

SELF-PROPELLED MODULAR TRANSPORTERS IN ACCELERATED BRIDGE CONSTRUCTION (PART FIRST): INTRODUCTION

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Abstract: Self-Propelled Modular Transporters (SPMTs) are advanced vehicles designed for transporting exceptionally heavy loads, such as bridge components, at walking speeds. They consist of modular units coupled longitudinally or laterally, with capacities ranging from 36 to 48 tons per axle line and lifting heights up to 500 mm. Controlled by computer systems, SPMTs offer high precision, minimizing traffic disruption and environmental impact while enhancing constructability, safety, and cost efficiency. Effective planning for SPMT operations involves designing optimal travel paths from staging areas to construction sites. This requires assessing existing infrastructure, ground bearing capacity, terrain slopes, weather conditions, and utility placements to determine reinforcements or new pathways. The project aims to establish a guideline for SPMT path planning, offering practical insights to engineers on mitigating challenges and ensuring efficient transport operations. This framework contributes to safer and more sustainable construction practices in complex infrastructure projects.

Key words: Self-Propelled Modular Transporters; Accelerated Bridge Construction; Heavy Loads; Travel Path

1. INTRODUCTION

1.1. Literature Review

User delays cost thousands of dollars per day in heavy traffic areas (Fowler & Eng, 2006) [1]. The exciting promise of ABC is that as more projects are completed and the engineering and construction industry knowledge increases, ABC will cost the same, if not less, than traditional construction methods and user delays and costs will be minimized (McMinimee, 2009) [2].

According to “Iowa DOT - Office of bridges and structures: Draft ABC policy” from 2012: “Accelerated Bridge Construction (ABC) can be described in a variety of ways but is generally defined as using prefabricated bridge elements, combining elements into systems, moving a complete bridge span, or using various contracting methods to quickly deliver a project and re-open a highway to traffic.” [3]. To accomplish the bridge placement, the railroad track was closed for 48 h. Total time for moving the 2,000-tonne (2,200-ton) bridge was 8 h (Russel et al., 2005) [4].

“Prefabricated bridge elements are a commonly used ABC method and can be incorporated into most bridge projects as a form of accelerated construction. Concrete bridge elements are prefabricated, transported to the construction site, placed in the final location, and tied into the structure. An entire bridge can be composed of prefabricated elements, or single bridge elements can be prefabricated as the need arises.” [5] is stated in WisDOT Bridge Manual from 2013. The use of prefabricated bridge elements can minimize traffic disruption, improve work-zone safety, and increase quality. Technology is applicable and needed for both existing and new bridge construction (Zhu & Ma, 2010) [6].

The use of highly reliable computerized, precision-controlled jacking systems to enable the lateral sliding of major complex bridge structures can have significant and even unique advantages in locations where it is necessary to: (a) carry out bridge construction without interfering with immediately adjacent facilities, (b) replace existing bridges, and (c) enable construction with virtually no impact on the natural and social environments (Anderson & Trenkler, 1996) [7]. Bridge construction techniques can be grouped into six main categories: 1) cast-in-situ on false work, 2) cantilever carriage, 3) stepping formwork, 4) launching girder, 5) pre-cast balanced cantilever, and 6) incremental launching (El-Said et al. 2006) [8].

Bridges have been constructed using the Incremental Launching Method (ILM) for many years. In this method of construction, the bridge superstructure is assembled on one side of the obstacle to be crossed and then pushed longitudinally (or “launched”) into its final position (La Violette, 2007) [9]. The incremental launching method for concrete structures was first developed in the early 1960'S.

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Since then it has spread all over the world. Bridges constructed by this method are cast in segments behind an abutment in a stationary form against a previously cast segment of the bridge girder (Zellner & Holger, 1983) [10].

Bridge Staging Area (BSA): The location of the temporary bridge supports where the bridge superstructure is constructed prior to transport to its final location (SPMT Bridge Construction – WisDOT). The SPMTs are computer-controlled vehicles used extensively in Europe to move and lift components of the petrochemical, offshore, power, and civil engineering industries, including bridges. A replacement bridge can be built near its final location and then moved to its final location in hours with SPMTs. Vertical lifting equipment can be mounted on the SPMT platform if required. The SPMT is self-propelled and can be coupled longitudinally and laterally to form multiple units, all controlled by one driver (Russell et al., 2006) [11].

The main benefit of SPMT construction is to facilitate the prefabrication of bridges off-site under carefully controlled conditions, subsequently followed by rapid deployment and installation on-site with minimal disruption and inconvenience to traffic and the community. It replaces the conventional construction sequential operations such as erecting beams, erecting forms, installing shear studs, tying reinforcement, placing and curing deck slab concrete, removing formwork and placing barriers and other appurtenances such as light poles, screens and signs. (UDOT's "Manual for the Moving of Utah Bridges Using Self Propelled Modular Transporters (SPMTs)", 2008) [12].

