. Below

It is expected that 90% of the fines accumulated at the pier plus the annual additions will be depleted in 21 years. During this period, Erie Pier could serve as a reuse facility since the dredged materials would be processed and recycled to serve customers' needs. The year-by-year plan for the overall optimal solution suggests serving Hibbard Power Plant in years 1-12 and the CN Railroad Ore Dock in years 12-21. The amount of fines to be delivered to these two customers in each designated year can be seen in Table 2. The year-by-year plan for this optimal solution also suggests Erie Pier supply UTAC in the first five years to satisfy its annual demand of 8,873 cubic yards and serve Waste Management at Canyon, MN in years 1-4 and 21 to meet its annual demand of 21,207 cubic yards. Table 2 below

Other scenarios analyzed include the following: serving only one long-term customer and several short-term customers; adding the transportation of sands to the model; a truck-only scenario; and eliminating the farmers from the customer list due to the purple loosestrife issue. In the truck-only scenario, the total transportation cost obtained from the optimal case is almost three fold.

Environmentally, the truck option also raises the important concerns of fuel emissions and traffic congestion on the road. In conclusion, among the three transportation modes being considered, RailMate™ stands out as the most cost effective and environmentally friendly option. As shown in Table 1, the total loading and equipment costs were a significant part of the total project cost. This is associated with the high labor cost of loading the materials to the RailMate™ trailers, and the purchase of 4 new bulldozers and 4 loaders during the project life. Since Erie Pier is located close to a rail track, it is suggested that Erie Pier consider installing an automatic loading system such as a belt conveyor to transfer the dredged materials directly to RailMate™ trailers on the rail track for long term benefits. ■

Table 1. Overall Optimal Solution

Project Selected	Total Fines Removed (Cubic Yards)	Transportation Option	Transportation Costs
Waste Management (Canyon, MN)	106,035 (recur 5 years)	RailMate	$176,452
UTAC	44,365 (recur 5 years)	RailMate	$73,827
CN Railroad Ore Dock	950,000	RailMate	$1,497,690
Hibbard Power Plant	1,000,000	RailMate	$1,664,100
Total Materials Used	2,050,400 cubic yards		
Total Transportation Costs	$3,412,069		
Total Loading and Equipment Costs	$11,998,359		
Total Project Costs	$15,410,428		

Table 2. Year-by-Year Plan for the Overall Optimal Solution

Project Selected	Years Selected	Cubic Yards Per Year
Waste Management (Canyon, MN)	1-4, 21	21,207
UTAC	1-5	8,873
CN Railroad Ore Dock	12-21	Year 12: 70,807 Years 13-20: 100,000 Year 21: 29,193
Hibbard Power Plant	1-12	Years 1-4: 69,920 Year 5: 91,127 Years 6–11: 100,000 Year 12: 29,293
Total Transportation Costs (including 4% inflation & interest)		$ 5,344,706.59
Total Project Costs		$17,343,065

Full research reports are available at www.glmri.org

Development of a Performance Evaluation Methodology for the Port/Terminal Sector Participation in the Green Marine Voluntary Environmental Program of the Saint Lawrence and Great Lakes Maritime Industry

PRINCIPAL INVESTIGATOR **Lynn A. Corson, Ph.D**

Director
Clean Manufacturing Technology Institute

Purdue University

Lynn A. Corson, Ph.D., is the Director of the Clean Manufacturing Technology Institute at Purdue University. He earned a Baccalaureate degree in Biological Science Education from the University System of New Hampshire, a Master of Science degree in Community Development from the University of Missouri, and a Doctor of Philosophy in Adult and Continuing Education from the University of Michigan. Dr. Corson served as Director of the Environmental Management and Education Program at Purdue from 1984 until his appointment in January 1994 as Institute Director. Prior to his employment at Purdue, he was a member of the Lifelong Education (Continuing Education) Program faculty at Michigan State University.

This project was intended to complement and supplement the work completed to date by Green Marine in the development of its voluntary Environmental Program of the Saint Lawrence and Great Lakes Maritime Industry. The Clean Manufacturing Technology Institute at Purdue University partnered with the Hamilton (Ontario) Port Authority to research and propose two additional significant environmental issues and corresponding performance indicators relevant to the operations of ports and terminals that choose to join the Environmental Program of the Saint Lawrence and Great Lakes Maritime Industry, known as Green Marine.

The Green Marine Environmental Program of the Saint Lawrence and Great Lakes Maritime Industry's mission is to "demonstrate and communicate the maritime industry's commitment to playing a leading role in environmental matters." Members choosing to participate are "required to adopt practices and technologies that will have a concrete impact on the issue being addressed." The current environmental issues identified by ports and terminals include aquatic invasive species, greenhouse gases (CO and CO_2), cargo residues and conflicts of use (noise, dust, light and odor). Each issue is defined by a recommended action plan for both collective and corporate actions and each has performance indicators established to measure up to five levels of performance by participants in Green Marine that seek "to minimize the environmental impacts of their operations and to continuously improve their environmental performance."

This research project was based on the findings and analysis of other research previously funded by the Great Lakes Maritime Research Institute, a literature review, including a thorough analysis of U. S. and Canadian environmental regulations, consultations with U.S. and Canadian regulatory authorities, and discussions with port authority representatives.

As a result, two additional environmental issues were proposed by the Principal Investigator for the Green Marine Self-Evaluation matrix: (1) prevention of stormwater runoff and (2) prevention of spills of oil and chemicals. Performance indicators (criteria for self-evaluation) were proposed for each of the five levels of performance and through telephone conferences, electronic communications, and a meeting of the Green Marine Great Lakes Environmental Committee chaired by Co-investigator Baxter. Some of the criteria for evaluating Best Management Practices were modified, others were re-assigned to a different level of performance and still others were added to the matrix at the meeting.

Through meetings, correspondence and conference calls with Green Marine participants, its staff and other stakeholders, the project team helped to refine the definition and application of the indicators and levels of performance for the additional issues. The Coordinator of the Green Marine program prepared a final version of the Water and Land Pollution Prevention Self-Evaluation Matrix for review and approval by the Green Marine Corporation. The manual of best management practices is available at www.glmri.org/resources/. ■

Economic Impact of the Great Lakes and St. Lawrence Seaway System (GLSLS): Phase I

PRINCIPAL INVESTIGATOR	**David J. Doorn**
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CO-PRINCIPAL INVESTIGATOR	**Peter Lindquist**
Department of Geography and Planning, Associate Professor and Department Chair, University of Toledo	**University of Toledo**

David Doorn is an Assistant Professor of Economics at the University of Minnesota Duluth. David has been on the UMD Economics faculty since 2004; he joined the university after working for two years at the Bureau of Labor Statistics in Kansas City. He received his undergraduate degree in Economics from the University of Wisconsin-Milwaukee. David received his Ph.D. from North Carolina State in December 2003 with a specialization in econometrics. His teaching interests are in the area of macroeconomics and econometrics. Dr. Doorn's research activities focus on macroeconomics, applied time series econometrics, wavelet analysis of time series, and business cycle behavior.

Dr. Peter S. Lindquist is Associate Professor of Geography and Chairman of the Department of Geography and Planning at the University of Toledo. He received his Ph.D. from the University of Wisconsin-Milwaukee. His research interests focus on geographic information systems applications in operations research, freight planning and location analysis.

This project represents the first phase of a larger multi-year study undertaken to develop an economic impact analysis of the Great Lakes and St. Lawrence Seaway (GLSLS) system and, further, to develop an economic index to track the activities and performance of the system over time. The goal of an economic impact study is to determine the effect of a given economic activity, or group of activities, on the overall economy of a region of interest, be it a city, county, state, nation, or some chosen combination of areas. The larger project intends to evaluate the impacts associated with the existence of current Great Lakes and St. Lawrence Seaway facilities and to develop a procedure through which such impact analysis can be regularly updated in subsequent periods.

Economic impact studies of maritime ports have been completed by different organizations over the years. These have included impact analyses applied to specific ports within a relatively localized geographic area, and also studies which have extended such analysis to take into account activities that take place across broader regions, such as multiple counties or states. The latest study undertaken for the Great Lakes and St. Lawrence Seaway system in particular was that produced by Martin Associates in 2001. Although each study tends to differ somewhat in application, many have made use of input-output (IO) modeling, which has become a relatively standard tool for economic impact analysis. The particular models used in these studies have ranged from those developed as generic models to models developed specifically for maritime analysis. Generic models, which have been used as a basis for a wide range of economic impact studies, include the IMPLAN model of the Minnesota Implan Group, Inc. (MIG) and that of Regional Economic Models, Inc. (REMI). Models that have been developed specifically for studying the impact of ports or

maritime activities include the MARAD Port Economic Impact Kit (developed by A. Strauss-Weider, Inc. and Rutgers University for the Maritime Administration of the U.S. Department of Transportation), the Rural Inland Waterways Economic Impact Kit (developed by the Institute for Regional Advancement at the University of Arkansas at Little Rock), and privately constructed models (such as those developed and used by the consulting firm Martin Associates).

