INVESTIGATOR'S SUMMARY[1]

Nomination 2005-04
Investigator: Ihab Ismail[2]

MAMMOET'S TITAN BRIDGE LIFTING SYSTEM

The Innovation

The MAMMOET's TITAN bridge lifting system is specially designed to install large pre-manufactured bridge spans, remove old bridges, or readjust existing bridges by moving it vertically or horizontally. This innovation is best introduced as part of the overall advancement in bridge technology. First the need for advancement in bridge technology is explained. Second, the types of advancement in bridge technology is briefly introduced and categorized. And lastly, the MAMMOET's TITAN bridge lifting system is explained in detail as one of the advancements in bridge technologies.

Advancement in bridge technology is in high demand; the increasing traffic volumes on current transportation systems necessitate expanding the bridge infrastructure as well as renewing the existing one. The new installed bridges are more complex structures than those installed in the past and require innovative engineering solutions. This is all done in a construction environment that fosters safe construction, demands high quality, and requires lower life-cycle costs. Additionally, the public demands faster and quicker construction technology that minimizes traffic disruption and reduces environmental impacts. Hence the demand for innovative and advanced bridge technology capable of maintaining and installing more complex bridges in less time, lower life-cycle costs, less environmental impacts, and improved safety.

Item Description	Number	Percentage
Bridge Inventory	575,583	(100%)
Backlog of Deficient Bridges	199,277	(35%)
Structurally Deficient	118,563	(21%)
Functionally Obsolete	80,714	(14%)

Source: The Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, Federal Highway Administration, Washington, D.C., January 1993.

In the United States for example 35% of the total bridges are deficient (as of 1993) and require major renovation or complete removal and installation of new sections. The estimated cost to eliminate the deficiencies is in excess of US $78 Billion (as of 1993). This is only the estimated direct cost and does not include other indirect costs such as traffic delays, public transportation system disturbances and other environmental

[1] September 1, 2005

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impacts. These costs can be significantly reduced and the impact on the public can also be minimized by introducing new innovative technologies for bridge construction and transportation.

Item Description	Budget
Cost to Eliminate Current Deficiencies	$78B
Average Annual Cost to Maintain Status Quo	$5.2B
Average Annual Cost to Eliminate Existing and Accruing Deficiencies	$8.2B
Estimated Current National Expenditures	$5.0B
Replacement/Rehabilitation (ISTEA)	$2.7B
Other Federal-aid, State, and Local Funds	$2.3B

Source: The Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, Federal Highway Administration, Washington, D.C., January 1993.

Conventional bridge construction is a sequential process starting with foundation work and followed by other substructure components, girders, decks, railing, and finishing components. This process is very time consuming because of its sequential nature that result in most activities falling on the critical path. The focus on current bridge technologies is on off-site fabrication of bridge components. Off-site fabrication improves quality and creates an opportunity for performing some of the conventional critical path activities in parallel. Advances in off-site fabrication, however, depend to a large extent on the ability to haul and install large pre-fabricated sections efficiently with minimum traffic disturbance.

Advances in bridge technology can be divided into two categories: innovative improvements in bridge design and construction such as innovative prefabrication methods and innovative improvements in bridge movement and transportation. The advancement in bridge movement focuses on building the new bridge in another location adjacent to the final bridge location then moving the bridge to its final location. Constructing the bridge off-site minimizes the traffic disturbances. The traffic is only disturbed when the final bridge is being located in place. This method is usually limited by the capacity of the moving system and its ability to horizontally and/or vertically move the bridge or section of the bridge from one place to another. These systems are much more common in Europe and Japan than in the United States. Bridge movement is primarily done using a series of vehicles known as Self Propelled Modular Trailers (SPMTs). These multi-axle computer-controlled vehicles have the capability of moving in any horizontal direction while maintaining their payload geometry un-deformed or distorted, horizontally, and keeping equal axle loads. The MAMMOET’s TITAN bridge lifting system is one of the innovative advancements in this second category.