1.2. Scope & Objective of the Study

This study focuses on the analysis and design of travel paths for Self-Propelled Modular Transporters (SPMTs), a critical aspect of their application in Accelerated Bridge Construction (ABC). The research draws on data and insights from the United States, Europe, and Japan, where the use of SPMTs has become increasingly prevalent in recent years. The primary objective is to provide a comprehensive guideline for planning and designing optimal travel paths for SPMTs. This study aims to serve as a practical tool for engineers, offering detailed recommendations on key considerations during the design process. By addressing critical factors and potential challenges, the study seeks to enhance efficiency, safety, and problem-solving strategies in future construction projects involving SPMTs.

1.3. Methodology & Limitations

The study employed the following approach: First, a comprehensive review of literature, including publications and studies, was conducted to gather general information on Accelerated Bridge Construction (ABC) and its advantages over traditional methods. Subsequently, data specific to Self-Propelled Modular Transporters (SPMTs) and their travel path design was collected. However, the review revealed limited detailed information on travel path design in existing publications, with only basic insights available.

Additionally, design approaches specific to different countries were examined. Second, numerous projects were analyzed to study various design approaches. Insights were drawn from these diverse approaches to address challenges encountered during the design process. Finally, all collected information from various sources was systematically analyzed, processed, and synthesized into a set of guidelines for travel path design, offering practical directions for future applications.

1.4. Remarks

Readers of this study and potential users in future research or design processes should note that the data provided herein are derived from scientific sources and design projects from various regions worldwide. Particular caution should be exercised when interpreting economic data, such as prices and price premiums, as these can vary significantly over time and between countries due to differing market conditions.

Construction managers preparing business plans are strongly advised to consult updated information on prices, regulations, and laws specific to the time and location of the intended construction project. This ensures the accuracy and relevance of financial and legal planning for successful project implementation.

1.5. General Problem Statement

Bridge construction using traditional methods is widely recognized as complex and costly. These challenges are particularly evident when replacing an existing bridge with a new one. Contractors must first provide alternative routes to manage traffic disruptions in the affected area. Given that such projects often span months or even years, planning these routes effectively is essential. However, even with careful planning, the long-term impact on transportation operations can be significant, as “time is money.” Studies have indicated that traffic control measures, including redirecting traffic to alternative routes, can increase construction costs by 20% to 40%. In high-traffic areas, delays can result in financial losses of thousands of dollars per day. Traditional construction methods also have a considerable environmental impact, as work is conducted on-site. This often leads to disturbances in environmentally sensitive areas or locations of special importance, such as historical monuments or critical installations. Additionally, contractors may face challenges such as limited working space, which can compromise the quality of the construction, increase costs and reduce site safety.

1.6. Characteristics & Advantages of ABC

When carefully selected, the ABC approach offers significant benefits to both project owners and contractors. Some key advantages include:

- *Minimized Environmental Disturbance:* ABC greatly reduces the impact on surrounding areas, particularly in environmentally sensitive zones. This is essential when construction occurs near protected habitats, historical monuments, or other areas of cultural significance.
- *Efficient Use of Space:* ABC methods often require more concentrated work areas, reducing the need for extensive space during superstructure assembly compared to traditional methods.
- *Enhanced Worker Safety:* By performing much of the construction at lower elevations or off-site, ABC reduces risks to workers, as activities like component assembly occur in safer, controlled environments.
- *Adaptability to Challenging Sites:* ABC is particularly effective in locations where traditional methods face significant challenges, such as: Sites with restricted or limited access, like deep valleys or water crossings; Areas with abrupt slopes or poor soil quality that hinder equipment access; Locations near culturally or environmentally sensitive areas.

1.7. Decision-Making Process for ABC Implementation

The decision to adopt ABC is typically a two-stage process:

1. *Initial Feasibility Assessment:* Teams of professionals analyze the project’s applicability to ABC using the “ABC Rating Score.” This method evaluates multiple factors to rank candidates for ABC suitability.
2. *Advanced Evaluation:* Projects that pass the initial criteria undergo further evaluation using the ABC AHP (Analytic Hierarchy Process) decision-making software. This ensures that ABC is adopted only where it offers clear benefits over conventional methods.