The goals of this initial phase of the project have included: 1) definition of the particular region to be modeled; 2) determination of data needs; 3) model assessment and selection, based on some potential alternatives from those listed above, and 4) a preliminary impact analysis using IMPLAN. All of these goals have been met to some extent and the following provides discussion of the process and outcomes.

In beginning the current phase, it was noted that the U.S. Army Corps of Engineers (USACE) provides data on overall tons of freight moving on this system and a partial breakdown by area, as indicated in the following tables:

Net Summary of Foreign and Domestic Freight Carried on the Great Lakes Freight Traffic, 2007 (thousand short tons)

Commodity	Grand Total
Total, all commodities	160,959
Total coal	39,572
Total petroleum and petroleum products	5,012
Subtotal petroleum products	4,826
Total chemicals and related products	1,068
Total crude materials, inedible except fuels	99,910
Subtotal soil, sand, gravel, rock and stone	34,600
Subtotal iron ore and scrap	56,574
Total primary manufactured goods	10,001
Subtotal lime, cement and glass	7,101
Subtotal primary iron and steel products	2,721
Total food and farm products	5,209
Subtotal grain	4,208
Total all manufactured equipment, machinery	161
Total unknown or not elsewhere classified	26

Source: Waterborne Commerce of the United States, 2007
U.S. Army Corps of Engineers

However, there is no corresponding information on the potential economic benefits of this activity. Important benefits such as employment generated, contribution to regional incomes, and tax revenues should be of interest to stakeholders in these activities, as well as to policy makers and the public in general. This, of course, outlines a primary goal of the larger project—to estimate the economic value of the Great Lakes and St. Lawrence Seaway system to different regions of interest, including individual port communities, states, the larger GLSLS region, and the nation. This will include reporting results in terms familiar to and useful for a range of stakeholders, including port authorities, government agencies, policy makers, and the general public.

The GLSLS area to be analyzed will follow the 2001 Martin Associates' report, which includes 16 port regions across eight states, as defined by the particular counties in which they are located. These are:

Port		County
Buffalo	NY	Erie
Oswego	NY	Oswego
Ogdensburg	NY	St. Lawrence
Milwaukee	WI	Milwaukee
Green Bay	WI	Brown
Duluth	MN/Superior, WI	Douglas, WI
Duluth	MN/Superior, WI	St. Louis, MN
Gary	IN	Lake
Burns Harbor	IN	Porter
Erie	PA	Erie
Detroit	MI	Wayne
Toledo	OH	Lucas
Lorain	OH	Lorain
Conneaut	OH	Ashtabula
Cleveland	OH	Cuyahoga
Ashtabula	OH	Ashtabula
Chicago	IL	Cook

This study will use IO modeling, which depends on inter-sectoral linkages that exist across a region's economy. The inter-industry transactions table used by the model represents links between industries in the economy. The IO model is also driven by final demand which represents sales to end users of finished goods and services. This includes exports, government

purchases, changes in inventory, investment, and household purchases. Another important aspect of the model is value added, or the value that an industry adds to the goods and services it uses as intermediate inputs in order to produce output. This includes wages and salaries, profit-type income, interest, dividends, rents, capital consumption allowances, and taxes. Value added also measures each industry's contribution to gross regional product for the area being modeled (GDP, gross state product, etc.).

The IO model uses matrix algebra to solve for a "Total Requirements Matrix" and then derives total output as a function of final demand. This total requirements matrix multiplied by any change in economic activity gives the impact on total output. This translates the direct economic effects of an event into the total economic effects on the modeled economy, and takes into account "ripple effects," which define the model's multipliers. The overall impact of any change in demand can be broken down into three stages that comprise this ripple effect: 1) The *direct effect* is the initial change in economic activity that affects demand in the economy. This influences directly affected industry's production decisions, and therefore its employment, value added, and demand for inputs from other firms. 2) The *indirect effect* accounts for any additional impact due to changes in demand on industries providing inputs to the directly impacted sectors, which causes additional effects on their suppliers as well. 3) The *induced effect* accounts for the resulting changes in employment and incomes causing additional changes in demand for consumer goods and services, affecting additional industries such as those in the retail, grocery, and leisure and hospitality sectors. Summing over the direct, indirect, and induced effects gives the total impact on a region's economy which results from some initial economic activity that is undertaken.

Actual IO models use links between hundreds of industrial sectors (for example, 517 in the MARAD model and 440 in the IMPLAN model). An important consideration for a study such as this one for port economics is that the total requirements matrix be representative of the region to be studied. (Another important consideration is the ability to adjust the model's default regional purchase coefficients to respond to specific additional regional industry information.) All IO models require that the direct effects be input into the model to determine total economic impact, including the induced and indirect. Results reported from the model can include impacts on employment and output in each sector, as well as taxes, value added, and more.

Table 1 gives an example of IO results generated through use of the MARAD Port Economic Impact Kit, as published by the Bay-Lake Regional Planning Commission in its report on the economic impact of the Port of Green Bay in 2008. Other IO models generate similar information.

The data needs involved in undertaking such analyses are defined by the chosen model's input requirements. This generally includes some measure of output and/or employment, but may also include other elements. The MARAD Port Kit in particular requires information on different cargo types that have gone through the region of interest. This includes tonnages as well as mode of transit into and out of each port. The determination of data accessibility has involved working with the University of Toledo's Great Lakes Maritime Information Clearinghouse to determine which data are publicly available and which will need to be obtained through surveys. In addition to informing the economic impact analysis procedure, many of the data needs necessary for future construction of a tracking index have also been identified.

Despite the MARAD Port Kit being designed specifically for port impact analysis, the version made available to the researchers at the start of this project turned out to be somewhat outdated, relying on 1992/1998 RIMSII multipliers and SIC coding of industries, instead of the more modern NAICS coding. This led to consideration of potential alternatives, including the IMPLAN model from MIG, Inc.; the R/ECON model developed by Rutgers University; and the latest RIMSII from the U.S. Department of Commerce Bureau of Economic Analysis. Some consideration was also given to other commercially available models and also to the possibility of building a model from scratch to conduct the study. After careful consideration of the alternatives, however, a newly available revised version of the MARAD Port Kit seems to be the best option.

We began by reviewing the IMPLAN model, which uses the most current underlying data and was initially considered the

best alternative. However, preliminary analysis using IMPLAN was problematic: Given the need to input employment or output data, it proved very difficult to get the necessary data at a county level for the required industry sectors. It also was recognized that specialized sectors of interest for port impacts are too aggregated in this model, resulting in IMPLAN not reporting results of optimal usefulness to the analysis of port activities. Given this, it was determined that an update of the MARAD Port Kit might be the best way to go. Upon contacting the original model builders to see about unlocking the underlying database, it was discovered that an updated model is soon to be released and that this version will report results based on NAICS industry sectors.

It is important to remember that much of the project activity in this initial phase of the project will have implications for methodology employed in later phases (detailed economic impacts and the construction of a Great Lakes maritime industries index). Planning for these future project phases also influenced the preference for the MARAD model over the IMPLAN model and others. Additional salient features recommending the MARAD Port Kit include data input requirements as well as the means by which results are reported of in terms of direct and indirect/induced effects by industry sector for the economic components of output, employment, income and GDP. Finally, and of perhaps most interest, the MARAD model also provides direct effects by industry, and total effects by industry, which are being reviewed for possible use as inputs into other IO models.