The presented innovation is built on the core technology of the Self-Propelled Modular Transporters (SPMTs). Although it has been very difficult to identify the company responsible for SPMTs, some sources mention 1984 as the date when SPMTs were first developed[3]. SPMTs have been primarily used in the Petrochemical industry, off-shoring transportation, and heavy-lifting projects. Although many companies own and operate SPMTs nowadays, two are recognized for using them regularly for the last 15-20 years; MAMMOET and Sarens.[4]

The MAMMOET TITAN system is essentially two systems fit in one: a moving system, namely the Self-Propelled Modular Transporters, and a heavy-lifting system, namely the TITAN system. The integration between the two systems happened to promote the use of those systems in civil engineering and infrastructure projects, and especially in bridges. Bridges always require moving from one location to another and at the same time adjusting the bridge vertically and horizontally into place. The integrated system will do the required movement, rotation, and vertical lifts in one step and in a very short period of time compared to other systems. To illustrate the system, the SPMT technology is first illustrated, then the TITAN climbing towers, followed by an explanation for how they work together as one integrated system.

Self-Propelled Modular Transporters (SPMTs). The Self-Propelled Modular Transporters (SPMT) is a method that can quickly remove existing bridges and move new bridge systems or complete bridges into place. The SPMTs are computer controlled vehicles used to move and lift components or the petrochemical, offshore, power, and heavy civil markets including bridges. A replacement bridge can be built near its final location and then moved to its final location in hours with SPMTs. This allows construction of the new bridge in a location that does not impact the traveling public, and on a timeline that allows attention to detail to achieve long-term performance.

A single SPMT until comes in 4 and 6 axle configuration, is self propelled and fully computerized. Each axle, consisting of 4 wheels, has a 30 Metric ton capacity. The SPMT's can be coupled longitudinally and laterally to form multiple units. The larger the load, the more units are coupled together. The units, when coupled together operate as one, usually controlled by one operator. The SPMT can move in any direction, pivoting 360 degress about a point. Its platform can be vertically adjusted p to 600 mm (24 in.) to remain horizontal while traversing uneven ground surfaces. SPMT's can operate on

[3] Verhoef, Peter. Versatile heavy-lift system - Brief Article - Statistical Data Included. World Oil. April 2000. http://www.findarticles.com/p/articles/mi_m3159/is_4_221/ai_61893057

grades up to 8 percent depending on ground conditions. Equipment for vertical lifting can be mounted on the SPMT as required.

Equivalent loads are maintained on each axle through the SPMT's hydraulic suspension system. Weight transferred to ground never exceeds 2,000 lbs per square foot.

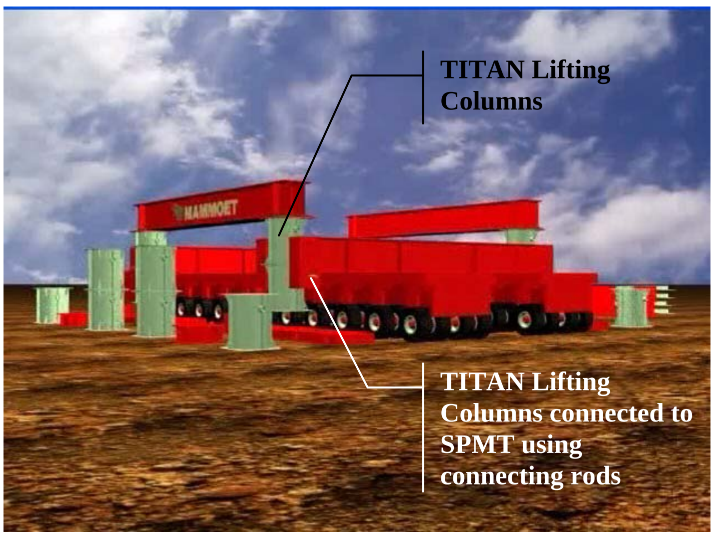
Complete bridge spans ranging from 40 to over 400 feet long and weighing up to several thousand tons, can be moved into place, over road, rail or water.

