

# Automated Monitoring of Launching Girder Operations Using Wireless Sensor Network

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**Abstract** - The rapid expansion of metro rail networks in urban areas demands innovative construction techniques to ensure speed, safety, and minimal disruption to existing infrastructure. This paper explores advanced concepts in the implementation of launching girders, focusing on their evolving role in accelerating elevated metro construction. It highlights the engineering innovations, automation strategies, and real-time monitoring technologies that are redefining girder launching methods. The study also presents a comparative analysis of traditional versus advanced launching techniques, emphasizing improvements in structural integrity, operational efficiency, and worker safety. Case studies from recent metro projects provide practical insights into deployment challenges and the effectiveness of modern solutions. This paper aims to serve as a reference for engineers and project managers seeking to optimize metro rail construction through cutting-edge girder launching technologies. Case studies from recent metro rail projects in India and abroad are analysed to demonstrate the successful implementation of these advanced concepts, with metrics including reduced construction time, enhanced safety, and cost efficiency. The challenges associated with deploying advanced launching girders such as site constraints, logistical complexity, and workforce training are also discussed along with potential mitigation strategies.

**Key Words:** Launching Girder, Metro Rail, Cutting-edge Girder Launching Technologies, Automation, Safety, Structural Integrity

## 1. INTRODUCTION

The global construction industry contributes to around 11 percent of the global GDP in 2011 and it is predicted to cross 13.2 % by the year 2020. The share of the construction industry in the global economy in 2015 is US\$8.5 trillion which is expected to climb to US\$10.3 trillion by 2020. A significant portion of this development comes from the construction scene of emerging economies which shows a higher rate of growth. Increasing population, growing economy and urbanization in these nations necessitate investments in various infrastructure projects. Growing urbanization in emerging nations is resulting in the initiation of a large number of urban transport projects such as metro rail construction. The Delhi Metro Rail Project revolutionized transport for the 17 million residents of this city. Based on the success of this project several other cities in India have also initiated metro rail projects. It is estimated that \$30 billion will be invested in these metro rail projects, which are to be completed before 2019. The overall success of these projects depends heavily on completion of construction within planned time and cost. To ensure this, the progress of the project has to be monitored and controlled on a continuous basis. The broad objective of this work is to develop a framework for real time automated construction progress monitoring of viaduct construction in metro rail projects. While manual monitoring is conventionally utilized, it is slow and inaccurate (Davidson & Skibniewski 1995). Further, there are overheads for manual monitoring, 2% of the work in construction is committed to tracking and recording progress data manually (Cheok et al. 2000). Also, construction supervisors spend about 30-50% of their time interpreting and analyzing field data, in many situations data for correct analysis is not available and

the supervisors resort to optimistic reporting (Goldratt & Cox 2004). As a result of these inefficiencies in data collection and interpretation, appropriate corrective actions are not implemented in a timely fashion and which lead to delays in the implementation of control measures. Theoretical frameworks for project monitoring and control are available with which precise project performance indices need to be computed (Navon 2005). However, massive amounts of accurate data need to be continuously generated for effective 1 project performance monitoring. Traditional methods employing manual data collection are slow and inaccurate. One solution to the above problem is automated data collection (Kiziltas et al. 2008). The main objective of automated monitoring is to acquire data, convert it to information and deliver it on time so that timely detection of discrepancies are noted (Rebolj et al. 2008) and corrective actions could be taken. Automated data collection can be implemented using real time monitoring systems with the aid of advanced sensing and signal processing technologies which would contribute towards checking quality, accuracy and progress of the project. The use of automated data collection techniques is increasingly used both for health monitoring and construction progress monitoring of the built environment. In the area of health monitoring, structural & functional parameters of high-rise buildings, bridges, tunnels, and heritage structures are monitored and controlled with the aid of sensor networks, data acquisition and communication, signal processing and information management systems. Long-term health monitoring systems have been deployed on structures such as high-rise buildings (Kijewski-correa et al. 2013), heritage buildings (Ramos et al. 2013), tunnels (Ran et al. 2012) and bridges.

Automated data collection has already been employed in construction for productivity and progress monitoring. This is achieved using technologies such as imaging (Dimitrov & Golparvar-Fard 2014), RFID (Jaselskis & El-Misalami 2003; Jang & Skibniewski 2009), distributed sensor networks (Ye et al. 2012), LIDAR (Golparvar Fard et al. 2011), accelerometers (Joshua & Varghese 2014) for progress monitoring, material tracking, safety monitoring, etc. These technologies have inherent limitations such as lack of mobility. For instance, an imaging technique for progress monitoring is constrained by its location and cannot be used for monitoring projects such as viaduct construction. Joshua & Varghese (2014) have addressed this issue to an extent by integrating a wearable sensor on workers to