In summary, this initial phase of the project has generated the following results: 1) A determination of the particular ports and areas to be used in the broader economic impact analysis. 2) A decision to use the updated and revised MARAD Port Kit model, as developed by Rutgers University, to conduct the next phase. 3) A determination of the data needs for use in the MARAD Port Kit, where the actual data collection will be conducted with the assistance of Dr. Lindquist's team through the Great Lakes Maritime Research Information Clearinghouse at the University of Toledo. 4) A plan to conduct an initial detailed case using the port of Duluth/Superior as the beta test for the larger study, which will then focus on the sixteen Great Lakes Ports listed above. Dr. Doorn will tentatively have the initial case ready for review by the steering committee in April 2010. ■

Table 1: Direct and Indirect Economic Effects of the Port of Green Bay, 2008

	Output (000$)	Employment (jobs)	Income (000$)	Gross State Product (000$)
Dry Bulk				
Direct Effects	52,028.0	385.9	15,073.2	21,928.8
Indirect and Induced	13,582.6	129.4	4,689.5	8,459.1
Total Effects	65,610.6	515.3	19,762.7	30,387.9
Liquid Bulk				
Direct Effects	5,407.6	59.3	1,871.7	2,760.7
Indirect and Induced	1,966.1	19.0	685.2	1,227.9
Total Effects	7,373.7	78.3	2,556.9	3,988.6
Break Bulk				
Direct Effects	2,000.4	22.3	698.1	1,031.7
Indirect and Induced	487.9	4.8	174.4	315.8
Total Effects	2,488.3	27.1	872.5	1,347.5
Total Direct and Indirect Effects – All Commodities				
Direct Effects	59,436.0	467.5	17,643.0	25,721.2
Indirect and Induced	16,036.6	153.2	5,549.1	10,002.8
Total Effects	75,472.6	620.7	23,192.1	35,724.0

Source: MARAD Port Economic Impact Kit and the Bay-Lake Regional Planning Commission, 2009.

PROJECT REPORT

Determining if Microbiologically Influenced Corrosion is Responsible for the Accelerated Loss of Port Transportation Infrastructure

PRINCIPAL INVESTIGATOR **Randall Hicks, Ph.D.**

Professor, Department of Biology
Director, Center for Freshwater and Policy
University of Minnesota Duluth

Dr. Randall E. Hicks is Director of the Center for Freshwater Research and Policy and a Professor in the Department of Biology and at the University of Minnesota Duluth. He completed a Ph.D. in Ecology at the University of Georgia and did postdoctoral work at Woods Hole Oceanographic Institution before joining the faculty at the University of Minnesota Duluth. Dr. Hicks is an environmental microbiologist who studies the diversity and productivity of aquatic microbial communities, their role in the degradation and transformation of organic compounds, and the survival and virulence of pathogenic microbes in these communities. This work has taken him to the bottom of the Great Lakes using a manned submersible, to Russia and various oceans. His current research efforts in his lab focus on the North American Great Lakes and watersheds in Northern Minnesota.

Sheet steel structures in the Duluth-Superior harbor (DSH) are reported to be corroding at an accelerated rate (Marsh et al. 2005, Bushman and Associates 2006). Many structures have developed large orange blister-like, raised tubercles. Corrosion tubercles are hollow mounds of corrosion products and deposits that cap localized region of metal loss. Under these tubercles, deep pits may form in the steel, and at its most severe, the corrosion can leave large holes that perforate the sheet steel of docks and bulkheads. Up to 20 km of structures may be affected by corrosion in the DSH. Many other harbors in western Lake Superior are also reported to show a similar corrosion phenomenon (Sharrow, J. and G. Clark, pers. comm.).

It is clear that corroding steel structures in the DSH are covered by complex microbial biofilms that contain bacteria of the type responsible for corrosion of steel in other environments (Hicks 2009). Several types of bacteria have been implicated in corrosion of steel in other environments, including iron-oxidizing bacteria (Xu et al. 2007). We previously isolated an iron-oxidizing bacterium tentatively identified as *Sideroxydans lithotrophicus* from corroded areas in the DSH. Also, electron microscopy has shown that large numbers of bacteria, possibly iron-oxidizers, grow on the underside of tubercles and associate with amorphous iron hydroxides. In addition to iron-oxidizing bacteria (FeOB), sulfate-reducing bacteria (SRB) have been implicated in corrosion in other environments (Hamilton 1985, Little et al. 2000). The concentration of sulfate varies with location in the DSH. Some areas with the highest dissolved sulfate concentrations also show the most aggressive corrosion and highest corrosion rates.

The pattern of corrosion in this harbor that correlates with dissolved sulfate concentration, the presence of iron-oxidizing bacteria, and the abundance of the dissimilatory sulfite reductase gene from SRBs found on the surface of corroding steel suggests that microbes are associated with this corrosion, possibly through a phenomenon known as microbiologically influenced corrosion (Little and Lee 2007, Xu et al. 2007). Microbiologically influenced corrosion (MIC) is rarely caused by a single microbial group, but more often by consortia of microbes including iron-oxidizing and sulfate-reducing bacteria (Hamilton 1985,

Rao et al. 2000, Starosvetsky et al. 2001). While data from our prior field research (Hicks 2009) lead us to suspect that MIC may be responsible for the accelerated corrosion seen in this harbor, they did not provide conclusive evidence. Thus, a laboratory experiment was designed to test the effects water quality and microbes in this corrosion process and demonstrate if the metabolism of microbial biofilms attached to these steel structures is accelerating the corrosion of the sheet steel material in the DSH.

The specific objectives of this project were to:
1. Construct and maintain a microcosm experiment to determine if microbiologically influenced corrosion is the cause of steel corrosion occurring in the Duluth-Superior harbor.
2. Measure the instantaneous rate of steel corrosion in non-biological and biological treatments to estimate the acceleration of corrosion due to microbial activities.
3. Determine if iron-oxidizing and sulfate-reducing bacteria are responsible for accelerating the corrosion of sheet steel used to construct docks and bulkheads in the Great Lakes.

A laboratory microcosm experiment of five different treatments was designed. The treatments included unaltered harbor water, harbor water supplemented with sodium sulfate, autoclaved harbor water, autoclaved harbor water with an iron-oxidizing bacterium inoculum, and unaltered Lake Superior water. Replicate steel coupons were placed in microcosms of the five treatments and maintained for 12 months. The instantaneous corrosion rate of steel coupons was measured semimonthly and biofilm samples were collected each month from additional coupons in each treatment. The highest instantaneous corrosion rates were observed in the harbor water treatments (with or without added sodium sulfate) and the lowest rate was observed in Lake Superior water. Cumulative corrosion parameters were measured at the end of the experiment and showed different trends than the instantaneous corrosion rate. The coupon area covered by corrosion tubercles was not different between treatments. More weight was lost from steel coupons immersed in Lake Superior water than from coupons in autoclaved harbor water. Other than this difference, the weight of steel lost from coupons was not different in the various treatments. The deepest corrosion pits formed on steel coupons in Lake Superior and unaltered harbor water. Extracellular polymers produced by microorganisms were more abundant on coupons in harbor water that was not autoclaved and by the end of the experiment, there were more iron-oxidizing bacteria on coupons immersed in harbor water (with or without added sulfate) than in any of the other treatments. The abundance of the dissimilatory sulfite reductase (*dsr*A) gene, a proxy for the abundance of sulfate-reducing bacteria, increased several orders of magnitude on coupons in harbor water from near zero to over 10^6 copies•cm^{-2}. After five months, coupons in harbor water (with or without added sulfate) had more copies of the *dsr*A gene than coupons exposed to Lake Superior water. These results indicate that the abundance of sulfate-reducing bacteria and to a lesser degree the abundance of iron-oxidizing bacteria and extracellular polymers were correlated with the instantaneous corrosion of steel coupons in the laboratory. Thus, these groups of bacteria as well as other types of bacteria within these biofilms should be investigated further in future studies because their activities may be directly or indirectly responsible for the accelerated corrosion of steel structures in the DSH. ■

Treatment	Area covered by tubercles (%)		Weight Loss Loss (g)	Pit Depth (µm)
	Month 2	End of experiment		
Lake Superior water	46^a (3)	45^a (11)	50^a (1)	558^a (32)
Unaltered harbor water	42^a (4)	48^a (7)	$46a,^b$ (2)	$526a,^b$ (19)
Autoclaved harbor water + *S. lithotrophicus*	41^a (4)	51^a (5)	$46a,^b$ (2)	512^b (36)
Harbor water + sodium sulfate	37^a (2)	54^a (4)	$46a,^b$ (1)	458^c (10)
Autoclaved harbor water	48^a (6)	46^a (3)	44^b (2)	411^d (13)

Cumulative corrosion measurements from steel coupons in the five experimental treatments. The area covered by tubercles is an average of measurements made on two coupons in each treatment (n=2) and the weight loss is an average for three coupons in duplicate treatment microcosms (n=6). The pit depth is an average of five independent measurements made on both sides of two experimental coupons from each treatment (n=2). Means with the same letter superscript were not significantly different. The standard error of the mean is shown in parentheses.