The TITAN Bridge Lift System. The Titan Bridge Lift System was designed and developed as a response to the high demand in bridge maintenance and construction in shot periods of time. The system utilizes existing lifting equipment with the SPMTs to create an integrated system that can move and lift bridges in the same motion. In this system the SPMTs are loaded with modular steel "stools" ranging in height from 16" to 4' per stool. The hydraulic suspension of the SPMT provides the lifting force for the Titan tower and the stools are lifted incrementally and new stools are inserted after each lift. This process is repeated until the bridge has reached its proper height and then the SPMT move the entire structure into place.

The SPMT/TITAN Lifting System.
Once the bridge is loaded on the lifting tower, the SPMT can be moved to the new location. The process is then reversed to lower the bridge into its location. During the movement the SPMT computer controller guarantees that the bridge is leveled. The modular nature of the SPMT and lifting tower is such that it can accommodate almost any type and load by adding additional units. The whole operation can be done in hours with very high accuracy.

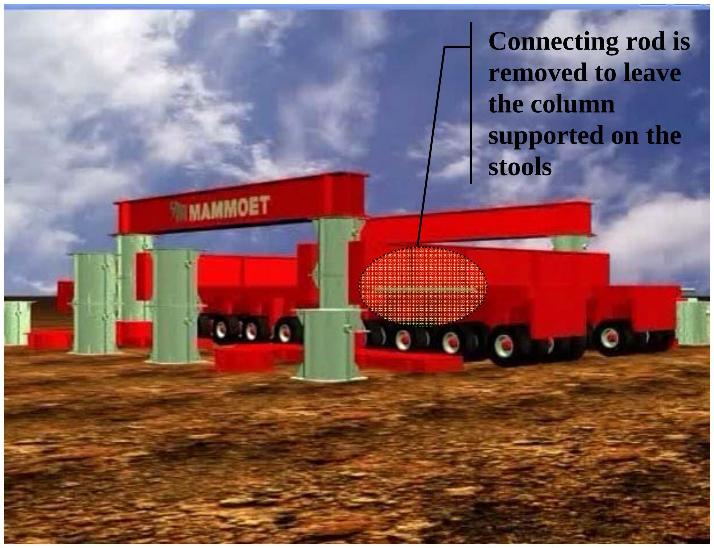
The integrated operation of the SPMT/TITAN system is best illustrated by animated pictures as follows:

Step 1:
The SPMT is moved to the desired location under the bridge to be transported (new bridge or old bridge to be removed)

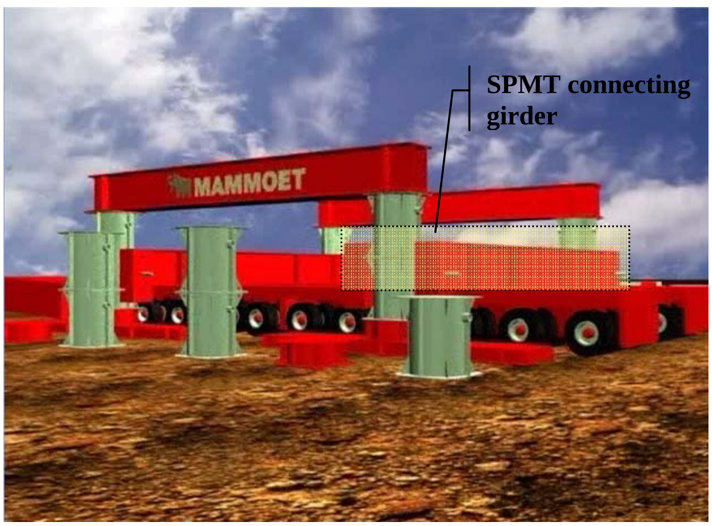


Step 2:
The TITAN lifting is assembled using the SPMT hydraulic supports. The SPMT hydraulic suspension is lowered to its lowest level. The modular tower column is attached to the SPMT. The SPMT hydraulic suspension is then raised, raising the lifting tower.