track productivity. Although this approach is suitable for productivity assessment, this might not be suitable to track progress, especially in large projects since it is challenging to consolidate the large amount of data from all the workers and finally evaluate progress from these data. These limitations could be overcome if the monitoring system is integrated with the equipment or supporting structure which is central to the construction activity. Therefore, as the 2 construction progresses, the monitoring system travels integrally with the equipment / supporting structure to the location of the construction. A monitoring system that measures structural responses is a potential technology which can be integrated with the equipment or temporary structure. However, construction monitoring using the responses from structural monitoring of construction equipment has not been explored yet. This study explores the feasibility of using structural responses from construction equipment to assess the productivity and progress of construction. This study tests this hypothesis on a metro rail viaduct construction to evaluate the feasibility

## 2. Literature Review

1. The research by Braunetal. (2015), titled "A concept for automated construction progress monitoring using BIM-based geometric constraints and photogrammetric point clouds", presents a novel approach to improving construction site management through automation. The study introduces a method that integrates Building Information Modeling (BIM) with photogrammetric point cloud data to monitor construction progress in a semi automated manner. By capturing site conditions through photogrammetry and generating 3D point clouds, the system compares this as-built data against the as designed BIM model. Geometric constraints defined within the BIM are used as reference parameters to assess whether construction elements have been built as intended. The method applies rule-based algorithms to detect and match constructed components with their digital counterparts in the BIM, thus enabling objective and regular monitoring of progress without the need for intensive manual inspections. While the approach significantly enhances the efficiency and accuracy of progress tracking, the authors also acknowledge limitations such as the dependency on the quality of image data and potential issues caused by site complexities like occlusions or poor lighting. Overall, the paper lays a strong foundation for future developments in automated construction

monitoring by leveraging digital modeling and visual data capture technologies.

2. The study by Chen, Zhou, and Luo (2014), titled "A Hybrid Monkey Search Algorithm for Clustering Analysis", presents a novel optimization approach for solving clustering problems using a biologically inspired metaheuristic technique. The authors propose a Hybrid Monkey Search (HMS) algorithm, which combines the Monkey Search algorithm—a nature-inspired method based on the climbing behavior of monkeys in search of food—with other optimization strategies to enhance performance and avoid local optima. The primary objective of the research is to improve the efficiency and accuracy of clustering, a fundamental task in data mining and machine learning. The hybrid algorithm integrates global and local search capabilities, allowing it to explore the solution space more effectively and converge on high-quality clustering results. Experimental evaluations are conducted on several benchmark datasets, and the results demonstrate that the proposed HMS algorithm outperforms traditional clustering methods and other metaheuristic approaches in terms of solution quality and computational efficiency. This study contributes to the growing field of intelligent optimization algorithms, offering a promising tool for complex data clustering tasks.
3. The study by Bae et al. (2013), titled "Prediction of WSN Placement for Bridge Health Monitoring Based on Material Characteristics", addresses the optimization of wireless sensor network (WSN) deployment for effective structural health monitoring (SHM) of bridges. Recognizing that material properties significantly influence the dynamic behavior of bridge structures, the authors propose a methodology that incorporates these characteristics to predict optimal sensor placement. By considering factors such as material stiffness and damping properties, the approach aims to enhance the sensitivity and accuracy of damage detection systems. The research underscores the importance of tailored sensor deployment strategies that align with the specific material attributes of bridge components, thereby improving the reliability and efficiency of SHM systems. This work contributes to the advancement of intelligent infrastructure monitoring by integrating material science with sensor network optimization techniques.
4. The study by Cheng et al. (2010), titled "Automated Construction Resource Location Tracking to Support the Analysis of Lean Principles", introduces a framework for enhancing lean construction practices through real-time tracking of resources on construction sites. The research focuses on utilizing emerging technologies, such as Ultra Wideband (UWB) and video-based systems, to monitor the location and movement of workers, equipment, and materials. By capturing detailed spatial data, the approach aims to provide insights into workflow efficiency, identify bottlenecks, and support rapid decision-making processes. The preliminary experimental results demonstrate the feasibility of accurately tracking construction resources in real-time, highlighting the potential of these technologies to inform lean planning and improve overall project performance.
5. Hwang and He (2006) introduced a novel optimization approach by developing a Hybrid Real-Parameter Genetic Algorithm (HRPGA) for continuous function optimization. Traditional genetic algorithms (GAs) often face challenges such as high computational costs in encoding and decoding processes and a tendency to converge prematurely to local optima due to their lack of hill-climbing capability. To address these issues, the authors integrated the GA with Simulated Annealing (SA), resulting in an Adaptive Real-Parameter Simulated Annealing Genetic Algorithm (ARSAGA). This hybrid algorithm combines the global search ability of GAs with the local refinement capabilities of SA, incorporating adaptive mechanisms to enhance solution quality and convergence speed. The performance of ARSAGA was evaluated using 16 benchmark functions and two engineering optimization problems, demonstrating its superior global search ability and faster convergence compared to traditional GAs, even with a small population size. The proposed algorithm offers an efficient and effective tool for continuous function optimization, addressing

the limitations of conventional genetic algorithms.