PROJECT REPORT

Great Lakes Marine Container Service Feasibility Study: Connecting Green Bay to Global Container Service providers serving ports on the St. Lawrence Seaway

PRINCIPAL INVESTIGATOR	**Earl Ray Hutchison, Ph.D.**
Professor, Sociology Chair, Urban and Regional Studies	**University of Wisconsin-Green Bay**
CO-PRINCIPAL INVESTIGATOR	**John R. Stoll**
Department of Department of Environmental Affairs Professor, Economics	**University of Wisconsin-Green Bay**

Ray Hutchison is Professor of Sociology and Chair of Urban and Regional Studies at the University of Wisconsin-Green Bay. He received his MA and Ph.D. from the University of Chicago and taught at the University of California-San Diego and the University of Nevada-Las Vegas before coming to UW-Green Bay.

John Stoll is Professor Economics in the Department of Public and Environmental Affairs at the University of Wisconsin-Green Bay. He received his M.S. and Ph.D. from the University of Kentucky in Agricultural Economics, and his B.S. from the University of Wisconsin-Green Bay in Regional Analysis and Economics.

The strength of our freight transportation system is being threatened by our overwhelmed roads and bridges—and the simple, smart solution is to ship more of America's goods by sea.

Senator Frank Lautenberg

On July 8, 2009, the U.S. Senate Commerce, Science, and Transportation Committee approved the *Maritime Administration Authorization Act of Fiscal Year 2010*, sponsored by Senator Frank Lautenberg. This legislation will create a grant program to establish America's Marine Highway as an extension of the surface transportation system by expanding short sea shipping to reduce the growing congestion on the nation's highways and railroads. The bill will also establish a Port Infrastructure Development Program to modernize port facilities. It is expected the legislation will result in changes to an antiquated tariff structure that has limited the movement of international freight on the Great Lakes. This will allow for the introduction of containerized freight into the Great Lakes, and many of the ports have sought funds to modernize existing facilities or construct new terminals; the Port of Oswego, for example, has proposed a new container terminal costing $3.5 million.

While countries in Europe and Asia have developed new port facilities to handle containerized freight for both international and domestic markets, the United States lags far behind; at present there is essentially no

Fox River flowing into Lake Michigan, Green Bay, Wisconsin.

containerized freight on the Great Lakes. Products that are produced in the Midwest must be shipped by truck or rail to coastal ports. The recent economic recession has highlighted the vulnerability of older manufacturing cities in the Great Lakes region, and there are many in local agencies and state governments who recognize the importance of introducing containerized freight to the Great Lakes to open new markets for manufacturing and other business.

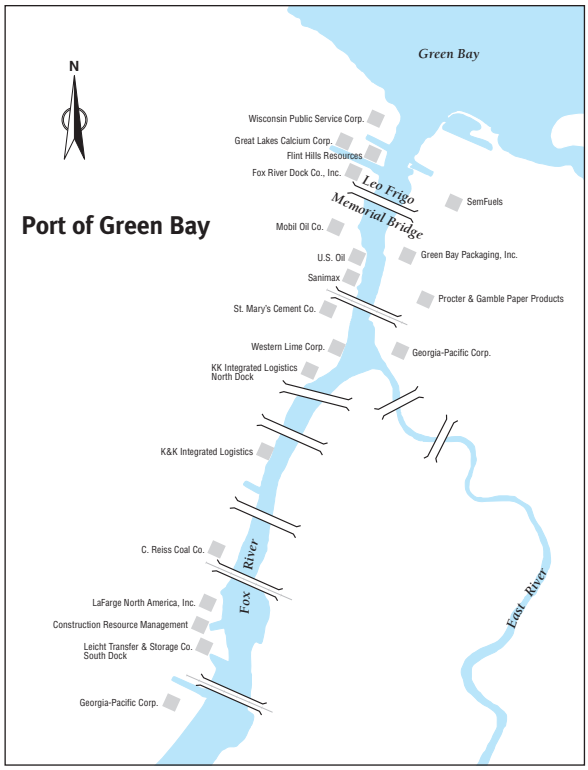
Green Bay is similar to many other cities on the Great Lakes; once a major manufacturing area with a diverse economy, over the last several decades many firms have closed and many high-paying jobs have disappeared. The largest employers in the region now are in the service sector (health insurance being the largest), not in manufacturing, and business activities of all kinds are threatened with further decline. The introduction of containerized freight to the Great Lakes and establishment of a new intermodal freight facility at the Port of Green Bay is viewed as an important first-step for the revitalization of the area economy; at the first-ever State Legislators Forum sponsored by the Municipal Issues Committee of the Green Bay Area Chamber of Commerce in June, 2009, our proposal for the introduction of containerized freight to the Port of Green Bay was recognized as the top economic priority for the region.

Port of Green Bay. The Port of Green Bay is the westernmost port of Lake Michigan and offers the shortest, most direct route for shipments between the Midwest and the world. The first merchant vessels arrived in Green Bay in 1816 with the establishment of the Ft. Howard military outpost, and the first shipment of timber from Green Bay to Chicago was registered in 1835. In 1867 the federal government authorized expenditures for the improvement of harbor facilities, and by the turn of the century, shipments of flour, barley, wood pulp, and coal would top 500,000 tons.

In 2008, the Port of Green Bay had an economic impact of $75 million and supported more than 600 jobs in Northeast Wisconsin. Each year, the port handles some 150 ships, with more than 2,300,000 metric tons of cargo. The majority of the ships are lakers with bulk commodities such as coal (1,000,000 metric tons), limestone (600,000 metric tons), and cement (350,000 metric tons); the largest foreign imports are salt (more than 200,000 metric tons) and pig iron (more than 25,000 metric tons).

The port includes 14 terminal operators, including bulk cargo, freight, and oil companies. It is accessed by a 500' wide channel maintained at 26' below low water datum, with a navigation channel 300' wide maintained at 24' below low water datum to the first operating bride. Facilities include newly-sheathed deep water river docks that can accommodate two 800' vessels. Nationally known truck lines provide overnight delivery within a 400-mile radius, and major railroads and highway infrastructure connect the Port with America's heartland.

Research Activity. Our first year research tasks included an analysis of potential freight flow, an on-line survey of shipper and intermediary requirements, and personal interviews with users screened based on freight lanes, commodity characteristics and interest in a marine supported operation from Green Bay. Our analysis of PIERS data for the State of Wisconsin shows limited freight flows for products



originating in the state (food and farming products are the largest commodities, with some 26.6 and 13.7 million tons respectively moved by truck FY 2008) as well as products imported to the state (again, food and farming products are the largest commodities, with volumes somewhat less than that for goods originating in the state). The on-line survey of shipper and intermediary requirements was developed in consultation with experts in the field, and pretested with two focus groups of representative users. This resulted in substantive modifications to the original survey prior to the final survey instrument being placed on-line. The Green Bay Area Chamber of Commerce sent a special request to several hundred businesses asking that they access and complete the survey.

By the end of the summer the website had been accessed by more than 150 persons, and we had responses from just under half that number. Nearly two-thirds (65 percent) of the respondents represented manufacturing firms from the northeast Wisconsin region. The respondents together reported an average of 18 inbound and 31.2 outbound lanes for goods moved more than 200 miles. More than a third (35.2 percent) said that they were somewhat or very uncomfortable with a mix of nine-month marine and three-month rail/truck transportation, while 58.8 percent said that they would be willing to utilize short sea shipping with a projected nine-month operating season. These results are similar to those reported in other studies, where seasonality was found to be of less concern to most shippers because they draw up their transport contracts according to spot markets, monthly arrangements or on short terms, and switching to other modes is less problematic for this group.

Two focus group sessions were scheduled with area manufacturing and transportation firms. These sessions provided valuable feedback concerning the survey instrument, as well as information about

shipping activities of several firms. But we also found that because of the diverse activities of many of the companies and general lack of knowledge about specific transportation logistics (for example, manufacturers that contract with shippers were unable to provide information about how the shipments were routed), the focus groups with area businesses were not a productive source of information. As a result, we shifted our discussions to more in-depth case studies of specific firms, and this has produced important information. For example, one manufacturer of heavy machinery must ship the oversized cargo to the Port of Houston (1,300 miles), and they estimated a savings of $750,000 per shipment if this were routed through the Port of Green Bay.