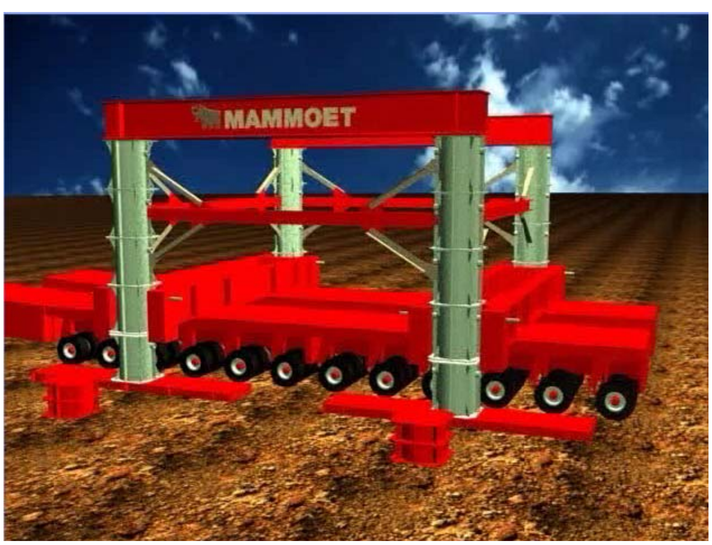
Step 3:
A stool is then inserted below the column to support it while the column is disconnected (released from the SPMT)



Step 4:
The column is supported on the stool and the connecting rod between the SPMT and the lifting tower is removed.



Step 5:
The SPMT is lowered using its hydraulic suspension system. The lifting tower column is attached to the SPMT connecting girder again at the column base. The lifting tower is lifted again using the SPMT suspension system. Steps 2, 3, 4, and 5 are repeated until desired height is reached.



Step 6:
Braces are added to the lifting tower as required.

Application of the Innovation

The TITAN bridge system was developed around the year 2000 and has been regularly used by MAMMOET since then. The following are some projects where the technology was used:

A4/A5 Highway Bridge – Near Amsterdam's Schipol, , The Netherlands

This project is a multi-sectional bridge over 330' in length and weighing 3300 metric tons. It links a newly constructed highway over one of the Netherlands's busiest highways. SPMT's with 13 axle lines moved the bridge in two hours to its final position

across the A4/A5 expressway near Amsterdam's Schipol Airport. The existing highway was closed for only one weekend to install the bridge, compared to almost a year that was initially scheduled for conventional bridge construction.

3rd Avenue Swing Bridge, Manhattan, New York

The benefit of the TITAN system to railroads is tremendous. When railways have a bridge go out of service, it creates a huge economic loss to reroute the railcars until the bridge is repaired. The rerouting in railroads is much more restricted than in highways and expressways. With this system , however, the

bridge can be repaired or replaced in few hours, and sometimes between scheduled trains. The 3rd Avenue bridge in New York City is only but one example of the success of this system in railroad bridges.

The 3rd Avenue Swing Bridge in downtown Manhattan, New York carries traffic from Bronx, NY into Manhattan, NY. The original bridge, built in 1898, was replaced by a new 2,000 ton bridge built in Alabama. The cost of building the bridge in Alabama was considerably lower than building it in New York. The new bridge was loaded onto an ocean going barge n Mobile, AL using SPMT's. After moving in Manhattan, the new bridge had to be transferred from the ocean going barge to two smaller barges, ,so that the bridge could be floated into its final position later. This was accomplished by rotating the bridge on the large barge using 72 lines of SPMT and ballasting to set the bridge onto the supports of the 2 smaller barges. It was because of the capabilities of the SPMT's and TITAN lifting system that this rotation and transfer was performed in minimal time.

