Attached is an article that was published by Ayres Associates in their May 2005 issue of their corporate magazine, TRENDS.

Ayres Associates was hired to handle the many logistical challenges involved with the Wisconsin DOT St. Croix River bridge redecking project.

Of special interest at the back of the article is an explanation of the equation that was used to calculate the "user-delay" costs associated with this project.
Typically, redecking a highway bridge isn't a major construction challenge. But when that bridge is the main thoroughfare connecting the states of Wisconsin and Minnesota – well, that complicates matters. So when the Wisconsin Department of Transportation began laying the groundwork to redeck the five-lane bridge that carries traffic across the St. Croix River on a heavily traveled commuter route, the logistical considerations were a major challenge.

"If you just look at the construction work itself, it was a relatively straight-forward project," said Bob Anderson, who was the Wisconsin Department of Transportation (WisDOT) project development supervisor overseeing last year's redecking of the bridge that carries westbound traffic on Interstate 94 across the St. Croix River at Hudson, Wisconsin. However, on the Minnesota-Wisconsin border, this is the highest-traffic-volume bridge in west-central Wisconsin, Anderson said. "On that stretch of road we have
70,000 cars a day, with peak traffic volumes in the morning and evening."

Normally those 70,000 cars – many carrying western Wisconsin residents to their jobs in Minneapolis and St. Paul, Minnesota – travel over the bridge. But during the six months it took to redeck the westbound bridge, only the five-lane eastbound bridge was open to all that traffic.

WisDOT hired Ayres Associates to figure out how to handle the many logistical challenges involved in the project. Those challenges ranged from managing traffic safety and maintaining traffic flow during peak travel hours to providing pedestrians and bicyclists transportation across the river and protecting a rare species of freshwater mussels that live in the St. Croix River.

As a result of these oftentimes conflicting interests, Ayres Associates had to coordinate the needs and requirements of a myriad of regulating authorities, including the Wisconsin and Minnesota DOTs, State Patrols, and environmental protection agencies; the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and Coast Guard; and dozens of municipal agencies from nearby communities on the Wisconsin and Minnesota sides of the St. Croix River.

"WisDOT had more work than manpower to do everything the project called for," Anderson said. "So we hired Ayres Associates because we needed somebody to help. Ayres Associates figured out how to handle traffic, how to build the approaches to the bridge, how to handle lane closures during construction, and how to handle all that agency coordination, which really was one of the toughest things with this project."

Andrew Dana, P.E., the final design engineer for Ayres Associates, said the biggest challenge was maintaining smooth traffic flow during the six months of construction when only one five-lane bridge was open.

For every hour someone is sitting in a vehicle waiting, engineers assign a
Above: The photo at left shows the evening barrier position, allowing two lanes of traffic to travel into Minnesota and three lanes into Wisconsin. The morning barrier position, shown at right, allowed three lanes of traffic into Minnesota and two lanes into Wisconsin.

Below: The biggest challenge of the redecking project was maintaining smooth traffic flow during the six months of construction when only one five-lane bridge was open. Opposite page: This aerial photo shows the St. Croix River Bridge on Interstate 94 at Hudson, Wisconsin.

dollar amount in user-delay costs, Dana explained. This includes things like lost work time and the amount of fuel burned by idling vehicles. "Going into this project, we projected the user-delay costs could be in the millions of dollars. So to minimize that we really needed to come up with a way to keep three lanes of traffic open in the primary direction of traffic at all times."

The answer came in the form of the Quickchange Moveable Barrier, a new technology that allowed contractors to quickly move the large concrete barriers that divided traffic on the eastbound bridge while the adjacent westbound bridge was being redecked (see accompanying story for explanation of this technology). Twice each day — at about 10 a.m. and 8 p.m. — 4,916 feet of concrete barriers were moved in about half an hour. In that way, three lanes were always kept open in the direction of the highest traffic volume.