Thinking outside the circle. Our original freight flow analysis was focused on commodities produced within a 200-mile catchment area surrounding the Port of Green Bay. As we examined information from the freight flow analysis, and from our survey results, it became clear the original research design was too conservative, and that the potential market area goes beyond the 200-mile radius illustrated in our survey. Indeed, with existing transportation links and harbor facilities, there is a much larger regional freight flow from the north-central region that could be captured by the port. Our revised strategy has been to identify specific commodities originating from this region that must be shipped to coastal ports that might better be directed through the Port of Green Bay. One such is glycerol, a by-product of bio-diesel fuel production, which originates from production facilities in Minnesota. Glycerol is containerized at the production facility and then transported by truck to terminals at the Port of Houston (a distance of more than 1,150 miles) for shipment to overseas markets. Transportation from the production facility to the Port of Green Bay is less than 300 miles—a 75 percent reduction. Oversized freight and heavy equipment shipped to/from production facilities in Edmonton to the Port of Houston (for shipment to South America and Asia) or the Port of Baltimore (for shipment to Europe) can be routed through the Port of Green Bay with a 35 percent reduction (800 miles) in transit. Both of these examples make a strong case for the development of new intermodal facilities at the Port of Green Bay.

Future Activities. We expect to work with other GLMRI affiliates to refine the data analysis presented above; particularly with Great Lakes Maritime Information Delivery System to locate better data sources for more port-specific data, and with Great Lakes Geospatial Intermodal Freight Transport Model to present state-of-the-art mappings of the case study information from our panel group interviews. We also want to expand our case studies to include other supply chains that can be directed through the Port of Green Bay. In keeping with the expanded freight flow analysis and supply chain outlined above, we will be working through the Green Bay Area Chamber of Commerce to partner with Wisconsin Manufacturers and Commerce and with the Minnesota Chamber of Commerce to obtain further survey results from businesses in this more expansive regional market.

Our proposal to GLMRI was intended as a two-year feasibility study, with additional tasks outlined for the second year: developing a business case to identify potential terminal size, location, and other requirements, and building the necessary partnerships among shippers, carriers, and local agencies to establish the balanced and efficient network support services, equipment supply and service delivery to realize global operations. Especially important for this effort is recent communication between the Port of Green Bay and Canadian National concerning future cooperation in the development a new intermodal facility. With the support and cooperation of local agencies and business, we are optimistic that we may achieve the number one priority for economic development in the region.

The UW-Green Bay research team includes Dr. Ray Hutchison (Urban and Regional Studies), Dr. John Stoll (Environmental Management and Business Institute), and Don McCartney (Business). ■

Port of Green Bay Catchment Area

SOURCE: US ARMY CORPS OF ENGINEERS DETROIT DISTRICT.

Full research reports are available at www.glmri.org

The Great Lakes Maritime Information Delivery System: A Resource for the Regional Analysis of Intermodal Freight Flows in the Great Lakes Region

PRINCIPAL INVESTIGATOR **Peter Lindquist**

Department of Geography and Planning
Associate Professor and Department Chair

University of Toledo

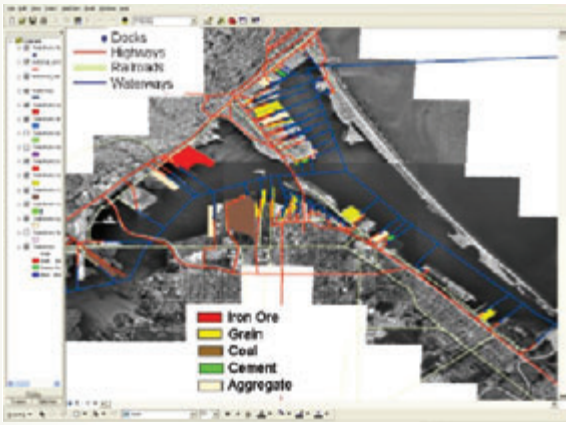
Dr. Peter S. Lindquist is Associate Professor of Geography and Chairman of the Department of Geography and Planning at the University of Toledo. He received his Ph.D. from the University of Wisconsin-Milwaukee. His research interests focus on geographic information systems applications in operations research, freight planning and location analysis.

This project represents the fourth phase of a long-term effort to develop and manage the Great Lakes Maritime Information Delivery System (GLMIDS), a web-based resource designed to serve as a comprehensive data repository and information clearinghouse in support of intermodal maritime commerce in the Great Lakes and St. Lawrence Seaway region. This year's efforts mark a major turning point diverging from previous design and development stages towards the implementation of a sustainable, long-term database management system featuring web delivery of information, an online GIS, and a secure, up-to-date and detailed repository for data in the Great Lakes Region.

GLMIDS is one component of a wider set of efforts to acquire, manage and analyze data for intermodal freight transportation in the upper Midwest that extends beyond the water to include highway, rail, air and the transfer of cargoes between these modes. By extending this wider perspective, the project team can furnish data for the study of maritime transportation within the context of the entire freight transportation system, including such diverse topics as the simulation of intermodal shipments through port facilities, the effects of competition between maritime and land-based modes, the opportunities to divert freight from congested landside modes onto the water, and in the implementation of innovative approaches to using freight such as short sea shipping (SSS) opportunities. To this end, the project team has integrated this project into an expanded scope of activity funded through contracts not only with GLMRI, but also with other organizations including The University of Toledo

Close-up on Port of Duluth/Superior
"Last mile" connections between waterway network and landside dock facilities, classified by commodities

SOURCE: TERRA SERVER IMAGERY.



University Transportation Center (UT UTC), the Center for Freight Infrastructure Research and Education (CFIRE), and the U.S. Army Corps of Engineers (USACE). The result is a comprehensive approach to the study of freight that places maritime transportation at its center.

The goal of this long term project is to maintain and continuously improve this integrated system which will thus serve as a resource for public policy decision-making and for linking maritime freight movements, economic viability, and environmental quality throughout the Great Lakes and St. Lawrence Seaway. The data gateway that has resulted from this effort is particularly focused on providing support data for analysis in several key focus areas including:

- Economic impact of Great Lakes shipping
- Safety issues associated with diverting freight traffic to Great Lakes Maritime Transportation System (GL MTS)
- Environmental impacts/benefits compared to other modes
- Shipper savings associated with GL MTS
- Congestion effects of other modes in comparison to GL MTS
- Competition effects of Maritime Transportation and rate increases in other modes
- Shift in intermodal connections and transshipment costs (*e.g.*, "full cost" studies - pavement damage, fuel, savings, crashes, *etc.*)
- The value of shipping to states, cities, regions, *etc.*
- Regional employment

Specific activities to report during this phase of the project includes continuing work devoted to the acquisition, storage, and management of data involving vessel and commodity flows, port facilities, physical characteristics of the lakes, navigation facilities, and the economy of the Great Lakes Region. This phase of the project focused on more advanced tasks to implement the data delivery system in a higher capacity, given this, the project team identified five overall objectives for Phase IV of the project as summarized below:

- Fill major data gaps identified by the research team
  - Detailed county-level economic data
  - AIS vessel tracking
- Development and customization of analytical tools
  - Network routing
  - Intermodal transfer simulation
  - Optimization of facility locations
  - Accessibility measures to origins and destinations of cargoes
  - Analysis of alternative and proposed modes (*i.e.*, short sea shipping)
- Information delivery
  - Regional economic impacts
  - Aggregate vessel traffic
  - Aggregate commodity flows
  - Port tonnages
  - Regional commodity flows
- Linkage of the Great Lakes waterway network to the wider freight transportation system of the upper Midwest: highway, rail, air, intermodal connections, air, *etc.* (additional funds acquired through CFIRE, UTC, USACE)
- Long-term plan for sustainability
  - Begin to divert data collection, management and distribution efforts to a formal Great Lakes maritime exchange (GLMX) in association with MISNA (Maritime Information Services of North America)
  - Principal functions of exchange: 1) to furnish data in support of maritime industry in region, 2) to promote new technologies and investments in the maritime industry, 3) to assist maritime industry in providing safe, efficient, secure and cost competitive freight movements within the region.