Central Artery Project, Boston, Customer: SIWP

For the construction of the second level of concrete viaducts, a huge overhead crane needed relocation to a 8 meters higher position. SIWP considered the full disassembly of the launching girder and re-assembly at higher elevation. However, since this process was estimated to take 3-4 months, SIWP needed a quicker alternative. Mammoet explore the possibility of lifting it one piece. Since the available space was very limited, Mamoet applied the TITAN jacking system. Two towers were built on 44 axle lines SPMT. The launching girder, which has the ability to move by cantilevering itself over large distance, was then "launched" onto Mammoets towers. Finaly, the cargo was moved sideways onto the concrete piers. The complete operation, including the demobilization of equipment was completed in less than three weeks.

Lewis and Clark Bridge, SR 433 over Columbia River between Washington & Oregon

The bridge is a 1929 historic steel truss bridge with a total bridge length of 5,478 ft (3 deck truss spans at 168 ft, 337 ft, 337 ft; 3 through truss spans at 760 ft, 1200 ft, 760 ft; plus approach spans), of which 3900 ft of the deck was replaced with 103 prefabricated deck panels that were 36 ft wide x 20 ft to 45 ft long (20 at 45 ft, 45 at 40 ft, 20 at 35 ft, 14 at 30 ft, and 4 at 20 ft). The panels were 6-in. thick plus 1-in. thick overlay and had a maximum panel weight of 96 tons.

The project was scheduled between September 2003 and February 2004. Full closures were allowed between 9:30 p.m. and 5:30 a.m. for only 120 nights, plus 4 weekend closures. One panel was replaced per night in a 6-hr move. The contractor earned a bonus of $185,000 for early completion.

This was a joint project by the Oregon Department of Transportation (ODOT) and the Washington State Department of Transportation (WSDOT) to widen and replace the deteriorating deck with a full-depth precast concrete deck, while maintaining full rush-hour traffic. WSDOT designed the prefabricated full-width deck panels and a placement procedure to accommodate the required rapid construction. The contractor revised the placement procedure using self-propelled modular transporters (SPMTs) with a specially designed steel truss frame for lifting and transporting that enabled him to meet the scheduling constraints. The SPMTs moved the new panel to the top of the bridge, removed the old panel that crews had just cut out, and then lowered the new panel into place before taking the old panel off the bridge. The majority of the existing bridge deck was replaced with 103 precast concrete deck panels made of 120 lb/cu ft lightweight concrete with a modified concrete overlay supported by two longitudinal steel stringers with intermediate transverse stringers. No post-tensioning was used. The bridge also used prefabricated widening sections supported by a single longitudinal steel girder. In addition, the project included precast approach slabs. ODOT and WSDOT extended the life of the bridge by an estimated 25 years. In addition, prefabrication allowed inspection of the new deck before installation without use of specialized equipment. For Max J. Kuney Company of Spokane, use of prefabricated elements and systems reduced workers exposure to traffic during construction and improved the constructability of the bridge. Use of prefabrication allowed the bridge to remain open for normal weekday operation, particularly important for traffic to and from the Port of Longview.

The detour length was 40 miles going west to Cathlamet and involved a ferry ride across the Columbia River (ferry at this location is small and slow). The other option was to go south to Portland, an 80-mile trip. Since these detours were so long and the bridge was closed all night for each panel placement, a helicopter with a landing pad was provided on the south side of the river. It was used a number of times for medical emergencies and a few child births.

The provisions in the contract documents are detailed below.