Throughout the redecking project, the typical rush-hour commuter had only five to 10 minutes added to normal travel time, Dana said "It could have easily turned into an extra 40 minutes in delays if we would have had the barriers fixed in one location."

Staci Mick, the construction site engineer for Ayres Associates who was on site throughout the six months of
construction, said the nearly $7.8 million project went very smoothly. "Basically we ended up right on schedule," Mick said. "Work began on the approaches to the bridge on March 15, 2004. When it came time, we poured 5,000 yards of concrete in less than a two-month period." The renovated bridge opened to traffic again on September 14. And all this occurred without a single significant traffic accident. "There were just a few fenderbenders, usually caused by drivers who were gawking at the construction work," Mick said.

Anderson was delighted with that safety record. "That was a real surprise," he said. "Typically, when you start taking lanes down like that, you increase your chances of a crash happening. But Ayres Associates had developed an excellent traffic-mitigation plan. We had extra State Troopers on site. We had two tow trucks on site during peak hours. We had alternate routes planned in the event we needed to close down the bridge. Fortunately, we never had to do that."

In addition to commuters, a colony of Higgins' eye pearly mussels that make their home in the St. Croix River near the bridge also survived the project unscathed. During the process of removing the old bridge deck, excavators were fitted with a specially designed attachment that allowed the deck to be removed in 8-foot by 22-foot pieces. Removing the old deck in such large chunks limited the amount of debris that fell toward the river. And barges positioned beneath the bridge captured most of the debris that did fall.

"The state of Wisconsin was very pleased with the project," Anderson said. "There were no major accidents. It was completed on time. That's what we wanted."
Normally one would look upon a large yellow contraption crawling along the highway at 5 mph as a major hindrance to the flow of traffic. Not so when that contraption is the Barrier Transfer Machine (or BTM), a machine used for the first time in Wisconsin and Minnesota during last year’s redecking of the westbound Interstate 94 bridge over the St. Croix River.

Rented at a cost of nearly $300,000, the machine is seen as the key to solving the trickiest puzzle that faced project planners – how to keep 70,000 vehicles a day moving across the St. Croix River between Wisconsin and Minnesota at something approximating normal traffic flow.

With only five traffic lanes available on the eastbound I-94 bridge while the westbound bridge was being renovated, the challenge was to find a way to keep three of those lanes open in the direction of the heaviest traffic volume. But with so many of those drivers using the bridge each day being commuters from western Wisconsin who work in Minneapolis and St. Paul, that meant having three lanes open westbound during the morning rush hour and eastbound during the evening rush hour.

With the bridge spanning more than half a mile, it would take a full day to move all the heavy concrete barriers used to divide eastbound and westbound traffic just once using a crane. Forget about doing it twice daily.

Andrew Dana, P.E., the Ayres Associates engineer who finalized project details such as how to maximize traffic flow during the bridge project, said the Quickchange Moveable Barrier moved the concrete lane dividers twice each day, each time completing the arduous task in half an hour. "The really nice thing about the machine is that it protects itself," Dana said. So by virtue of its design, there was no need to close down a lane of traffic while the barriers were moved.

Looking like some kind of prehistoric beast, the BTM gobbled up the concrete sections (called the Quickchange Moveable Barrier) in its path on the right side of the machine and, while creeping forward at that 5 mph pace, neatly deposited each slab on the opposite side of the machine, almost magically leaving an open lane of traffic in its wake.

"The barrier machine worked great," said Staci Mick, the Ayres Associates project engineer who was on site throughout the six months of the bridge project. "We never had any problems with it breaking down or anything." Without the machine allowing for three open lanes of traffic at all times in the direction of maximum traffic flow, commuters would have experienced extensive travel delays each day, Mick said.