In its present form users can take advantage of the GIS location-based query and selection capabilities as well as mapping functions. In addition, advanced analysis capabilities have been incorporated into the system. One notable function is the incorporation of *Quickmaps*. This tool allows novice users with little or no GIS experience to illustrate the linkage between freight movements to population characteristics and economic activity. Additional tools that support advanced analysis capabilities such as routing, travel time and cost computations, location optimization and site selection are undergoing final development. These functions have completed algorithms and scripting and are expected to be implemented in the next phase. As a result, the system will be fine-tuned as an effective tool for economic impact analysis and economic development planning using its capabilities in measuring accessibility to markets, locating bottlenecks in the network that restrict freight flows, and identifying feasible locations for warehousing, manufacturing, retail and intermodal connection facilities. The complete GLMIDS system includes:

- A detailed data repository for vessel movements, port functions, commodity flows, economic activities and environmental impacts, etc.
- A GIS data viewer for advanced users to view and analyze a variety of data.
- An information delivery site for maps, tables, graphics, text and other features in the form of the Atlas of Great Lakes Maritime Commerce.
- Assembly of data and report information among different Geographic areas of impacts and jurisdictions (*e.g.*, States and Provinces, Congressional districts, Cities, Counties, Ports, *etc.*).
- A data exchange to support user inquiries and furnish information on demand.
- A communication link within the system (*e.g.*, email access) for regional stakeholders to request specific information to be posted on the site.
- A system for data exchange to analysts in maritime agencies and organizations; also develop a site in the system for analysts within the region to publish the results of their analysis—particularly with regard to public policy issues of interest to the Great Lakes maritime industry.
- A library function in the form of a data clearinghouse that reviews and summarizes data from diverse sources—both public and commercial—and provide links for users to branch to from the site.
- A comprehensive centralized resource for providing linkages to additional data resources that do not necessarily represent core functions of the data repository (*e.g.*, links to taxes, fees, and other tangential data); this portion of the site would also serve as a gateway to maritime agencies (*e.g.*, Coast Guard, USACE, *etc.*)

AIS Vessel Tracing on Secure Web Page.

SOURCE: CISS, INC.

The vision for the Great Lakes Maritime Research Information Clearinghouse has evolved over the course of the project to produce a multidimensional system that can support a wide array of functions that include data storage, delivery of prepared documents, GIS functionality, and a clearinghouse of information for maritime commerce. The main objective originally envisioned for the project remains the same: to maintain a long-term database and data distribution system that is available for port authorities, state transportation agencies, regional planning agencies and economic development organizations, as well as other interested decision-makers and stakeholders within the region. The project team solicits feedback and suggestions for continuous improvement of the information delivery system; communication with the industry has been and will continue to be a major objective as this resource evolves and expands over years to come. ■

Cold Flow Testing of Biodiesel Blends with Additives

PRINCIPAL INVESTIGATOR **Daniel N. Pope, Ph.D.**

Associate Professor
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University of Minnesota Duluth

Dr. Daniel N. Pope is an Associate Professor in the Department of Mechanical and Industrial Engineering at the University of Minnesota Duluth. His education includes a B.S.M.E. (1989), M.S.M.E. (1993) and Ph.D. (2001) from the University of Nebraska-Lincoln, as well as Naval Nuclear Power School and Naval Prototype Training (1990). Pope has held jobs as an officer in the U.S. Navy, a consulting engineer for Black and Veatch's Power Division, and a Research Assistant Professor in the Department of Mechanical Engineering at the University of Nebraska-Lincoln. His research interests include computational fluid dynamics, the fundamental processes present in fuel droplet vaporization and combustion, biodiesel production and use, and sustainable energy systems. He is a member of ASME, SAE, ASEE, and The Combustion Institute.

Legislative and industrial efforts point to the use of biodiesel blends up to 20 percent (B20) for both on-road and off-road applications in the near future. Ship systems that utilize biodiesel blends instead of No. 2 diesel are more susceptible to fuel gelling when exposed to cold weather environments due to the increase in cold flow properties associated with the use of biodiesel. Winterization of biodiesel consists of removing the saturated methyl esters by inducing crystallization with cooling and then separating the high melting temperature components by filtration. The liquid biodiesel that remains has improved cold flow properties and can be used neat, or in the preparation of a blend. The winterization process tends to result in low yields, on the order of 25 percent [6, 15]. Thus, instead of winterization, the usual method employed to improve cold flow properties is through the use of additives.

There are several advantages associated with using biodiesel blends in shipboard diesel-powered systems: reduced overall emissions, reduced engine wear through increased lubricity, and reduced consumption of petroleum. However, biodiesel has higher Cloud Point (CP), Pour Point (PP), and Cold Filter Plugging Point (CFPP) than diesel oil. The increase in these cold flow properties is related to the gelling of biodiesel at higher temperatures than diesel fuel oil. The use of biodiesel blends, thus, pose potential operational problems in ship systems exposed to the cold external environments present in the Great Lakes region.

CP, PP, and CFPP quantify cold weather operating limits for a fuel and are determined via standard test procedures defined by ASTM International. The CP is the highest temperature at which wax crystals first appear in a fuel sample and is the highest of the three cold flow properties. The PP is the lowest of the three cold flow properties and indicates the temperature at which a fuel gels. CFPP testing simulates a cold start of an engine and defines the lowest temperature at which fuel can be moved through a fuel filter of defined pore size. The primary means of lowering the cold flow properties of a fuel and improving cold weather operability of diesel ship systems is through the use of cold flow additives.

This project was undertaken to identify the effect that a select number of cold flow additives have on the CP, PP, and CFPP of biodiesel

blends. No. 2 low sulfur diesel and soybean biodiesel (soy methyl ester) were used to produce the six blends employed; No. 2 diesel, B5, B10, B20, B50, and B100. Four commercially available cold flow additives were tested; AMSOIL Diesel Cold Flow Improver, FPPF Deluxe Total Power, Howe's Diesel Treat, and Power Service Diesel Fuel Supplement + Cetane Boost. The CP, PP, and CFPP of the blends both with and without additives were measured using a Tanaka MPC-102L CP/PP tester and a Tanaka AFP-102 CFPP tester. The amount of additive (loading) was also varied from the manufacturer's recommended amount (100 percent loading) to twice the recommended amount (200 percent loading). Each CP, PP, and CFPP measurement for a given blend and additive loading combination was conducted three times to ensure repeatability of the results.

The results for fuel blends without additives indicated the following:

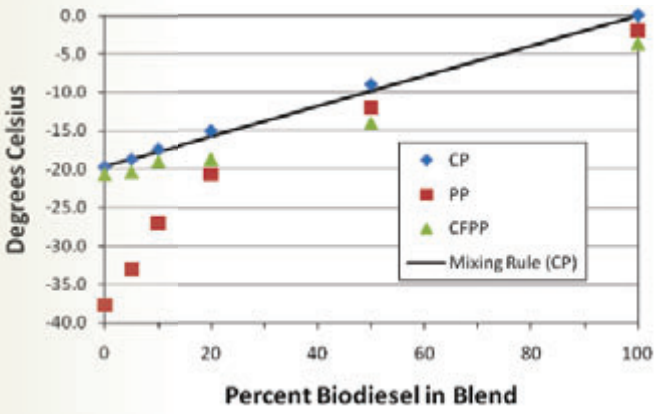
- A simple volume average mixing rule was employed to estimate the CP of intermediate blends (B5, B10, B20, and B50) to within 1°C.
- A linear correlation of CFPP with CP was observed, in agreement with the literature.
- As the biodiesel content in the blend increases, the CP, PP, and CFPP increases, and the difference between the CP, PP, and CFPP decreases.

The difference between the CP, PP, and CFPP obtained at a given additive loading and those obtained without the use of an additive was used to define the additive effectiveness. An effective additive will cause a large reduction in the cold flow properties. Data obtained for 100 and 200 percent additive loading revealed the following general trends:

- The additives had no noticeable effect on CP at either loading, in agreement with the literature.
- At 100 percent loading, all four additives were effective in decreasing the PP, particularly for B50 blends and lower (B50, B20, B10, B5, and No. 2 diesel).
- One of the additives (AMSOIL) produced a significant reduction in CFPP for B20 and lower blends, and another two additives (FPPF and Power Service) caused a significant reduction in CFPP for B10 blends and lower.
- Increasing the additive loading from 100 to 200 percent:
  - Tended to decrease PP at higher biodiesel percent blends.
  - Had very little effect on the PP of B100.
- No general trend could be established for the effect of increased additive loading on CFPP with some additive/blend combinations showing a slight increase in CFPP and some showing a slight decrease in CFPP.
- None of the additives were effective in reducing the CFPP of B50 and B100.