### 3. Methodology

Previous chapters discussed the need of automated monitoring in construction and also the need to monitor launching girder. In chapter two, previous works on various studies such as automated progress monitoring, wireless sensor networks in construction and its need, sensor placement methodologies, and system identification methodologies were discussed. This chapter builds on the previous chapters and narrows down on the objectives of this work, its scope, and the methodologies.

The need to monitor the launching girder and the challenges associated with setting up a monitoring system was discussed in the previous chapters. The common automated data collection methods used in construction may not be adequate to monitor the operations of the launching girder. Hence, it is necessary that a new method of ADC should be developed to address the issues arising from the common ADCs. This problem could be addressed by installing a structural health monitoring system on an equipment and relate the structural responses to the construction activity. Success of this method requires systematic placement of sensors. Sensors should be placed at locations which would give distinct structural responses capable of distinguishing between construction operations. Also, inferring the construction operation from the structural responses requires well designed algorithms and methodology tailored for the purpose. Therefore, this study's focus is to develop a monitoring system that classifies the operations of the launching girder to assess the progress of the metro rail viaduct construction. This is tried out by using the strain responses from the plate girder of the launching girder and evaluating the strain pattern.

### 4. Objectives

The overall objective of this study is to develop a framework for real-time automated progress monitoring of launching girder operations.

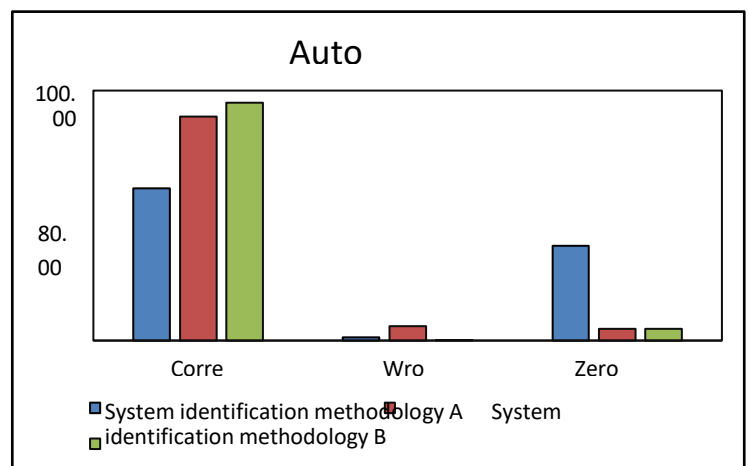
This objective is further subdivided into three sub-objectives. They are as follows.

- To design a wireless sensor network for acquisition and transmission of data from launching girders for real-time monitoring
- To determine the optimum sensor locations for inferring launching girder operations
- To evaluate and improve existing methodologies to infer the state of launching girders from sensor data

### Result

- This chapter presents the results from the experiments as specified. Results from the performance evaluation of the wireless sensor network is presented in section
- The comparison of efficiencies of the intuitive and scientific sensor placement methodologies are discussed in Section 8.3. Section 8.4 compares the accuracies three system identification methodologies.

#### Performance Evaluation at Laboratory



Variation of RSSI (Received Signal Strength Indicator) with distance is shown in Figure 1, Consistent with the results reported in the literature (Piyare *et al.* 2013). RSSI decreases with distance from the coordinator. However, the reduction in strength if plotted logarithmically will not result in a linear relationship with distance as expected. This is in conformation with (Parameswaran *et al.* 2009) wherein it was observed

that even in ideal scenarios RSSI does not give a consistent behavior. The fluctuations at distances from 40 to 60 m in 10 bytes and 30 bytes can be correlated with reflection and multipath phenomena due to end walls and presence of electromagnetic interference from equipment such as Wi-Fi routers. This is also supported by the findings of Bae *et al* (2013)<sup>10</sup> and Piyare *et al* (2013)<sup>29</sup>. Despite the observations that RSSI fluctuated from the theoretical expectation, all the values lie above the threshold of XBee requirements, which is -102dBm ([http://www.digi.com/pdf/ds\\_XBeeMultipointModules.pdf](http://www.digi.com/pdf/ds_XBeeMultipointModules.pdf) [Accessed 10th January 2015]) Therefore, it can be concluded that the current wireless sensor network has enough signal strength to support data transmission in the range specified.

tracking to support the analysis of lean principles. *Challenging Lean Construction Thinking: What Do We Think and What Do We Know?* - 18th Annual Conference of the International Group for Lean

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