Bob Anderson, who was the Wisconsin Department of Transportation’s project development supervisor overseeing the project, said the Quickchange Moveable Barrier was a crucial component to the redecking project. "That machine is the main reason the project was so successful," he said.
Moveable Barrier System

Saves Money, Time

User Delay Cost
A large portion of the Interstate 94 traffic traveling over the St. Croix River bridges is commuter traffic between the Hudson area in Wisconsin and the Twin Cities in Minnesota. Because of this, the directional split of vehicles changes for the morning and afternoon peak traffic times. Approximately two-thirds of the morning peak traffic (4,045 vehicles per hour) travel on the westbound lanes, and about two-thirds of the afternoon peak traffic (4,907 vehicles per hour) travel on the eastbound lanes.

The Quickchange Moveable Barrier system allowed Ayres Associates to reconfigure the lanes twice a day to take advantage of the directional flow of traffic, thus minimizing the user-delay cost. The equation to calculate user-delay cost is shown below.

\[
\text{User - DelayCost} = \frac{1}{2} \times \text{DurationOfProject} \times (\%Trucks \times (am\text{Delay} + pm\text{Delay}) \times \text{TruckCost} + \%Cars \times (am\text{Delay} + pm\text{Delay}) \times \text{CarCost})
\]

\[
\text{User - DelayCost} = \frac{1}{2} \times \left(0.2 \times (103 + 257) \times 24.00 + 0.8 \times (103 + 257) \times 8.00\right) = 480,000
\]

Duration of Project = \(\frac{1}{2}\) the total time of project stage in days (119 days)
am Delay = Delay for the three peak a.m. hours in vehicle hours (103 hours)
pm Delay = Delay for the three peak p.m. hours in vehicle hours (257 hours)
% Trucks = Percentage of trucks (20%)
% Cars = Percentage of cars (80%)
Truck Cost = $24.00 per vehicle per hour
Car Cost = $8.00 per vehicle per hour

User delay cost with Quickchange Moveable Barrier = $480,000
User delay cost without Quickchange Moveable Barrier = $1,810,000

Average time delay with Quickchange Moveable Barrier - 0.8 minutes per vehicle
Average time delay without Quickchange Moveable Barrier - 6.4 minutes per vehicle

Average speed through construction zone with Quickchange Moveable Barrier - 51 mph
Average speed through construction zone without Quickchange Moveable Barrier - 9 mph
Schedule
The Quickchange Moveable Barrier System allowed the Westbound Interstate 94 St. Croix River Bridge project to be completed in one construction season. If the redecking of the Westbound St. Croix River Bridge needed to be staged to maintain traffic flow, it would have taken two construction seasons to complete.

Schedule with Quickchange Moveable Barrier: May 2004 - October 2004
Schedule without Quickchange Moveable Barrier: May 2004 - July 2005

Staging
Traffic switches between stages were simplified by using the Quickchange Moveable Barrier System. The barrier was set up on the shoulder of the road, before the traffic switch, without disrupting traffic. During the traffic switch the barrier was moved into position with minimal interruption to traffic.

A traditional temporary concrete barrier would have required two travel lanes to be closed for 16 hours to install and remove the traditional barrier with a crane or backhoe.

Crash Reduction
By maintaining highway speeds and reducing queuing, the Quickchange Moveable Barrier System reduced crashes. Traffic entering the work zone encountered fewer stopped vehicles and congestion. The Quickchange Moveable Barrier System provided a safer work zone for motorists and the contractor.

Construction Costs
Construction costs for redecking the Westbound Interstate 94 St. Croix River Bridge and Approaches was $7,560,000. If the same number of lanes were maintained using traditional methods, the westbound traffic would need to be split with half the lanes on the Eastbound Interstate 94 bridge and half the lanes on the Westbound Interstate 94 bridge. This would allow the Westbound Interstate 94 bridge to be constructed one-half at a time. On average, staged construction increases the cost of the bridge construction by 20% and road construction by 10%. The estimated construction cost savings for using the Quickchange Moveable Barrier System was between $1,000,000 and $1,500,000.

The photo at left shows the evening barrier position, allowing two lanes of traffic to travel into Minnesota and three lanes into Wisconsin. The morning barrier position, shown at right, allowed three lanes of traffic into Minnesota and two lanes into Wisconsin.