The present study investigated four of the many commercially available cold flow additives, each of which contain proprietary chemical compounds. The four additives employed were specifically designed for diesel fuel. This is most likely the reason that the additives were unable to significantly decrease the PP of B100, and the CFPP of B50 and B100. The experimental results indicate that none of the additives should be used with high biodiesel content blends (B50 and B100). Future studies will include additives designed specifically for use with biodiesel to determine if significant reductions in the cold flow properties of B50 and B100 can be achieved. The low sulfur no. 2 diesel employed in the current study will be replaced by ultra low sulfur diesel (ULSD) in future tests to reflect the coming transition to ULSD for marine fuel supplies. ■

Full research reports are available at www.glmri.org



PROJECT REPORT

Continued Test of B20

PRINCIPAL INVESTIGATOR

Richard D. Ricketts, Ph.D.

Marine Superintendent
Blue Heron

University of Minnesota Duluth

Dr. Richard D. Ricketts is the marine superintendent for the University of Minnesota Duluth's research vessel, the Blue Heron, and is a research associate at the Large Lakes Observatory. When not working with the Blue Heron, he studies past climate using sediment from lakes in Asia and Africa. Ricketts received his Ph.D. in Geology from Duke University in 1996.

In 2008, the University of Minnesota Duluth research vessel *Blue Heron* took part in a study of the use of biodiesel in a marine setting. The study, initiated by Dr. Dan Pope of UMD's Department of Mechanical and Industrial Engineering, compared fuel consumption, atmospheric emissions, ship operations and maintenance issues when using 100 percent conventional diesel versus B20, a fuel mixture consisting of 80 percent conventional diesel and 20 percent biodiesel. During 2009, we continued to test the use of B20 on board the *Blue Heron* to see if the trends in fuel consumption and emissions persisted and to determine if any operational or maintenance issues appeared after extended use of biodiesel.

The *Blue Heron* is the largest University-owned research vessel on the Great Lakes. The vessel is owned by the University of Minnesota and operated by the Large Lakes Observatory at UMD. During the 2009 season, the ship was on the water for 69 days, working mostly with scientists specializing in the physical sciences such as biology, chemistry, geology, and physics. The ship also has several educational cruises each year and has worked with scientists from other fields, such as engineering (this project) and physiology (motion-sickness studies).

The vessel is an 86-foot former Grand Banks fishing trawler purchased by the university in 1997 when made available through the U.S. federal government fisheries buyback program. The ship is outfitted with three diesel powered systems: the main engine, a Caterpillar 3508TA 750HP, and two generator sets, a Caterpillar 3304 65KW and a Caterpillar C4.4 76KW. For the 2008 and 2009 projects a data acquisition system, fuel logging systems, and flue gas analyzer were installed in the engine room and bosun's locker. This equipment measured and recorded fuel consumption, engine RPM, exhaust temperature, exhaust pressure and emissions of CO, NOx, CO_2, and O_2. In addition, fuel logs were kept, which noted time and amount of refueling as well as engine hours of service for fuel filters and when the filters were replaced.

During 2009, the *Blue Heron* refueled with B20 seven times between January and September. Each refueling consisted of between approximately 1,500 and 2,500 gallons of biodiesel. The refueling

University of Minnesota Duluth research vessel *R/V Blue Heron.*

process has not been simplified since the 2008 season and still consists of the fuel being mixed at the refinery in a large tanker truck, transferred to a smaller tanker truck for ease of access to the *Blue Heron* at the pier and then a final transfer to the Blue Heron. This process has the potential of introducing contaminants into the fuel.

As Pope noted in his 2008 report, the U.S. Environmental Protection Agency (EPA) has collected results from the literature on dynamometer tests conducted with on-road diesel engines using B20. These laboratory tests indicate that using B20 in on-road diesel engines decreases the emissions of unburned hydrocarbons (HC), particulate matter (PM), and carbon monoxide (CO) while increasing the emission of oxides of nitrogen (NOx) compared to the use of standard diesel. In addition, the EPA study indicates no change in emission of carbon dioxide (CO_2) and predicts a slight drop in fuel economy. As Pope noted, it is difficult to compare the dynamometer analyses to field analyses. Engine load, approximated in this report by engine speed (revolutions-per-minute or RPM), will vary due to external variables such as sea state, water currents and wind speed. We make no attempt to control for these variables in the report. Data are averaged over periods of constant engine speed which vary from 10 minutes to several hours.

Data were collected from mid-May to mid-September 2009. Fuel filter life-spans were noted for the entire period. Engine speed and fuel consumption data were collected from mid-June to mid-September. Exhaust temperature data was collected throughout August to mid-September, while emissions data (NOx, CO_2, CO, and oxygen O_2) were collected intermittently (due to equipment failure) throughout August to mid-September. The data for fuel consumption, exhaust temperature and emissions were analyzed as a function of engine speed (RPM). Engine speeds vary from low (RPM in the 400s) while on station and not moving, to medium speeds (RPM in the 500s to 900s) while doing survey work, to high speeds (RPM in the 1200s to 1400s) during transits.

When comparing the 2009 data to data collected in 2008 the following is noted:

- During 2008, B20 and standard diesel exhibit similar fuel consumption rates. The drop in fuel economy predicted by the EPA analysis is small enough that its existence may be hidden by the noise in the data. The 2009 B20, interestingly enough, indicates generally lower fuel consumption at low to medium engine speeds when compared to the 2008 B20 data and fuel consumption rates similar to the 2008 B20 data at high engine speeds.
- Some of the B20 2008 and 2009 data indicate higher fuel consumption rates than standard diesel at high engine speeds. Clogging in the fuel filters while using B20 may cause higher readings from the fuel logging system.
- NOx, CO_2, CO, and O_2 emissions were similar between the B20 and standard diesel and between the B20 data collected in 2008 and 2009.
- NOx values for B20 in 2009 at medium engine speeds (600 to 800 RPM) were slightly higher than the NOx values for B20 in 2008 or the standard diesel. These data were collected while the ship was undertaking mid-water trawling for a fisheries stock assessment study. This type of work may place an extra load on the main engine.
- CO_2 values for the B20 data from 2009 is slightly lower than the data collected in 2008, possibly indicative of the lower fuel consumption.
- As Pope noted in his 2008 report, unburned hydrocarbons (HC) were too low for our equipment to measure during the constant engine speed conditions we have outlined here. The CO concentrations are also low and therefore difficult for the emissions probe to accurately measure. The emissions probe's lack of accuracy at such low CO concentrations probably contributes to the high level of scatter seen in the CO data.

In addition to fuel consumption and emissions, operational and maintenance issues associated with the continued use of B20 were studied. There continues to be no material incompatibility issues (e.g. weeping or failing hosing, o-rings, etc.) since initiating the use of B20 on July 21, 2008. Biodiesel gels at a higher temperature than diesel, noting that there will not be operational issues in the Spring of 2009 after the fuel was stored for six months over winter in the fuel tanks. Fuel filter usage is still high. Pope noted a significant decrease in operational lifetime of the primary fuel filter when using B20 during the 2008 season. This decreased primary fuel filter lifespan continued during 2009. We suspect that prefiltering the fuel before use will limit this problem and are planning on putting in place a prefiltering program before the 2010 season. ■

PROJECT REPORT

Energy, Economic, and Environmental Tradeoffs Associated with Freight Transportation in the Great Lakes Region: Development and Application of the Great Lakes Geospatial Intermodal Freight Transportation Model

PRINCIPAL INVESTIGATOR **James J. Winebrake, Ph.D.**

Chair, Department of STS/Public Policy
Rochester Institute of Technology

Rochester Institute of Technology

James J. Winebrake, Ph.D. is Chair of the Department of STS/Public Policy and Co-Director of the Laboratory for Environmental Computing and Decision Making at Rochester Institute of Technology in Rochester, New York. His research focus is on sustainable goods movement. Dr. Winebrake holds a B.S. in Physics (Lafayette College), a M.S. in Technology and Policy (M.I.T.), and a Ph.D. in Energy Management and Policy (University of Pennsylvania).

The Great Lakes region is an important corridor for freight transportation in the United States (U.S.). The region serves as a connection between the Midwest and the Eastern seaboard and includes such major industrial cities as Detroit, Chicago, Cleveland, Buffalo, and Toronto, among others. Within this region, three modes of freight transportation dominate: rail, truck, and ship. Each of these modes presents a different set of attributes to shippers, consumers, and society, including: economic costs, time-of-delivery, environmental impact, reliability, and energy use.

For the most part, shipping decisions in the Great Lakes region (as in other parts of the country) are made by considering economic costs, reliability, and time-of-delivery. Unless mandated by law, environmental impacts are usually ignored, as they represent social costs that are not captured in the market prices for transportation services. Moreover, few tools exist that can help decision-makers characterize and evaluate the environmental impacts of their shipping decisions.