1.8. Types of ABC Methods

- **Prefabricated Bridge Units (PBUs):** Those involve constructing structural bridge components such as deck panels, beams, modular units, or even entire superstructures off-site or near the project location. These components are then transported to the site for final assembly. The primary advantages include: *Time and Cost Efficiency:* On-site construction time is significantly reduced, leading to lower overall project costs; *Reduced Environmental Impact:* Off-site assembly limits disruption to the surrounding area; *Improved Safety:* Prefabrication minimizes the exposure of workers to hazardous site conditions; *Enhanced Constructability:* Precision manufacturing ensures high-quality components. PBUs are suitable for a wide range of elements, including precast footings, piers, abutments, or complete bridge structures, offering versatility across various projects.
- **Lateral Slide:** This method involves assembling the bridge’s superstructure at a temporary location (staging area) and then transporting it laterally into its final position. Key features of this approach include: *Efficient Construction:* The new bridge is built adjacent to the existing

one, allowing traffic to continue using the old structure during construction; *Quick Transition*: Once the new superstructure is complete, it is moved into place within a few hours or days, minimizing traffic disruption; *Phased Replacement*: The old structure is dismantled only after the new one is ready. This method is particularly effective for replacing bridges in high-traffic areas where downtime must be minimized.

- **Incremental Launching Method (ILM)**: The ILM has been widely used for decades and is characterized by assembling the bridge superstructure on one side of an obstacle and moving it longitudinally into place in sections. Key attributes include: *Step-by-Step Assembly*: The bridge is launched in sequential steps, with each section fully assembled before advancing; *Versatility*: ILM can be applied to bridges made of concrete, steel, or even wood; *Complex Structures*: This method is ideal for constructing intricate designs such as tied arches or truss spans, as these can be fully completed before launching. ILM is particularly beneficial in locations where on-site construction is impractical due to limited space or environmental concerns, as being presented at the Figure 1.



Figure 1: Prefabricated Bridge Units, Lateral Slide & Incremental Launching [13]

2. SELF-PROPELLED MODULAR TRANSPORTERS

2.1. Description

Self-Propelled Modular Transporters (SPMTs) are specialized vehicles capable of transporting extremely heavy and oversized loads, such as large bridge sections, oil refinery equipment, heavy industrial machinery, and other objects that cannot be transported using conventional trucks due to their size and weight. Operating at a walking speed of approximately 5 km/h, SPMTs can be combined into modular units, either longitudinally or laterally, to create a single cohesive system tailored to the load's requirements.

SPMTs are equipped with specialized platforms designed for precision and strength. They are often paired with trucks for additional traction and braking support on sloped terrains. A typical SPMT configuration includes modules of 4 or 6-axle lines, with each axle line capable of carrying 36 to 48 tons (8.5 tons per tire). Axle lines consist of wheels installed in pairs, spaced roughly 1.5 meters apart. The platform's lifting height can reach up to 500 mm, and cargo is positioned with incredible accuracy, with errors reduced to just centimeters - even for loads ranging from 160 to 3,600 tons.

SPMTs are highly maneuverable, thanks to advanced computer-controlled electronic steering systems. Some units feature 60-degree rotation, while others offer full 360-degree pivoting capabilities, enabling movement in any horizontal direction. Cables connect all units, and a driver operates the transporter using a control unit while walking alongside, issuing commands such as steering, lifting, driving, and braking.

SPMTs come in standardized widths of 2.4 meters (4 wheels per axle line) and 3 meters (6 wheels per axle line), though their capacity and lifting limitations vary by manufacturer. Several factors influence travel height, including load type, tire compression, platform camber, terrain topography, and travel path design. Special equipment for lifting can be integrated into the platform to accommodate unique transport needs. For stability, the platform can be adjusted to the terrain's slope, and shock-absorbing systems ensure cargo safety.



Figure 2: SPMT with its main characteristics & SPMT's implementation examples [13]

2.2. SPMTs' General Implementation

SPMTs are widely used across multiple industries, which can be seen at the Figure 2, including:

- *Construction and Civil Engineering*: Transporting large bridge components, prefabricated structures, and heavy equipment to construction sites.
- *Oil and Gas Industry*: Moving entire oil platforms, pipelines, and refinery equipment.
- *Shipbuilding Industry*: Transporting massive ship sections for assembly.
- *Offshore Industry*: Relocating offshore platforms and components.
- *Power and Petrochemical Industries*: Transporting generators, turbines, and nuclear reactors.
- *Aerospace Industry*: NASA space shuttles and large aircraft.

SPMTs' ability to handle immense loads with precision has made them invaluable in projects requiring careful handling and transportation of oversized components.

2.3. SPMTs in Construction Engineering

In the USA, Europe, and Japan, the use of SPMTs in construction has grown rapidly over the past few decades. They are primarily employed in bridge construction but are also used for transporting oversized items like petrol pipeline segments, industrial generators, gas turbines, and other heavy equipment. SPMTs are particularly effective in bridge construction, where they are used to transport entire prefabricated bridge sections to the installation site. This reduces on-site construction time and enhances safety and efficiency, making SPMTs indispensable for complex construction projects.