Incentives

- $100,000 if all work requiring Weekend or Total Bridge Closure is completed by April 30, 2004.
- $55,000 per Weekend Bridge Closure (WBC) less than 4. [Note: Contractor was allowed 4 WBCs, and only utilized 3. Therefore, WBC Incentive Paid = (4 allowable WBCs - 3 utilized WBCs) * $55,000 = $55,000]
- $4,000 per Total Bridge Closure (TBC) less than number of TBCs bid. [Note: Contractor utilized all allowable TBCs. Therefore, TBC Reduction Incentive Paid = $0]
- $1,000 per Single Lane Closure (SLC) less than number of SLCs bid. [Note: SLC Reduction Incentive Paid = (173 allowable SLCs - 143 utilized SLCs) * $1,000 = $30,000]

Disincentives

- $16,000 per Total Bridge Closure more than number bid.
- $4,000 per Single Lane Closure more than number bid.
- $1,700 per 15-minute period beyond times specified for Weekend Bridge Closure or Total Bridge Closure.
- $900 per 15-minute period beyond times specified for Single Lane Closure.

The approximate cost range for use of SPMTs to lift old panel out, lower new panel in, and haul old panel off bridge is $15,000-$25,000 per maximum 45 ft x 45 ft panel.

Background of the Innovation

Several companies, including MAMMOET, have been moving bridges for many years using a variety of ways. In the year 2000, however, MAMMOET were approached to remove an 800 ton bridge over a very fast flowing river. It was imperative that the assembly of equipment, because of the limited size barges used to be quick, easy and efficient. The TITAN Bridge lift system uses a variety of 4 foot diameter "stools" ranging in height from 16" to 48". These stools were something that MAMMOET had in their inventory that support heavy equipment in storage, transit or during transport. MAMMOET then developed a method whereby, using the existing stools, they could quickly assemble high capacity towers in limited workspace using limited equipment. These stools are readily inserted under each other (with small forklifts) while the SPMTs doing the jacking.

After this project, MAMMOET determined that there was a definite need to be able to get into "tighter" more "congested" areas. Many key bridges that are in very "downtown" areas need replacing. There was also a need for speed for removal /installation of new bridges. Traffic congestion has, in many areas, made conventional bridge building a long process requiring extensive traffic delays or detours. The overall workspace is as large as the bridge and the system has proven to be much quicker. It is much easier working over water on barges, due to the smaller, modular pieces. The system can all be delivered on regular flatbed trucks and requires minimal equipment to offload and assemble. The previous way this was done was using larger equipment (beams, cranes etc.) to assemble the lift mechanism on top of the SPMT prior to lifting and moving the bridge. This requires a large amount of space which in high traffic areas is very restricted.

The TITAN system was then refined and used over and over again in bridge projects and has been known as the MAMMOET TITAN bridge lifting system.

Responsibility for the Innovation

The following companies have the capability of using SPMTs for bridge construction:

- Mammoet: Bill Halsband, phone 519-242-3402, email bill.halsband@mammoet.com
- Sarens: Dirk Verwimp, Belgium phone 32-477-319-343, email dirk.verwimp@sarens.com steven.sarens@sarens.com
- Jim Parkinsons LTD.
- Abnormal Load Engineering

The only company, however, that has the TITAN lifting system or any system with this innovative capabilities is Mammoet. Therefore, we recommend Mamoet for the NOVA award based on the TITAN system. Mr. Bill Halsband will be receiving the award on their behalf. Please refer to investigator's comments for further discussion on the responsibility of the innovation.

Opinions of Persons Contacted

Two people were contacted who have first hand knowledge about the Titan system as well as all heavy-lifting systems available in the US, European and Japanese market. Those are: Mary Lou Rolls, and Hary Capers. Both were very enthusiastic about the Titan system and they clearly understand and distinguish between this system and other SPMTs when used with heavy lifting cranes. They both strongly recommended the Titan system for the NOVA award for innovation in construction.

Investigator's Comments

As mentioned before one must clearly distinguish between the innovations discussed in this report. First, there is the new approach of lifting bridges using SPMTs and lifting equipment. The innovation here is in the new application of the existing technology of SPMT to bridge construction. For this to be considered both Mammoet ad Sarens should be considered for the NOVA award. The two companies are selected because they both individually started using SPMTs in civil engineering projects about 15-20 years ago. It is my opinion, however, that this technology now is used commonly by many other heavy-lifting companies and may not be categorized as "new" innovation.