This project provides such a tool for the Great Lakes region by enhancing the Geospatial Intermodal Freight Transport (GIFT) model currently under development in a joint research collaborative between Rochester Institute of Technology (RIT) and the University of Delaware (UD). GIFT is a Geographic Information Systems (GIS) based model that integrates water, rail, and road transportation networks and intermodal transfer facilities to create an intermodal network that can be used to solve a variety of interesting problems. In particular, GIFT calculates optimal routing of freight between origin and destination points based on user-defined objectives. GIFT not only solves for typical objectives such as least-cost and time-of-delivery, but also for energy and environmental objectives, including emissions of carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur oxides (SO_x), particulate matter (PM_{10}), and volatile organic compounds (VOCs). This project focuses on the refinement and extension of GIFT for the Great Lakes region. We call this model Great Lakes-GIFT (GL-GIFT).

In this report we discuss our model development over the past year, apply the GL-GIFT model to two case studies in the Great Lakes region, discuss our 2009 GL-GIFT Summer Workshop, and describe our plans for model improvement.

There are three key model developments this year; (1) we have integrated a novel emissions calculator, (2) we have added a new graphical user interface to manage the output from the emissions calculator into the GL-GIFT model, and (3) we are developing online capabilities for GIFT. The emissions calculator allows the user to input specific information about the truck, locomotive, and ship they wish to model. The emissions calculator also contains a method to save characteristics for predefined trucks, locomotives, and ships to be called up at a later time. Therefore, even if a user doesn't know exactly what inputs to use, they can choose a predefined truck, locomotive, or ship to model. The output from the emissions calculator is contained in the Manage Analysis Values window. This output can be modified and saved as a separate file.

To exercise the model, we conducted two case studies with two objectives, as defined in our scope-of-work. The first objective was to conduct a "micro-level" case examining the energy, environmental, time-of-delivery, and cost tradeoffs associated with moving a single type of cargo among different modes in the Great Lakes region; Case Study 1 achieves this objective, exploring containerized freight transport between Montreal, Quebec and Cleveland, Ohio.

From the results of Case Study 1, we found that truck was the fastest mode of containerized freight transport but also the most cost- and carbon-intense compared to rail and ship. We also found that the type of vessel being modeled for the ship mode can affect the modal choice of the optimal least-CO_2 route. Depending on the vessel, the least-CO_2 route may be by rail or by ship. As a caveat, these results are dependent on the inputs chosen for each mode and the transfer penalties applied to intermodal transfers.

Our second objective was to conduct a "sectoral-level" case involving the tradeoffs associated with moving a set of cargo affiliated with a particular supply chain in the Great Lakes region; Case Study 2 achieves this objective. Case Study 2 examines Great Lakes coal sector freight flows from the Rosebud Mine in Montana, the 13th largest coal mine in the country in terms of total production, to the St. Clair Power Plant in southeastern Michigan. We model not only the total CO_2 emissions, operating costs, and time-of-delivery for one trip, but also the aggregate CO_2 emissions, operating costs, and vehicle-hours for an annual coal shipment from the Rosebud Mine to the St. Clair Power Plant. This gives a better understanding of the total emissions, economic, and temporal impact of modal choice for the transport of coal in the Great Lakes region. This is our first instance of performing a bulk cargo case study using the GL-GIFT model. We evaluate coal movement using three different modes: truck, rail, and ship (including intermodal movements). Although in this case truck is infeasible given the volume of coal being shipped, we include it in our analysis to help illustrate the economic, environmental and energy differences across modes in a bulk cargo example.

From the results of Case Study 2, we found that truck is the fastest mode of coal transportation; however, it also is the most expensive and most carbon-intense mode by far. Truck is expensive and carbon-intense because of its low maximum tonnage capacity compared to the other modes (rail and ship). The rail and intermodal rail/ship routes are much less expensive and carbon-intense per ton-trip. We also found that the fastest mode of annual coal transport is an intermodal rail/ship route since these modes have a much higher maximum tonnage capacity than truck. The rail/ship route costs the same as the rail-only route; however, there are some costs that are not captured in this case study such as intermodal transfer costs and fees associated with rail line ownership. The rail/ship route is also the least carbon-intense compared to a rail-only and truck-only route.

These results help to explain why coal is shipped via a rail/ship route from Montana to Michigan. The rail/ship route offers time savings (which could equate to further cost savings), operating cost savings, and CO_2 emission reductions. Carbon dioxide emissions reductions could lead to operating cost savings if a price for carbon (i.e. a carbon tax) were eventually implemented.

On August 17, 2009, members of the RIT and UD GL-GIFT team held our first GL-GIFT Summer Workshop at RIT. The workshop was a success, with representatives from GLMRI, energy and environmental consulting firms, universities, and U.S. and Canadian transportation agencies in attendance. The workshop aimed to introduce GL-GIFT to those unfamiliar with the model, allow for hands-on exploration of the model, and request suggestions for improvement of the GL-GIFT model. We recorded all comments made at the workshop and intend on addressing some of those comments in the coming year.

Our plans for future model development and improvement include:

1. Integrate the Ship Traffic, Energy, and Environmental Model (STEEM) model into GL-GIFT to allow for trans-oceanic freight route analysis. The STEEM model was developed at the University of Delaware and includes international on-water shipping routes. The integration of the STEEM model will allow for the analysis of trans-oceanic freight route analysis. Therefore, origins and destinations will not be limited to the U.S. and Canada.

2. Enable metric conversion. This will allow for easier analysis for international GL-GIFT users.

3. Generating trip profiles by mode. This would include data such as the percent of the route travelled by each mode and the emissions associated with that particular mode.

4. Include more predefined vehicle, locomotive, and vessel choices. This will allow users to select a vehicle, locomotive, or vessel to model from a drop down menu.

5. Reduce unrealistic routes through major cities. GL-GIFT may be generating optimal routes through major cities that are unrealistic based on real-world problems along the truck and rail networks such as highway and rail congestion.

6. Enable multiple origin/destination pairs to be run programmatically to model the impacts of regional flows.

7. Refine speed limit data. We expect to improve the resolution of data for each of our modes. For example, at this point we are limited to assigning one constant speed limit to our rail and waterway network. This is despite the obvious fact that certain sections of railroad tracks have a higher speed limit and railroad segments in urban areas are becoming very slow due to congestion. We are in the beginning phases of attempting to find quality data to allow for more realistic modeling of freight transport in the Great Lakes region and throughout the entire GL-GIFT network.

8. Improve intermodal transfer time estimates. It has become clear that a better understanding on the time it takes to transfer freight from one mode to another is necessary to improve the usefulness and accuracy of the GL-GIFT model. We plan to collect better data through various mechanisms in the future.

9. Incorporate speed, traffic control, and congestion constraints. Currently, the GL-GIFT model uses road classes to assign speed limits to the U.S. and Canadian road network rather than one constant speed for any road regardless of its classification. As of now, the speed limit for the entire rail and ship networks are one constant speed. We are in the beginning phases of incorporating more realistic speed constraints for rail across the GL-GIFT network, potentially based on rail class. To improve our road network, we are investigating methods for incorporating traffic control devices and congestion constraints. For example, we may be able to incorporate time penalties for intersections and traffic patterns throughout the network. We would also like to find ways to incorporate delays at locks for the water network.

10. Conduct freight systems modeling. We are developing ways to move from a single origin-destination analysis to a system-wide analysis that could be used to inform larger, system-wide decisions.

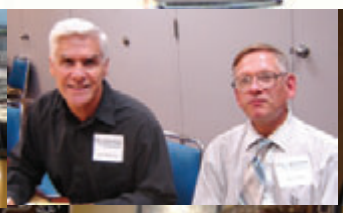
11. Examine methods of modeling bulk freight transport. Currently, GL-GIFT is set up to model containerized freight transport and adjustments need to be made in order to model bulk cargo.

12. Limit intermodal freight transfer facilities based on their freight handling capabilities. Currently, GIFT does not determine whether a given facility, such as a port, has equipment for the specific type of cargo, such as cranes for container movement, or bulk cargo load/unload capability.

With these and other improvements, we expect GL-GIFT to be an important tool for policymakers, planners, shippers, carriers and others interested in sustainable shipping in the Great Lakes region. ■

Full research reports are available at www.glmri.org

GLMRI 2009 ANNUAL EVENTS AND MEETINGS



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Supported by the U.S. Maritime Administration
Grant Number DTMA1G06005