2.4. Advantages of Using SPMTs

The use of SPMTs offers several significant advantages over traditional construction and transportation methods:

- *Minimized Traffic Disruption*: Traditional bridge construction often requires road closures lasting months, creating significant traffic issues. SPMTs enable large bridge components to be transported and installed in minutes or hours, significantly reducing traffic disruption.
- *Improved Construction Quality*: Prefabrication in controlled environments improves quality by reducing errors and ensuring consistent standards. The ability to build entire bridges in staging areas minimizes the need for deck joints and allows for continuous work without accommodating traffic.
- *Reduced Construction Time*: On-site construction time is minimized, enabling projects to be completed more quickly and efficiently.
- *Enhanced Site Safety*: Workers operate in safer, controlled environments during prefabrication and assembly, reducing the risk of accidents on-site.
- *Lower Environmental Impact*: By reducing on-site activity, SPMTs help minimize disturbances to environmentally sensitive areas and limit emissions caused by prolonged construction operations.
- *Cost Efficiency*: Shortened construction timelines, reduced on-site activity, and optimized resource allocation result in significant cost savings.

- *Global Versatility*: SPMTs' modular design and standardized dimensions make them suitable for transport worldwide, regardless of location-specific challenges.

SPMTs represent a transformative approach to heavy load transportation, offering unprecedented flexibility, efficiency, and safety. Their adoption across industries is a testament to their ability to address challenges that traditional methods cannot easily overcome.

3. CONCLUSION

SPMTs have revolutionized the transportation and construction industries by offering unparalleled flexibility, precision, and load capacity. Their modular design, advanced maneuverability, and ability to handle oversized loads have enabled their application in a wide range of industries, from civil construction and shipbuilding to aerospace and oil and gas.

This paper provided an overview of SPMT design, functionality, and the wide range of industries where they are applied. By highlighting their technical specifications, operational mechanisms, and the significant advantages they offer, this study underscores SPMTs as essential tools for complex infrastructure projects. The adoption of SPMTs has led to substantial improvements in safety, constructability, cost efficiency, and environmental impact.

The next step in this research will focus on one of the most critical aspects of SPMT operations - the design and planning of travel paths. Given the importance of optimal path design for successful transport, future work will delve into technical considerations, including geotechnical analysis, design principles, utility relocations, and case studies from real-world projects.

4. REFERENCES

- [1] Fowler, John R., and P. Eng. "Accelerated Bridge Construction." Bridges for the 21st Century Session, 2006 Annual (2006).
- [2] McMinimee, James C. "An Owner's Perspective on Implementing an Accelerated Bridge Construction Program." In 2009 Mid-Continent Transportation Research Symposium. 2009.
- [3] Iowa DOT - Office of bridges and structures: Draft ABC policy" from 2012.
- [4] Russell, Henry G., Mary Lou Ralls, and Benjamin M. Tang. "Part 3: Concrete Bridges: Prefabricated Bridge Elements and Systems in Japan and Europe." Transportation Research Record: Journal of the Transportation Research Board 1928, no. 1 (2005): 101-109.
- [5] WisDOT Bridge Manual from 2013.
- [6] Zhu, Peng, and Zhongguo John Ma. "Selection of durable closure pour materials for accelerated bridge construction." Journal of Bridge Engineering 15, no. 6 (2010): 695-704.
- [7] Anderson, W. Victor, and Ferdinand Trenkler. "Lateral sliding of multispan steel bridges." Transportation Research Record: Journal of the Transportation Research Board 1544, no. 1 (1996): 57-63.
- [8] Marzouk, Mohamed, Hisham Zein El-Dein, and Moheeb El-Said. "Application of computer simulation to construction of incremental launching bridges." Journal of Civil Engineering and Management 13, no. 1 (2007): 27-36.
- [9] Officials, Transportation, Mike LaViolette, Terry Wipf, Yoon-Si Lee, Jake Bigelow, and Brent Phares. "Bridge Construction Practices using Incremental Launching." (2007).
- [10] Zellner, Wilhelm, and Holger Svensson. "Incremental launching of structures." Journal of Structural Engineering 109, no. 2 (1983): 520-537.
- [11] Russell, Henry G., Mary Lou Ralls, and Benjamin M. Tang. "Part 3: Concrete Bridges: Prefabricated Bridge Elements and Systems in Japan and Europe." Transportation Research Record: Journal of the Transportation Research Board 1928, no. 1 (2005): 101-109.
- [12] UDOT's "Manual for the Moving of Utah Bridges Using Self Propelled Modular Transporters (SPMTs), 2008.
- [13] Ostojic, M. & Aktan, H. "Designing SPMT's Travel Path for Accelerated Bridge Construction" Western Michigan University, MI – USA, 2014.