The "new innovation, however, that was tested and implemented in late 2000-early 2001 and then refined to its current status is the Mammoet Titan system. This system is not only innovative in terms of applying existing technology to construction. It is also innovative in using existing tools and equipment to create a modular, flexible system that can fundamentally change bridge replacement. Even SPMTs when conventionally used with heavy cranes and lifting systems would require much more space than the Titan system. This should be the innovation to be considered for the NOVA award. If such is the case, the Mammoet should be the responsible company.

SELECTED INTERVIEW SUMMARIES

Mary Lou Rolls
Rolls Newman, LLC.
Phone: 512-422-9080
Telephone interview by Ihab Ismail, September 2, 2005

Mrs. Rolls was heading the FHWA International Technology Exchange Programs tour of pre-fabricated bridge elements and systems in Japan and Europe in April 2004. She was with the Texas State Bridge Authority before starting Rolls Newman, LLC.

Mrs. Rolls has a first hand knowledge about the MAMMOET/TITAN system. She was first introduced to the system while visiting MAMMOET facilities in Europe and has witnessed the operation of the system in Germany and France in 2004. Later this was recommended as part of the FHWA prefabricated bridge elements ad systems in Japan and Europe as part of the innovative technology for bridge construction. She was also part of the owner's team when the system was utilized on the I-95 bridge in Virginia.

Mrs. Rolls strongly recommend the system for an award. She is convinced that this is a fundamental change and new approach to replacing bridges in highly congested areas. The removal of an old bridge and replacement by new one can be literally done in hours and days instead of weeks and months. There is no comparison as far as user cost. Traffic is delayed for very limited time compared to any other available system. Her opinion is that the system is "absolutely innovative in construction and fundamentally change bridge construction."

The difference between the MAMMOET/TITAN system and other systems utilizing SPMTs is fundamental. The TITAN system is modular, easily transportable to the project location, easily assembled, and offers great flexibility. It offers great advantage because it requires much less space and offers greater maneuverability with extreme accuracy (millimeters accuracy in any direction). Unlike other systems, that utilize SPMTs for movement and cranes and other equipment for lifting. Cranes require bigger space to work freely in addition to the space used by the SPMTs, and they offer less flexibility and much lesser accuracy.

According to her the cost of mobilizing the equipment (TITAN system) ranges from $50,000 to $500,000 depending on location and extent of the project. But once the equipment is there the mobilization cost can be offset in one day. For example, the I-95 project in Virginia had incentives of $250,000/day for earlier completion. Not to mention that the end user savings is huge since the closure of the highway can be reduced to hours or days instead of weeks or months.

She strongly recommends the TITAN system for the NOVA award.

Hary Capers
Phone: 609-530-2558
New Jersey Department of Transportation
Telephone interview by Ihab Ismail, September 2, 2005

Mr. Capers was first introduced to the system while visiting MAMMOET facilities in Europe and has witnessed the operation of the system in Germany and France in 2004. This visit was part of the FHWA prefabricated bridge elements and systems technology scan in Japan and Europe.

Mr. Capers opinion is the TITAN system was the most innovative solution they have seen during the visit. The fact that the system can move en entire bridge in one step would provide for a new approach to bridge construction.

Mr. Capers is also aware of other competitors systems and visited other companies like Sarens in the same 2004 tour. Sarens also has bridge lifting system but not like the MAMMOET system. The specific advantage that this system has over any of the other competing ones is that it is extremely modular, flexible with tremendous capacity, and offers very fine movement capability in all dimensions. The TITAN system also does not take a lot of time to assemble and requires less setup and operational space.

To his knowledge, this is the only system that is currently available that offers this flexibility and integrates the lifting and SPMT technology in one solution. He highly recommends it for the NOVA award and encourages its use worldwide.